Global Journals Inc.

Global Journal of Science Frontier Research
Environment & Earth Sciences
Volume 12 Issue 3 Version 1.0 Year 2012
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

NOAA AVHRR NDVI/MODIS NDVI Predicts Potential to Forest Resource Management in Çatalca District of Turkey

By Farooq Ahmad, Qurat-ul-ain Fatima & Hira Jannat Butt

University of the Punjab, New Campus, Lahore, Pakistan

Abstract - Çatalca, located on the ridge between the Marmara and the Black Sea, is a rural district of Istanbul having the temperate climate. Landuse involves farming and forestry. This study makes a contribution and revises the applicability of two medium spatial resolution satellite sensors, NOAA AVHRR NDVI and MODIS (Terra) NDVI, for prediction to potential forest resource management in Çatalca district of Turkey on various spatial scales. The NOAA AVHRR NDVI sensor was chosen in view of its unique value for long-term climate impact studies. The MODIS (Terra) sensor, as a newer generation sensor specifically designed for, inter alia, terrestrial applications, since it provides the opportunity for observations at higher spatial and spectral resolution compared to NOAA AVHRR (NDVI). The required data preparation for the integration of MODIS data into GIS is described with a focus on the projection from the MODIS/Sinusoidal projection to the national coordinate systems. However, its low spatial resolution has been an impediment to researchers pursuing more accurate classification results. This paper summarizes a set of remote sensing applications of NOAA AVHRR NDVI/MODIS (Terra) NDVI datasets in estimation and monitoring of seasonal and inter annual ecosystem dynamics which were designed for forest resource management and can be implemented over Turkey.

Keywords : Çatalca, MODIS NDVI, NOAA AVHRR, vegetation index, remote sensing.

GJSFR-H Classification : FOR Code: 070504

NOAA AVHRR NDVI/MODIS NDVI Predicts Potential to Forest Resource Management in Çatalca District of Turkey

Farooq Ahmad [α], Qurat-ul-ain Fatima [σ] & Hira Jannat Butt [ρ]

Abstract - Çatalca, located on the ridge between the Marmara and the Black Sea, is a rural district of Istanbul having the temperate climate. Landuse involves farming and forestry. This study makes a contribution and revises the applicability of two medium spatial resolution satellite sensors, NOAA AVHRR NDVI and MODIS (Terra) NDVI, for prediction to potential forest resource management in Çatalca district of Turkey on various spatial scales. The NOAA AVHRR NDVI sensor was chosen in view of its unique value for long-term climate impact studies. The MODIS (Terra) sensor, as a newer generation sensor specifically designed for, inter alia, terrestrial applications, since it provides the opportunity for observations at higher spatial and spectral resolution compared to NOAA AVHRR (NDVI). The required data preparation for the integration of MODIS data into GIS is described with a focus on the projection from the MODIS/Sinusoidal projection to the national coordinate systems. However, its low spatial resolution has been an impediment to researchers pursuing more accurate classification results. This paper summarizes a set of remote sensing applications of NOAA AVHRR NDVI/MODIS (Terra) NDVI datasets in estimation and monitoring of seasonal and inter annual ecosystem dynamics which were designed for forest resource management and can be implemented over Turkey.

Keywords : Çatalca, MODIS NDVI, NOAA AVHRR, vegetation index, remote sensing.

I. INTRODUCTION

Remote sensing of land surface parameters in mountainous region does not differ from remote sensing elsewhere with respect to a basic underlying principle (Lillesand and Kiefer, 1994; Lillesand et al., 2004; Fontana, 2009): land surface types may be discriminated based on their inherent spectral and emittance properties (Campbell, 1987; Fontana, 2009) in certain portions of the electromagnetic spectrum (Lillesand et al., 2004; Fontana, 2009). The benefit obtained from a remote sensing sensor thereby largely depends on its spectral resolution (Jensen, 2005), which determines the sensor's capability to resolve spectral features of land surfaces (Fontana, 2009). Photosynthetically active vegetation is characterized by very low reflectance values (Jensen, 2005) in the red part of the electromagnetic spectrum due to the absorption of solar radiation by the leaf pigments involved in photosynthesis (Lillesand et al., 2004), and by increased reflectance in the near infrared portion of the spectrum due to reflection of incoming solar radiation at the leaf internal structures (Gitelson and Merzlyak, 1996; Fontana, 2009). In contrast, snow and ice covered surfaces are typically characterized by strong reflectance in the visible part of the spectrum and low reflectance in the short wave infrared part (Dozier and Painter, 2004; Fontana, 2009). Such differences in the reflective properties of a surface between certain wavelengths can be employed to compute spectral indices that give an indication of the abundance of a given land cover type within the area covered by a pixel (Lillesand and Kiefer, 1994; Lillesand et al., 2004; Fontana, 2009). With regard to the monitoring of terrestrial vegetation, the Normalized Difference Vegetation Index (Rouse et al., 1973; Tucker, 1979) is the most commonly used index and serves as a measure of photosynthetic activity within a certain area (Fontana, 2009).

The global importance of forests has never been in question, but interest in them has been increasing in recent years because of their obvious commercial value, importance in maintaining regional biodiversity and growth of forests reflect responses to longer term variation in climate and atmospheric properties (Coops et al., 1998). As a result of this interest the regional distribution of major forest and other vegetation types, has received increasing attention, with improved definition through satellite derived data (Matthews, 1983; Prentice, 1990; Townshend et al., 1991; Running et al., 1994; Coops et al., 1998).

Change detection is one of the most successful implementations of remote sensing (Singh, 1989). This is because remote sensing data is usually the most accurate and up-to-date 'map' available especially in developing countries. Additionally, such areas could be benefited from using RS data as can follow up the fast growing towns and cities (Pesaresi, 2000; Baudot, 2001; Hurskainen and Pellikka, 2004; Brenner and Roessing, 2008; Nicandrou, 2010) and other human impact on the environmental change such as deforestation and land used for agriculture. With a repetitive acquisition of imagery, it is possible to determine the types and extent

---

Author α: Department of Geography, University of the Punjab, New Campus, Lahore, Pakistan. e-mail: F.Ahmad@sheffield.ac.uk
Author σ ρ: GIS Centre, PUCIT, University of the Punjab, Lahore, Pakistan.

of changes in the environment (Nicandrou, 2010). The most widespread technique used in change detection and monitoring is image-to-image comparison. Image-to-image comparison methods include: image differencing (Dale et al., 1996; Teng et al., 2008; Berberoglu and Akin, 2009; Nicandrou, 2010), image enhancement techniques like principal component analysis and/or tasseled cap transformation (Healey et al., 2005; Jin and Sader, 2005; Pal et al., 2007; Koutsias et al., 2009; Nicandrou, 2010), band ratioing classification comparisons (Muchoney and Haack, 1994; Jensen et al., 1995; Dale et al., 1996; Kaiser, 2009; Nicandrou, 2010) and NDVI analysis (Mikkola, 1996; Binh et al., 2005; Lee and Yeh, 2009; Nicandrou, 2010).

Los et al. (1994) and Sellers et al. (1996) were the first to derive land surface parameters with realistic seasonal and spatial variations for the globe from NDVI data collected by the AVHRR satellite (Los et al., 2000). Estimation of land surface vegetation parameters from satellite is based on the spectral properties of vegetation; vegetation strongly absorbs visible light, using the energy for photosynthesis, and strongly reflects near-infrared (NIR) radiation (Rouse et al., 1973; Los, 1998; Los et al., 2000; Ahmad, 2012).

The NDVI values range from -1.0 to 1.0, where higher values are for green vegetation and low values for other common surface materials. Bare soil is represented with NDVI values which are closest to 0 and water bodies are represented with negative NDVI values (Jasinski, 1990; Sader and Winne, 1992; Lillesand et al., 2004; Karaburun, 2010; Ahmad, 2012a), the NDVI provides useful information for detecting and interpreting vegetation land cover it has been widely used in remote sensing studies (Myneni and Asrar, 1994; Gao, 1996; Sesnie et al., 2008; Karaburun, 2010; Ahmad, 2012a). The theoretical basis for the NDVI lies with the red-NIR contrast of vegetation spectral reflectance signatures (Rahman et al., 2004). As the amount of live, green vegetation increases within a pixel, the red reflectance will decrease due to chlorophyll absorption while the non-absorbing NIR spectral region will generally increase especially leaf structure and amount (Baret and Guyot, 1991).

The NDVI (Sellers, 1985) as an indicator of vivid green vegetation and as a descriptor of ecosystem functions has proved to be very valuable for assessing ecological responses to environmental changes (Pettorelli et al., 2005; Alcaraz-Segura et al., 2009; Höpfner and Scherer, 2011). The NDVI is successful as a vegetation measure is that it is sufficiently stable to permit meaningful comparisons of seasonal and inter-annual changes in vegetation growth and activity (Choudhury, 1987; Jakubauskas et al., 2002; Chen et al., 2006; Zoran and Stefan, 2006; Ahmad, 2012a; 2012b). The NDVI is established to be highly correlated to green-leaf density and can be viewed as a proxy for above-ground biomass (Tucker and Sellers, 1986).

The NDVI is the most commonly used index of greenness derived from multispectral remote sensing data (USGS, 2010), and is used in several studies on vegetation, since it has been proven to be positively correlated with density of green matter (Townshend et al., 1991; Huete et al., 1997; Huete et al., 2002; Debien et al., 2010).

II. Study Area

Çatalca (Fig. 1) is a rural district in Istanbul. Its neighbouring districts include Büyükçekmece to the south, Silivri and Tekirdağ to the west, while Avcılar, Küçükçekmece and Gaziosmanpaşa lie to the east (Ahmad, 2010). It is in Eastern or Turkish Thrace, on the ridge between the Marmara and the Black Sea.

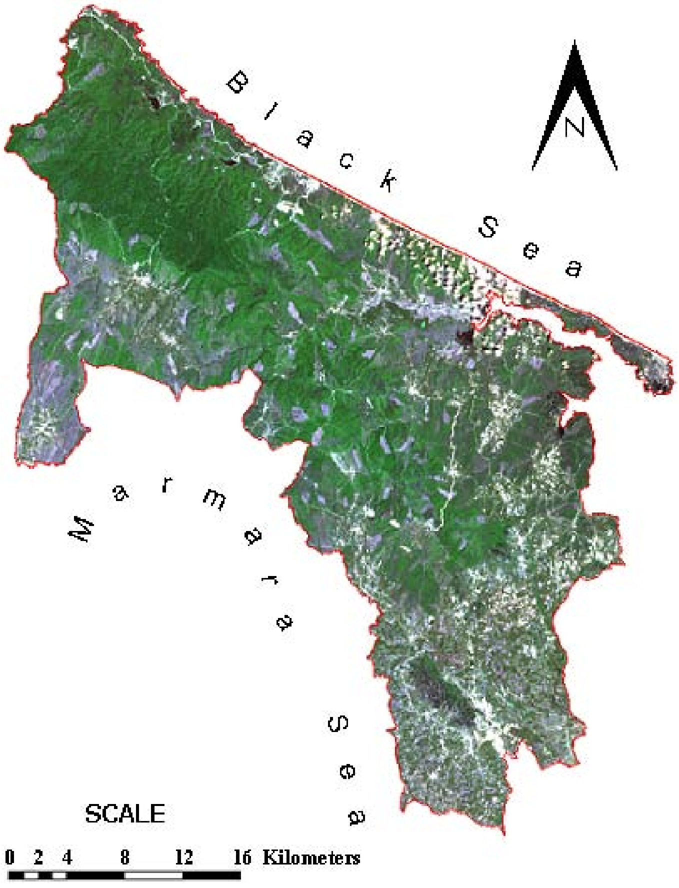


Figure 1 : Çatalca District - Landsat ETM+ 08 May, 2003.

Source: http://glovis.usgs.gov/

III. Research Design and Methods

The objective of the National Oceanic and Atmospheric Administration (NOAA) series (James and Kalluri, 1994; Rao and Chen, 1995), NOAA-6, 7, 9, 11, and 14 (NOAA-6 data span the years 1980-1981, NOAA-

7, 1982-1985, NOAA-9, 1986-1989, NOAA-11, 1989-1995, NOAA-14, 1995-2000) sun-synchronous orbits with nadir afternoon Polar Orbiting Environmental Satellites (POES) is to generate consistent (Kidwell, 1991; James and Kalluri, 1994), well-calibrated (Teillet et al., 1990; Weinreb et al., 1990; Los, 1993; Vermote and Kaufman, 1995; Bannari et al., 2005; Ahmad, 2012), long-term datasets from archived operational environmental satellite data and make them easily accessible for climate research (Stowe et al., 2002) at local, national, regional and global scale. The dataset was produced by the Department of Geography, University of Wales at Swansea. The FASIR NDVI dataset and derived biophysical parameter fields were generated to provide satellite record from August 1981 to December 1998 of changes in the photosynthetic activity of terrestrial vegetation (Los, 2010). The FASIR adjustments concentrated on reducing NDVI variations arising from atmospheric, calibration, view and illumination geometries and other effects not related to actual vegetation change (Sellers et al., 1994; Gamon et al., 1995; Los et al., 2000; Los et al., 2005; Hall et al., 2006; Los et al., 2006; Baldi et al., 2008; Hashemi, 2010; Ahmad, 2012). The NDVI has been used widely in remote sensing studies since its development (Jensen, 2005).

The MODIS sensor combines characteristics of the AVHRR (Maselli et al., 1996) and the Landsat TM and was designed to improve and complement monitoring of land, ocean, and atmosphere by these previous missions (Barnes et al., 1998). The MODIS provides higher radiometric sensitivity compared to AVHRR (Barnes and Salomonson, 1993; Fontana, 2009). In each of the 36 spectral bands, the 12-bit resolution results in 4096 levels of discrimination in measured response (Guenther et al., 1998; Fontana, 2009). The bands are sensitive to different portions of the electromagnetic spectrum between 0.46 μm and 14.39 μm at spatial resolutions of 250 m, 500 m, and 1 km, depending on the spectral band (Fontana, 2009). The output delivered by the MODIS level 1B algorithm includes geolocated at aperture radiances in all 36 spectral bands (Isaacman et al., 2003; Xiong et al., 2003; 2003a; Xiong et al., 2005; Fontana, 2009).

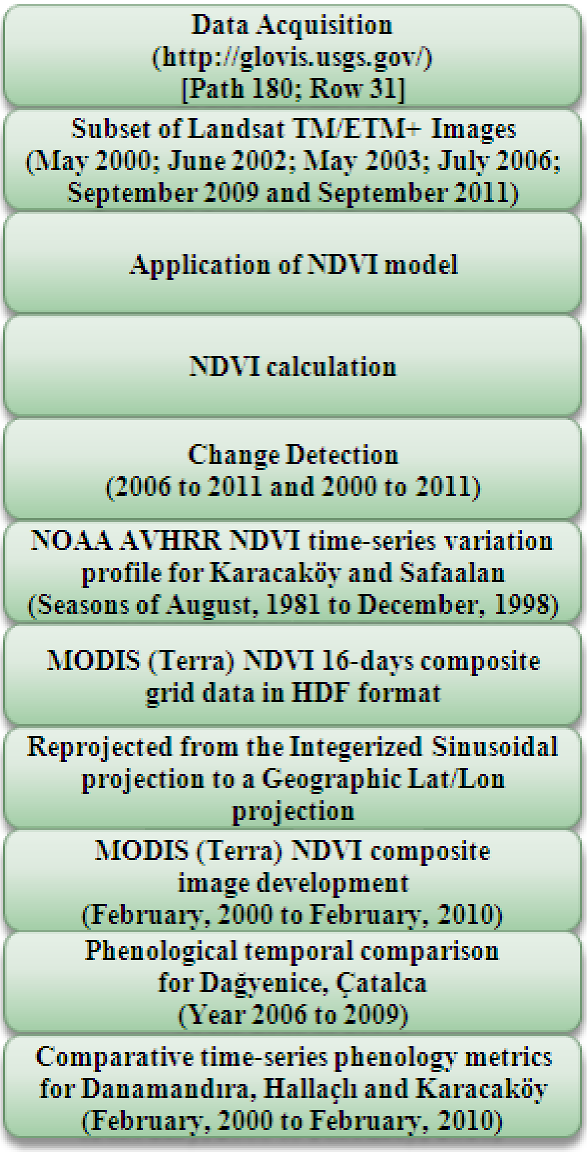


Figure 2 : Scheme for research design and methods.

The MODIS (Terra) NDVI 16-days composite grid data for Çatalca district of Turkey in HDF format were acquired; February 2000 to February 2010 from the NASA Earth Observing System (EOS) data gateway. Details documenting the MODIS (Terra) NDVI compositing process and Quality Assessment Science Data Sets can be found at NASA's MODIS web site (MODIS, 1999; USGS, 2008). Tile number covering Çatalca is h20v04, reprojected from the Integerized Sinusoidal projection to a Geographic Lat/Lon projection (Fig. 2), and Datum WGS84 (GSFC/NASA, 2003; Ahmad, 2012a).

The MODIS is a key instrument onboard the Terra satellite. MODIS provides images over a given pixel of land just as often as the Advanced Very High Resolution Radiometer (AVHRR) but in much finer detail and with measurements in a greater number of wavelengths using detectors that were specifically designed for measurements of land surface dynamics (Huete, 2005). The MODIS design team gave substantial emphasis to instrument calibration and characterization recognizing these activities as critical for generation of accurate long-term time-series products needed for global change studies (Huete et al., 1999; Justice et al., 2002).

ERDAS imagine 2011 and ArcGIS 10 software were used for application of NDVI index and calculation upon Landsat TM/ETM+ images (path 180, row 31); May 2000, June 2002, May 2003, July 2006, September 2009 and September 2011 respectively and change detection technique was applied to investigate forest resource change for the period of 2006 to 2011 and 2000 to 2011 at Çatalca district of Turkey (Fig. 2). NOAA AVHRR NDVI (seasons of August, 1981 to December, 1998) was used to generate time-series variation profile for Karacaköy and Safaalan villages and MODIS (Terra) NDVI composite image for phenological temporal comparison at Dağyenice during 2006 to 2009 and comparative time-series phenology metrics for Danamandıra, Hallaçlı and Karacaköy (seasons of February, 2000 to February, 2010) villages of Çatalca.

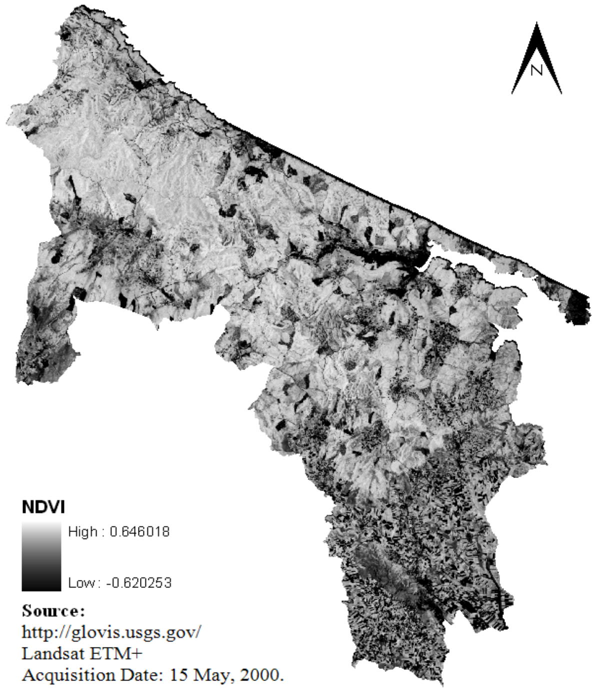
Vegetation Indices are seamless data products that are computed from the same mathematic formulae across all pixels in time and space, without prior assumptions of biome type, land cover condition, or soil type and thus represent actual, long-term measurements of the land surface (Huete et al., 2002).

Spectral-based change detection techniques have tended to be performance limited in biologically complex ecosystems due, in larger part, to phenology-induced errors (Lunetta et al., 2002; Lunetta et al., 2002a; Lunetta et al., 2006). An important consideration for land cover change detection is the nominal temporal frequency of remote sensor data acquisitions required to adequately characterize change events (Lunetta et al., 2004; Lunetta et al., 2006).

IV. Results

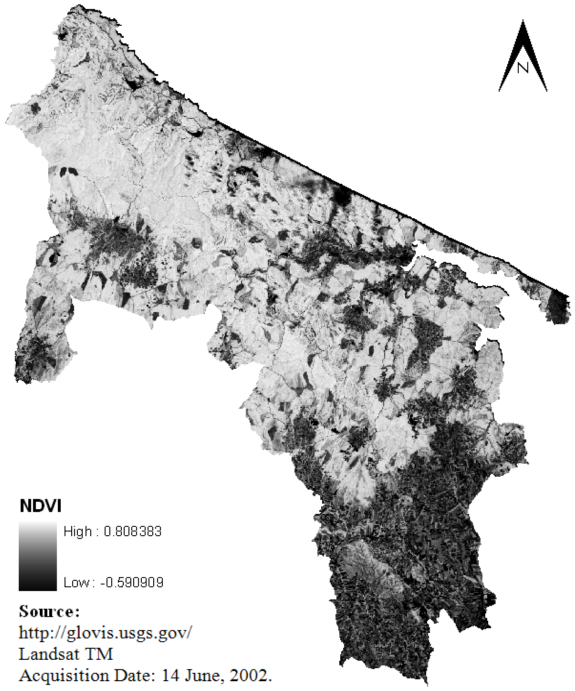
Fig. 3, 4, 5, 6, 7, 8 (Table 1) shows NDVI values of Landsat TM/ETM+ images for May 2000; June 2002; May 2003; July 2006; September 2009 and September 2011 respectively. The NDVI index was applied upon the Landsat TM/ETM+using ERDAS imagine 2011 software while ArcGIS was used for NDVI calculation. The result showed that there was a relationship between forest cover and NDVI values. The NDVI is an attractive tool to monitor herbivore habitat quality, its interpretation requires caution. The significance of NDVI index may vary according to habitat type (Pettorelli et al., 2005; Hamel et al., 2009).

Fig. 9 (Table 2) shows change detection using NDVI classification at Çatalca. The result showed that in May 2000, the forest cover was 1018.38 km^2, in June 2002, the forest cover was 926.41 km^2. The forest cover reduced from 96% in May 2000 to 87% in June 2002. In May 2003, the forest cover was 920.64 km^2 while in July 2006, the forest cover reduced to 794.29 km^2. The forest cover was continuously decresing with respect to time. In September 2009, the forest cover was 785.24 km^2 while in September 2011, further reduced to 768.30 km^2. The findings showed that forest cover reduced from 96% in May 2000 to 73% in September 2011.



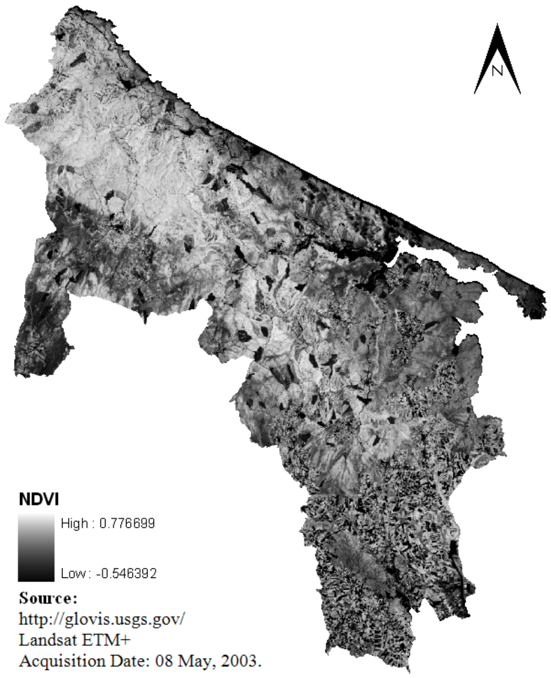
Source:
http://glovis.usgs.gov/
Landsat ETM+
Acquisition Date: 15 May, 2000.

Figure 3 : NDVI 2000, Çatalca.



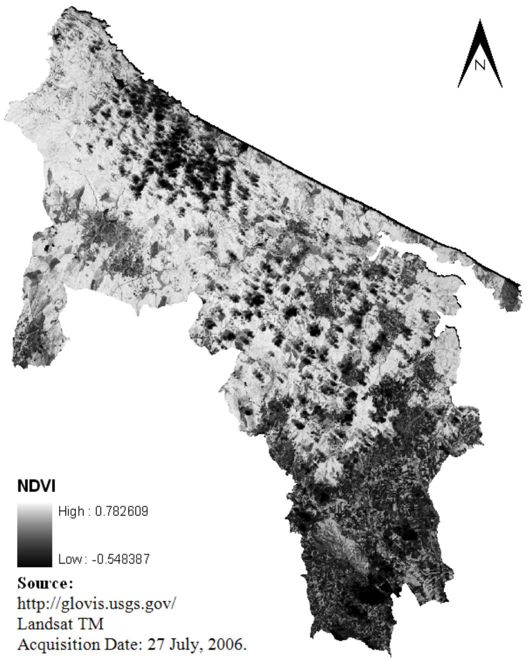
Source:
http://glovis.usgs.gov/
Landsat TM
Acquisition Date: 14 June, 2002.

Figure 4 : NDVI 2002, Çatalca.



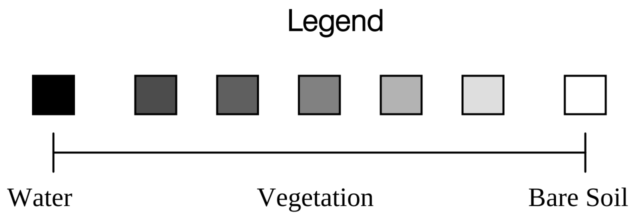
Source:
http://glovis.usgs.gov/
Landsat ETM+
Acquisition Date: 08 May, 2003.

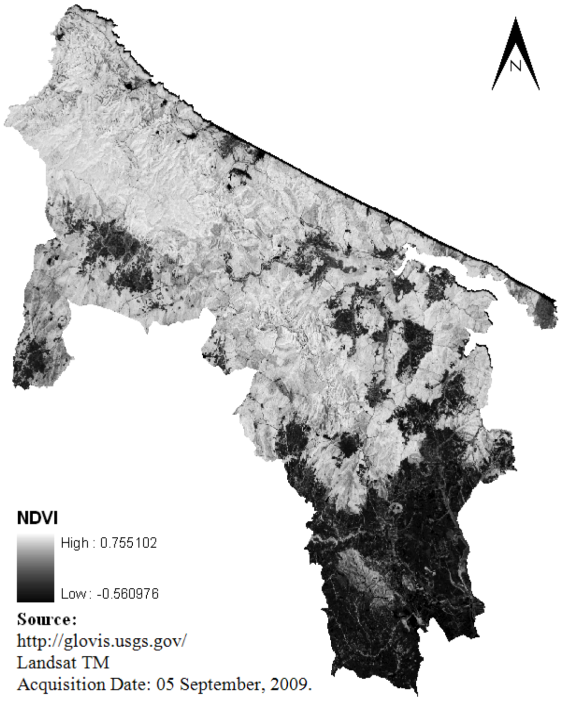
Figure 5 : NDVI 2003, Çatalca.



Source:
http://glovis.usgs.gov/
Landsat TM
Acquisition Date: 27 July, 2006.

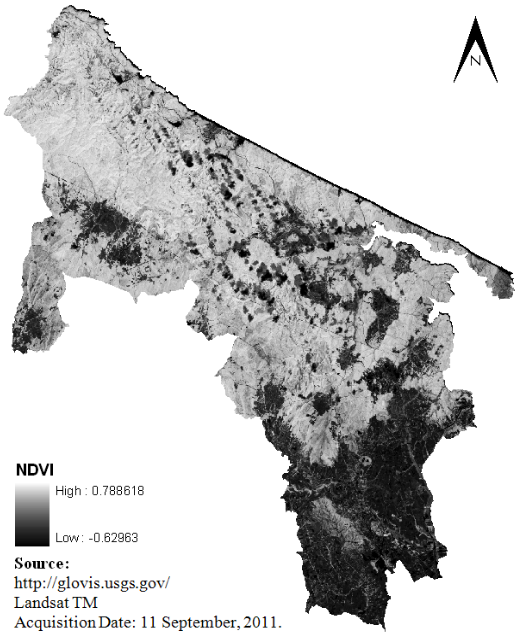
Figure 6 : NDVI 2006 Çatalca.





Source:
http://glovis.usgs.gov/
Landsat TM
Acquisition Date: 05 September, 2009.

Figure 7 : NDVI 2009, Çatalca.



Source:
http://glovis.usgs.gov/
Landsat TM
Acquisition Date: 11 September, 2011.

Figure 8 : NDVI 2011, Çatalca.

Table 1 : NDVI values of Landsat Images.

Image Acquisition Date	Maximum NDVI	Minimum NDVI	Mean NDVI	Standard Deviation
15 May, 2000 (ETM +)	0.65	-0.62	0.36	0.21
14 June, 2002 (TM)	0.81	-0.59	0.56	0.20
08 May, 2003 (ETM +)	0.78	-0.55	0.44	0.19
27 July, 2006 (TM)	0.78	-0.55	0.47	0.23
05 September, 2009 (TM)	0.76	-0.56	0.47	0.23
11 September, 2011 (TM)	0.79	-0.63	0.46	0.23

Multi-year time series of NDVI can reliably measure yearly changes in the timing of the availability of high-quality vegetation and or forest resource (Hamel et al., 2009). The NDVI values may inaccurately represent productivity due to the difference in reflectance in heterogeneous habitats, such as those with interspersed woody and herbaceous vegetation or sparse vegetation and abundant bare ground (Elvidge and Lyon, 1985; Huete et al., 1985; Huete and Tucker 1991; Hamel et al., 2009). The biological significance of NDVI indices should be assessed in various habitat types before they can be widely used in ecological studies (Hamel et al., 2009). The premise is that the NDVI is an indicator of vegetation health, because degradation of ecosystem vegetation, or a decrease in green, would be reflected in a decrease in NDVI value (Meneses-Tovar, 2011). Therefore, if a relationship between the quantity of an indicator – aerial biomass – in various forest ecosystems and the NDVI can be identified, processes of degradation can be monitored (Meneses-Tovar, 2011; Zaeen, 2012).

Table 2 : NDVI Classification of Landsat Images.

Image Acquisition Date	Classes	Area (km^2)	Area (%)
15 May, 2000 (ETM +)	Forest	1018.38	96
	Vegetation	37.75	4
	Lakes	0.90	0
	SUM	1057.03	100
14 June, 2002 (TM)	Forest	926.41	87
	Vegetation	123.55	12
	Lakes	7.08	1
	SUM	1057.03	100
08 May, 2003 (ETM +)	Forest	920.64	87
	Vegetation	127.67	12
	Lakes	8.72	1
	SUM	1057.03	100
27 July, 2006 (TM)	Forest	794.29	75
	Vegetation	256.08	24
	Lakes	6.66	1
	SUM	1057.03	100
05 September, 2009 (TM)	Forest	785.24	74
	Vegetation	265.32	25
	Lakes	6.47	1
	SUM	1057.03	100
11 September, 2011 (TM)	Forest	768.30	73
	Vegetation	282.49	27
	Lakes	6.24	0
	SUM	1057.03	100

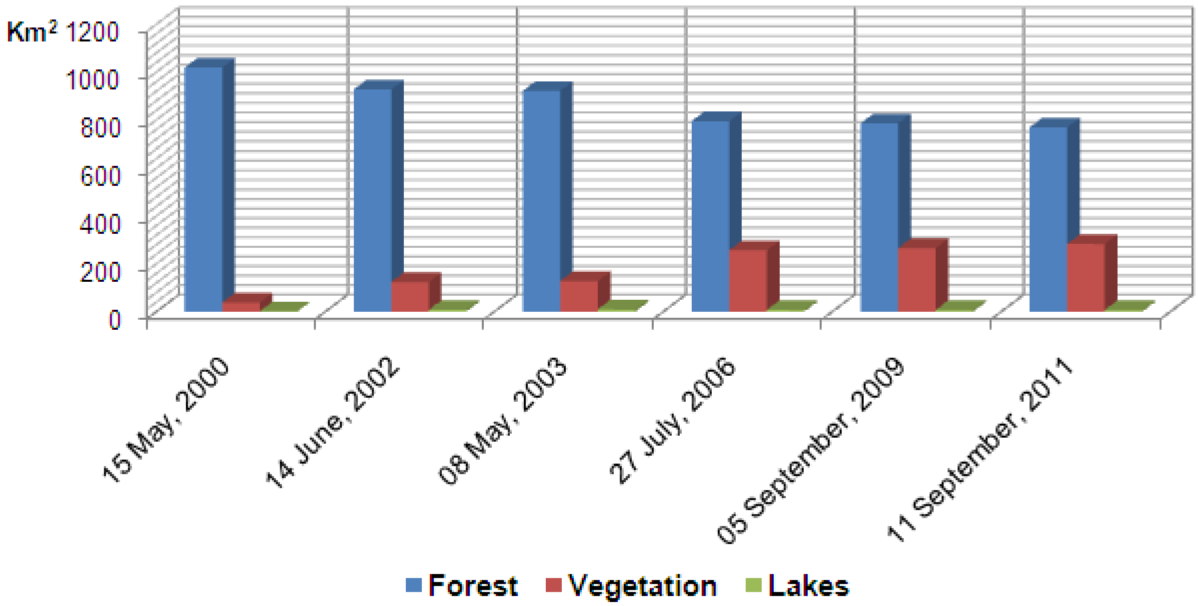


Figure 9 : Change Detection using NDVI Classification at Çatalca.

Fig. 10 shows change detection during 2006-2011 at Çatalca district of Turkey. The findings showed that decreased in the forest cover was 122.31 km^2 (12%), some decrease was 542.81 km^2 (51%), unchanged was 1.37 km^2, some increase was 272.16 km^2 (26%), while increased was 118.38 km^2 (11%). Decreased and some decrease > some increase and increased while unchanged in forest cover was negligible. The change detection technique was performed upon NDVI images; July 2006 and September 2011. The results and accuracy assessment is given in Table 3.

A variety of change detection techniques have been developed and many have been summarized and reviewed (Singh, 1989; Mouat et al., 1993; Deer, 1995; Coppin and Bauer, 1996; Jensen, 1996; Jensen et al., 1997; Yuan et al., 1998; Serpico and Bruzzone, 1999; Lu et al., 2004). Due to the importance of monitoring change of Earth's surface features, research of change detection techniques is an active topic, and new techniques are constantly developed (Lu et al., 2004).

Fig. 11 shows change detection during 2000-2011 at Çatalca district of Turkey. The findings showed that decreased in the forest cover was 152.26 km^2 (14%), some decrease was 91.57 km^2 (9%), unchanged was 0.29 km^2, some increase was 486.55 km^2 (46%), while increased was 326.36 km^2 (31%). Some increase and increased > decreased and some decrease while unchanged in forest cover was negligible. The change detection technique was performed upon NDVI images; May 2000 and September 2011. The results and accuracy assessment is given in Table 3.

Fig. 12 shows comparative change detection, during 2006 to 2011 and during 2000 to 2011 at Çatalca district of Turkey. The findings showed that deforestation was increased with respect to time (Fig. 9), the enchroahment or removal of forest for small-scale farming or agricultural land use was increasing. Change information of the earth's surface is becoming more and more important in monitoring the local, regional and global resources and environment. The large collection of past and present remote sensing imagery makes it possible to analyze spatio-temporal pattern of environmental elements and impact of human activities in past decades (Jianya et al., 2008).

Digital change detection is the process that helps in determining the changes associated with land use and land cover properties with reference to geo-registered multi-temporal remote sensing data (Prenzel and Treitz, 2004; Ramachandra and Kumar, 2004). It helps in identifying change between two or more dates that is uncharacterized of normal variation. Change detection is useful in many applications such as land use changes, habitat fragmentation and rate of deforestation through spatial and temporal analysis techniques such as GIS and Remote Sensing along with digital image processing techniques (Ramachandra and Kumar, 2004).

Fig. 13 shows NOAA AVHRR NDVI time-series variation profile for Karacaköy, Çatalca. The trend analysis showed that climate was not stable during the seasons of August 1981 to December 1998. The NDVI value in August 1981 was 0.66 and in December 1998 was 0.35 (Fig. 13). Remarkable fluctuations were observed at start/end NDVI values. The fluctuations in the phenological profile were due to variation in the temperature and precipitation/rainfall at Karacaköy.

At seasonal to inter-annual time scales, vegetation phenology reflects dynamics of the Earth's climate and hydrologic regimes, and is diagnostic of coupling between the Earth's biosphere and atmosphere. Information related to large-scale phenology (Nightingale et al., 2008) is therefore useful for studies of seasonal and inter-annual variability in carbon exchange and vegetation-climate interactions.

Fig. 14 shows NOAA AVHRR NDVI time-series variation profile for Safaalan, Çatalca. The trend analysis showed that climate was not stable during the seasons of August 1981 to December 1998. The NDVI value in August 1981 was 0.38 and in December 1998 was 0.45 (Fig. 14). Fluctuations were observed at start/end NDVI values, the fluctuations in time-series profile were due to variation in the temperature and precipitation/rainfall. Remarkable fluctuations were observed during April 1997 (NDVI value 0.69) to November 1998 (NDVI value 0.61) at Safaalan. The changes in the NDVI belong to the temperature-precipitation driving type (Weishou et al., 2011), of which temperature was the dominant driving factor. Precipitation was the main reason for the NDVI change at Safaalan.

The NDVI has the potential ability to signal the vegetation features of different ecoregions and provides valuable information as a remote sensing tool in studying vegetation phenology cycles at a regional scale (Guo, 2003). An understanding of vegetation phenology is very important in assessing various forestry-related activities (Linkosalo et al., 2006; Westerling et al., 2006; Sekhon et al., 2010).

Phenology has emerged recently as an important focus for ecological research (Menzel et al., 2001; Hashemi, 2010). Several biophysical as well as terrestrial ecological models relating to climate change studies require phenology information at large spatial scales. Satellite remote sensing provides powerful techniques that can monitor and characterize phenological trends at large scales (Justice et al., 1985; White et al., 2005; Hashemi, 2010; Ahmad, 2012). Changes in the phenological events may therefore signal important year-to-year climatic variations or even global environmental change (Botta et al., 2000; Jolly et al., 2005; Hashemi, 2010; Ahmad, 2012).

Fig. 15 shows phenological temporal comparison for Dağyenice during 2006-2009 using MODIS (Terra) NDVI, 250 m at 16-days interval. The findings showed that maximum precipitation/rainfall occurred in the months of January to May, while August was dry. The climate was stable at Dağyenice, Çatalca except January 2006, severe dryness was observed in this month. Reed et al. (1994) used NDVI time series data to describe seasonal dynamics of vegetation cover by deriving multiple phenologic parameters related to vegetation activity and forest resource management. Several studies used these phenologic metrics or dealt with additional indicators to describe vegetation phenology (Bradley and Mustard, 2008; Funk and Budde, 2009; Höpfner and Scherer, 2011).

Fig. 16 shows comparative time-series phenology metrics for Danamandıra using MODIS (Terra) NDVI, 250 m at 16-days interval. The trend analysis showed that climate was not stable during the seasons of February 2000 to February 2010. Fluctuations were observed at start/end pixel values. Severe dryness was observed in January 2002, December 2002, February 2003, January 2004, February, 2005, December 2005 and January-February 2006. Minor fluactions were observed during March 2006 to February 2010. Remote sensing provides a key means of measuring and monitoring phenology at continental to global scales and vegetation indices derived from satellite data are now commonly used for this purpose (Nightingale et al., 2008; Tan et al., 2008; Ahmad, 2012).

Vegetation phenology refers to the relationship between climate and periodic development of photosynthetic biomass (Ahl et al., 2006). Satellite monitoring of vegetation phenology has often made use of a vegetation index such as NDVI because it is related to the amount of green leaf biomass (Lillesand and Kiefer, 2000; Beurs and Henebry, 2004; Ahl et al., 2006).

Fig. 17 shows comparative time-series phenology metrics for Hallaçlı using MODIS (Terra) NDVI, 250 m at 16-days interval. The trend analysis showed that climate was not stable during the seasons of February 2000 to February 2010. Fluctuations were observed at start/end pixel values, the fluctuations in time-series phenology metrics were due to variation in the temperature and precipitation/rainfall. Severe dryness was observed in December 2001, January 2002, December 2002, February 2003, February 2005, December 2005, January 2006 and January-February 2010. Minor fluactions were observed during February 2000 to November 2001. Accurate estimates of canopy phenology are critical to quantifying carbon and water exchange between forests and the atmosphere and its response to climate change (Ahl et al., 2006).

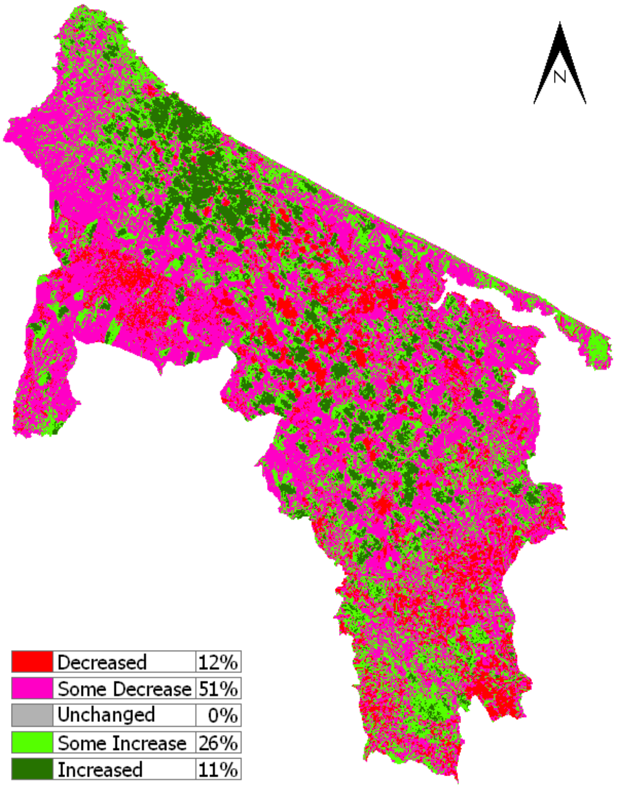


Figure 10 : Change Detection during 2006-2011 at Çatalca.

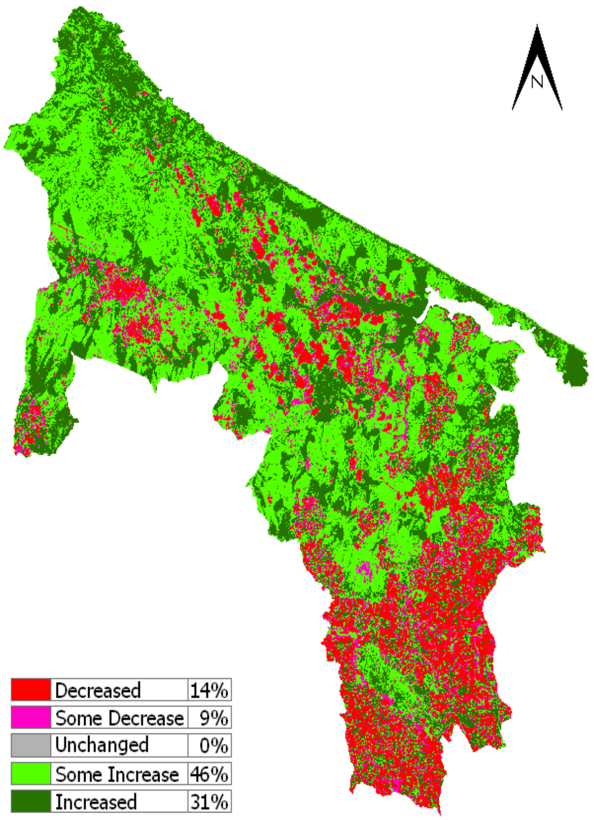


Figure 11 : Change Detection during 2000-2011 at Çatalca.

Table 3 : Change detection using NDVI calculation.

Classes	During 2006 to 2011			During 2000 to 2011		
	Area (km^2)	Area (%)	Accuracy Assessment (%)	Area (km^2)	Area (%)	Accuracy Assessment (%)
Decreased	122.31	12	80.25	152.26	14	83.37
Some Decrease	542.81	51	91.67	91.57	9	89.45
Unchanged	1.37	0	86.92	0.29	0	92.34
Some Increase	272.16	26	90.52	486.55	46	84.53
Increased	118.38	11	82.15	326.36	31	87.42
SUM	1057.03	100	-	1057.03	100	-

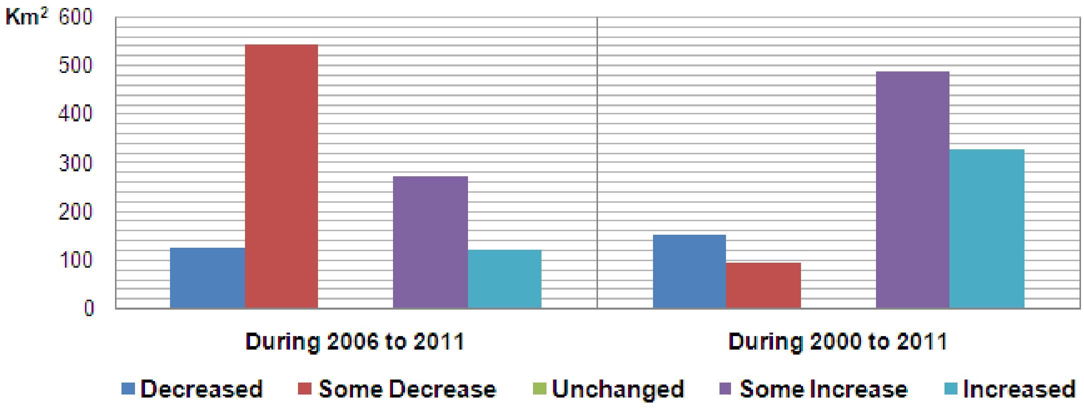


Figure 12 : Comparative Change Detection at Çatalca.

Fig. 18 shows comparative time-series phenology metrics for Karacaköy using MODIS (Terra) NDVI, 250 m at 16-days interval. Fluctuations were observed at start/end pixel values. Severe dryness was observed in February 2003, January 2004, February 2005 and February 2006. Minor fluactions were observed during January-March and November-December 2009. The MODIS (Terra) NDVI profiler for viewing phenological change in multi-year NDVI associated with known or suspected regionally apparent forest disturbances and to detect, track, and assess several biotic and abiotic regional forest disturbance events across Çatalca, including ephemeral and longer lasting damage from storms and drought. Such change products are most effective for viewing severe disturbances affecting multiple MODIS pixels (Spruce et al, 2012).

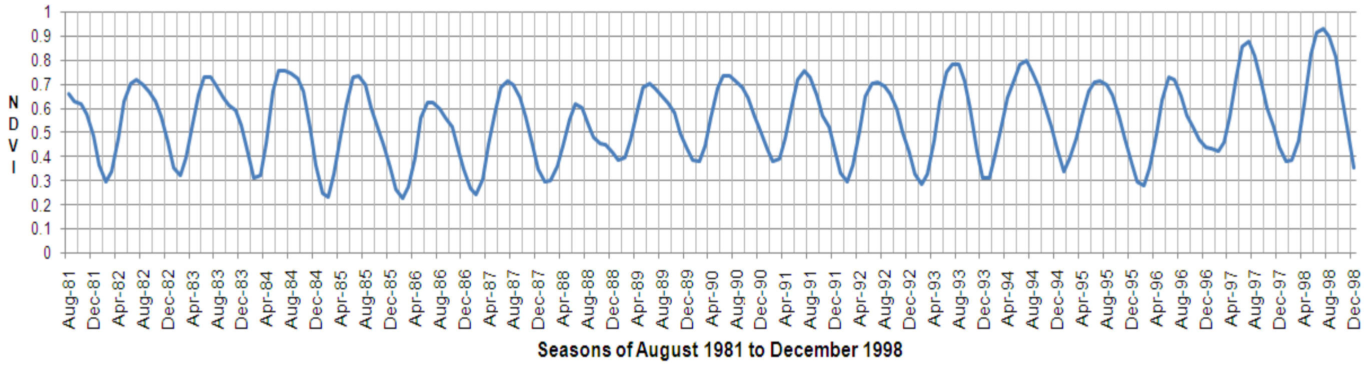


Figure 13 : NOAA AVHRR NDVI time-series variation profile for Karacaköy, Çatalca.

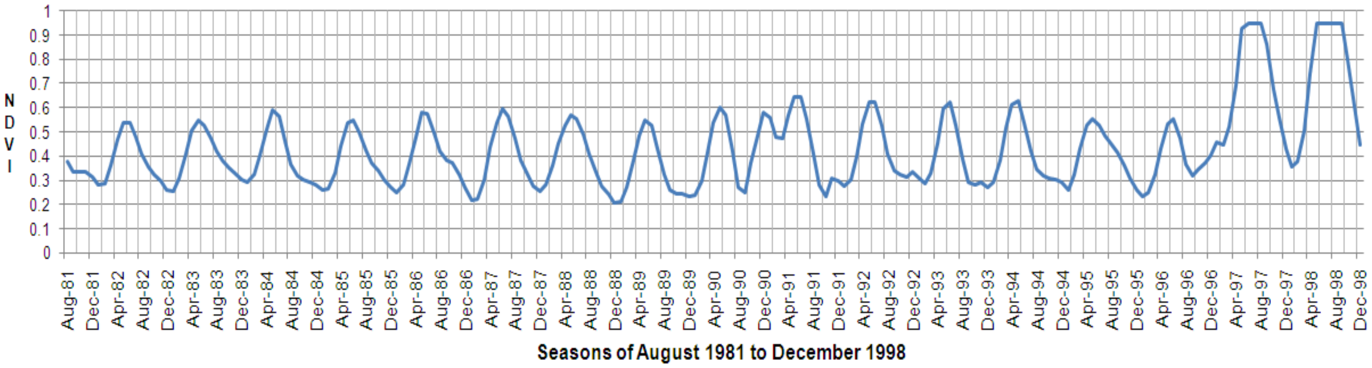


Figure 14 : NOAA AVHRR NDVI time-series variation profile for Safaalan, Çatalca.

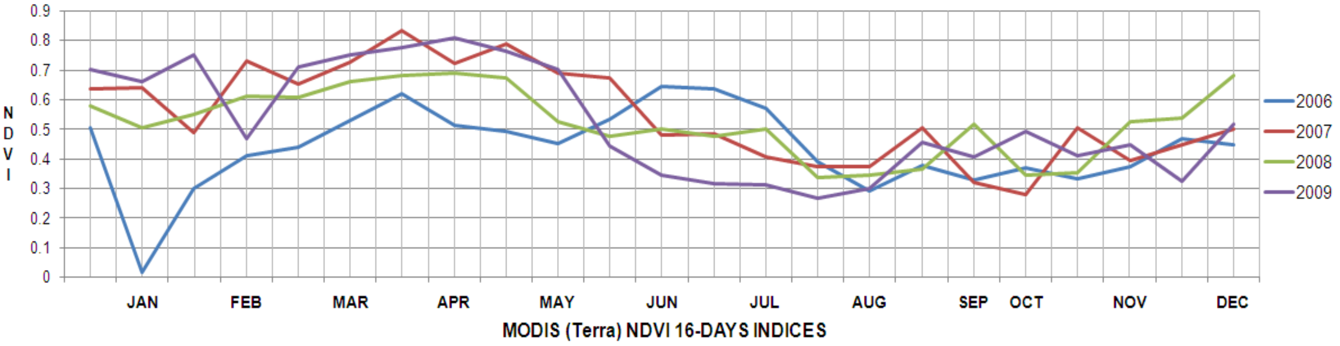


Figure 15 : MODIS (Terra) NDVI phenological temporal comparison for Dağyenice, Çatalca.

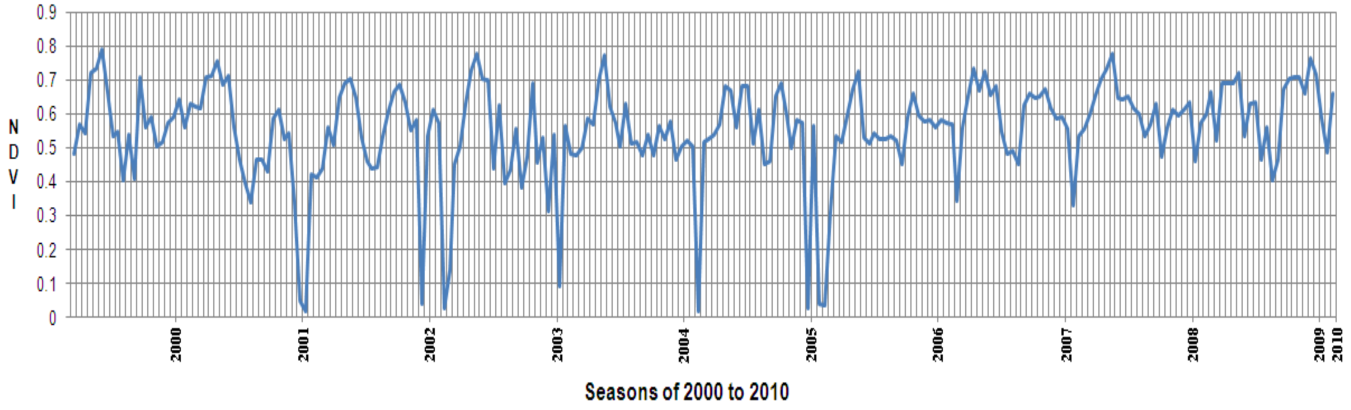


Figure 16 : MODIS (Terra) NDVI comparative time-series phenology metrics for Danamandıra, Çatalca.

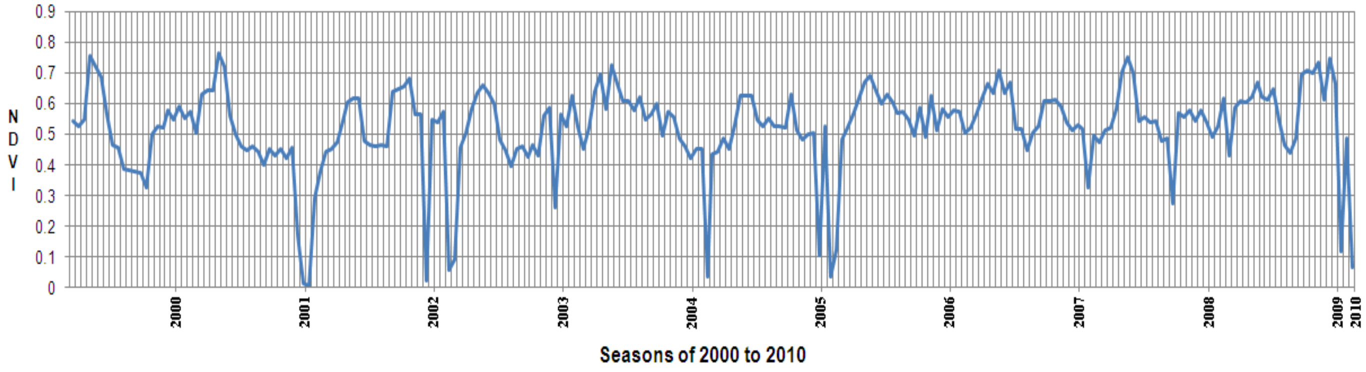


Figure 17 : MODIS (Terra) NDVI comparative time-series phenology metrics for Hallaçlı, Çatalca.

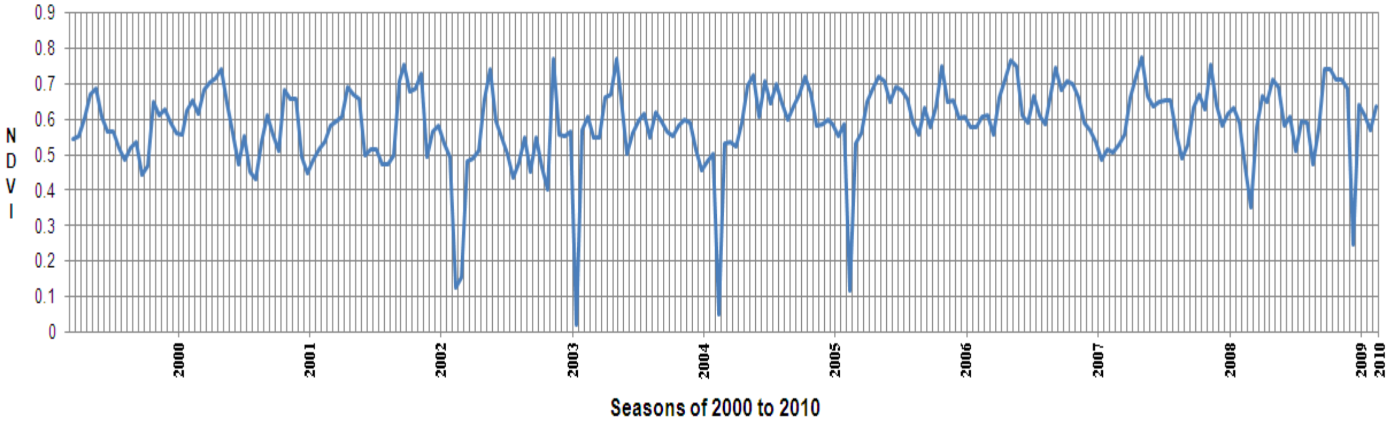


Figure 18 : MODIS (Terra) NDVI comparative time-series phenology metrics for Karacaköy, Çatalca.

V. DISCUSSION AND CONCLUSIONS

The NOAA AVHRR satellite series was originally designed as a weather satellite. However, from the early 1980s, AVHRR data has found increasing use to monitor the type and condition of land vegetation. The AVHRR vegetation data archives extend back to August 1981 (Emery and Brown, 1989; Kidwell, 1991; James and Kalluri, 1994). The AVHRR dataset has been used in several studies in the past few years (Zeng et al., 1999; DeFries et al., 2000; Lotsch et al., 2003; Tucker et al., 2005; Brown et al., 2006; Chris and Molly, 2006; Ahmad, 2012).

Information from conventional ground-based data has significant deficiencies as demonstrated by an analysis of these sources. Data from the NOAA AVHRR NDVI has been used to carry out classification at Çatalca district of Turkey. The specific data sets that have been used, have substantial limitations. The MODIS NDVI of the Earth Observing System (EOS) will be a substantially better instrument in terms of several spectral, radiometric, and geometric properties than the AVHRR NDVI (Townshend et al., 1991).

The comparison between the NDVI and biomass indicate that NOAA AVHRR NDVI/MODIS NDVI data products are suitable for monitoring of forest cover across Çatalca. The climatic variation is the major contributor to inter-annual NDVI variation. Precipitation has stronger effects on NDVI than temperature (Li and Guo, 2012).

The study demonstrates the successful application of NOAA AVHRR NDVI/MODIS NDVI data products on forest cover management. The MODIS vegetation phenology products contribute vital current information on forest conditions (Spruce et al, 2012). Through the application and analyses of time-series data, this research provides valuable understanding of the impact of environmental drivers on the spatial, annual and inter-annual variation of forest cover dynamics across Çatalca. The methodology presented in this research paper has several desirable properties. Since it treats each pixel individually without setting thresholds or empirical constants, the method is globally applicable (Vermote and Vermeulen, 1999; Vermote et al., 2002). In practice, different algorithms are often compared to find the optimal change detection algorithm for a specific application.

VI. ACKNOWLEDGEMENTS

The author wishes to thanks Dr. Sietse O. Los, Department of Geography, University of Wales at Swansea, United Kingdom for providing valuable NOAA AVHRR (FASIR) composite data from August 1981 to December 1998 and thankful to Prof. Dr. Martin A.J. Williams, Department of Geographical & Environmental Studies, University of Adelaide, Australia and grateful to his respected mentor Dr. Robert Bryant, Sheffield Centre for International Drylands Research, Department of Geography, The University of Sheffield, United Kingdom for review and providing valuable comments on draft-version of this paper.

REFERENCES RÉFÉRENCES REFERENCIAS

1. Ahl, D.E., Gower, S.T., Burrows, S.N., Shabanov, N.V., Myneni, R.B. and Knyazikhin, Y. (2006). Monitoring spring canopy phenology of a deciduous broadleaf forest using MODIS. Remote Sensing of Environment, Vol. 104, pp.88-95.
2. Ahmad, F. (2010). Multi-temporal MODIS-EVI smoothing algorithms and their contribution to forest resource management in the Çatalca district of Turkey. Abstract to IUFRO Joint Conference, Sustainable Utilization and Conservation of Forests in the Genomics Era, 7-12 March 2010, Kuala Lumpur, Malaysia. URL: http://fgilab.wordpress.com/2010/02/05/iufro-kuala-lumpur-2010-2/ (Accessed on November 22, 2012).
3. Ahmad, F. (2012). NOAA AVHRR satellite data for evaluation of climatic variation and vegetation change in the Punjab Province, Pakistan. Journal of Food, Agriculture & Environment, Vol. 10(2), pp.1298-1307.
4. Ahmad, F. (2012a). A review of remote sensing data change detection: Comparison of Faisalabad and Multan Districts, Punjab Province, Pakistan. Journal of Geography and Regional Planning, Vol. 5(9), pp.236-251.
5. Ahmad, F. (2012b). Spectral vegetation indices performance evaluated for Cholistan Desert. Journal of Geography and Regional Planning, Vol. 5(6), pp.165-172.
6. Alcaraz-Segura, D., Cabello, J., Paruelo, J.M. and Delibes, M. (2009). Use of descriptors of ecosystem functioning for monitoring a national park network: A remote sensing approach. Environmental Management, Vol. 43(1), pp.38-48.
7. Baldi, G., Nosetto, M.D., Aragón, R., Aversa, F., Paruelo, J.M. and Jobbágy, E.G. (2008). Long-term satellite NDVI datasets: Evaluating their ability to detect ecosystem functional changes in South America. Sensors, Vol. 8, pp.5397-5425.
8. Bannari, A., Omari, K., Teillet, P.M. and Fedosejevs, G. (2005). Potential of Getis statistics to characterize the radiometric uniformity and stability of test sites used for the calibration of Earth observation sensors. IEEE Transactions on Geoscience and Remote Sensing, Vol. 43(12), pp.2918-2926.
9. Baret, F. and Guyot, G. (1991). Potentials and limits of vegetation indices for LAI and APAR assessment. Remote Sensing of Environment, Vol. 35, pp.161-173.

10. Barnes, W.L. and Salomonson, V.V. (1993). MODIS: A global image spectroradiometer for the Earth Observing System. Critical Reviews of Optical Science and Technology, CR47, pp.285-307.
11. Barnes, W.L., Pagano, T. and Salomonson, V.V. (1998). Prelaunch characteristics of the Moderate Resolution Imaging Spectroradiometer (MODIS) on EOS-AM1. IEEE Transactions on Geoscience and Remote Sensing, Vol. 36(4), pp.1088-1100.
12. Baudot, Y. (2001). Geographical analysis of the population of fast-growing cities in the third World. In: Donnay, J.P., Barnsley, M.J. and Longley, P.A. (Eds.), Remote Sensing and Urban Analysis. Taylor & Francis, New York, pp.225-241 and p.268.
13. Berberoglu, S. and Akin, A. (2009). Assessing different remote sensing techniques to detect land use/cover changes in the Eastern Mediterranean. International Journal of Applied Earth Observation and Geoinformation, Vol. 11, pp.46-53.
14. Beurs, de K.M. and Henebry, G.M. (2004). Land surface phenology, climatic variation, and institutional change: Analyzing agricultural land cover change in Kazakhstan. Remote Sensing of Environment, Vol. 89, pp.497-509.
15. Binh, T.N.K.D., Vromant, N., Hung, N.T., Hens, L. and Books, E.K. (2005). Land cover changes between 1968 and 2003 in Cai Nuoc, Ca Mau Peninsula, Vietnam. Environment, Development and Sustainability, Vol. 7, pp.519-536.
16. Botta, A., Viovy, N., Ciais, P., Friedlingstein, P. and Monfray, P. (2000). A global prognostic scheme of leaf onset using satellite data. Global Change Biology, Vol. 6(7), pp.709-725.
17. Bradley, B.A. and Mustard, J.F. (2008). Comparison of phenology trends by land cover class: a case study in the Great Basin, USA. Global Change Biology, Vol. 14(2), pp.334-346.
18. Brenner, A.R. and Roessing, L. (2008). Radar imaging of urban areas by means of Very High Resolution SAR and Interferometric SAR. IEEE Transactions on Geoscience and Remote Sensing, Vol. 46(10), pp.2971-2982.
19. Brown, M.E., Pinzon, J.E., Didan, K., Morisette, J.T. and Tucker, C.J. (2006). Evaluation of the consistency of long-term NDVI time series derived from AVHRR, SPOT-vegetation, SeaWiFS, MODIS, and Landsat ETM+ sensors. IEEE Transactions on Geoscience and Remote Sensing, Vol. 44(7), pp.1787-1793.
20. Campbell, J.B. (1987). Introduction to Remote Sensing. The Guilford Press, New York, p.281.
21. Chen, P.Y., Fedosejevs, G., Tiscareño-LóPez, M. and Arnold, J.G. (2006). Assessment of MODIS-EVI, MODIS-NDVI and VEGETATION-NDVI composite data using agricultural measurements: An example at corn fields in western Mexico. Springer, Netherlands, Environmental Monitoring and Assessment, Vol. 119(1-3), pp.69-82.
22. Chris, C.F. and Molly, E.B. (2006). Intra-seasonal NDVI change projections in semi-arid Africa. Remote Sensing of Environment, Vol. 101, pp.249-256.
23. Choudhury, B.J. (1987). Relationship between vegetation indices, radiation absorption, and net photosynthesis evaluated by sensitivity analysis. Remote Sensing of Environment, Vol. 22, pp.209-233.
24. Coops, N.C., Waring, R.H. and Landsberg, J.J. (1998). Assessing forest productivity in Australia and New Zealand using a physiologically-based model driven with averaged monthly weather data and satellite-derived estimates of canopy photosynthetic capacity. Forest Ecology and Management, Vol. 104, pp.113-127.
25. Coppin, P.R. and Bauer, M.E. (1996). Digital change detection in forest ecosystems with remote sensing imagery. Remote Sensing Reviews, Vol. 13, pp.207-234.
26. Dale, P.E.R., Chandica, A.L. and Evans, M. (1996). Using image subtraction and classification to evaluate change in subtropical intertidal wetlands. International Journal of Remote Sensing, Vol. 17, pp.703-719.
27. Debien, A., Neerinckx, S., Kimaro, D. and Gulinck, H. (2010). Influence of satellite-derived rainfall patterns on plague occurrence in northeast Tanzania. International Journal of Health Geographics, Vol. 9, pp.1-10.
28. Deer, P.J. (1995). Digital change detection techniques: Civilian and military applications. International Symposium on Spectral Sensing Research 1995 Report, Greenbelt, M.D: Goddard Space Flight Center. URL: http://ltpwww.gsfc.nasa.gov/ISSSR-95/digitalc.htm. (Accessed on November 15, 2012).
29. DeFries, R.S., Hansen, M.C. and Townshend, J.R.G. (2000). Global continuous fields of vegetation characteristics: A linear mixture model applied to multi-year 8 km AVHRR data. International Journal of Remote Sensing, Vol. 21, pp.1389-1414.
30. Dozier, J. and Painter, T.H. (2004). Multispectral and hyperspectral remote sensing of alpine snow properties. Annual Review of Earth and Planetary Science, Vol. 32(1), pp.465-494.
31. Elvidge, C.D. and Lyon, R.J.P. (1985). Influence of rock-soil spectral variation on the assessment of green biomass. Remote Sensing of Environment, Vol. 17, pp.265-279.
32. Emery, W.J. and Brown, J. (1989). AVHRR image navigation: Summary and review. Photogrammetric Engineering & Remote Sensing, Vol. 55, pp.1175-1183.

33. Fontana, F.M.A. (2009). From single pixel to continental scale: using AVHRR and MODIS to study land surface parameters in mountain regions. Ph.D. dissertation, Institute of Geography, University of Bern, Switzerland. URL: http://www.climate studies.unibe.ch/students/theses/phd/31.pdf. (Accessed on October 15, 2012).
34. Funk, C. and Budde, M.E. (2009). Phenologically-tuned MODIS NDVI-based production anomaly estimates for Zimbabwe. Remote Sensing of Environment, Vol. 113(1), pp.115-125.
35. Gamon, J.A., Field, C.B., Goulden, M.L., Griffin, K.L., Hartley, E., Joel, G., Peñuelas, J. and Valentini, R. (1995). Relationships between NDVI, canopy structure, and photosynthesis in three Californian vegetation types. Ecological Applications, Vol. 4, pp.322-343.
36. Gao, B.C. (1996). NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space. Remote Sensing of Environment, Vol. 58, pp.257-266.
37. Gitelson, A.A. and Merzlyak, M.N. (1996). Signature analysis of leaf reflectance spectra: Algorithm development for remote sensing of chlorophyll. Journal of Plant Physiology, Vol. 148, pp.494-500.
38. GSFC/NASA. MODIS technical specifications. (2003). URL: http://modis.gsfc.nasa.gov/about/ specs.html. (Accessed on September 05, 2011).
39. Guenther, B., Godden, G., Xiong, X., Knight, E., Qiu, S., Montgomery, H., Hopkins, M., Khayat, M. and Hao, Z. (1998). Prelaunch algorithm and data format for the level 1 calibration products for the EOS-AM1 Moderate Resolution Imaging Spectroradiometer (MODIS). IEEE Transaction on Geoscience and Remote Sensing, Vol. 36(4), pp.1142-1151.
40. Guo, X. (2003). Relationships between NDVI and climatological variability in the Prairie ecozone of Canada. Prairie Perspectives, Vol.6, pp.32-46.
41. Hall, F.G., Brown, de C.E., Collatz, G.J., Landis, D., Dirmeyer, P., Betts, A., Huffman, G.J., Bounoua, L., and Meeson, B. (2006). ISLSCP Initiative II global data sets: Surface boundary conditions and atmospheric forcings for land-atmosphere studies. Journal of Geophysical Research, Vol. 111(D22S01), 20 p. URL: http://www.agu.org/pubs/ crossref/2006/2006JD007366.shtml. (Accessed on January 10, 2012).
42. Hamel, S., Garel, M., Festa-Bianchet, M., Gaillard, J-M. and Côté, S.D. (2009). Spring Normalized Difference Vegetation Index (NDVI) predicts annual variation in timing of peak faecal crude protein in mountain ungulates. Journal of Applied Ecology, Vol. 46, pp.582-589.
43. Hashemi, S.A. (2010). Evaluating phenological events of shrubs land by AVHRR data. American Journal of Scientific Research, Issue 12, pp.23-31.
44. Healey, S.P., Cohen, W.B., Zhiqiang, Y. and Krankina, O.N. (2005). Comparison of tasseled cap-based Landsat data structures for use in forest disturbance detection. Remote Sensing of Environment, Vol. 97(3), pp.301-310.
45. Höpfner, C. and Scherer, D. (2011). Analysis of vegetation and land cover dynamics in north-western Morocco during the last decade using MODIS NDVI time series data. Biogeosciences, Vol. 8, pp.3359-3373.
46. Huete, A.R. (2005). Global variability of terrestrial surface properties derived from MODIS visible to thermal-infrared measurements. Proceedings of IGARSS 05 Geoscience and Remote Sensing Symposium, 25-29 July 2005. URL: http://ieeexplore.ieee.org/iel5/10226/32601/01526782.pdf. (Accessed on September 05, 2011).
47. Huete, A.R. and Tucker, C.J. (1991). Investigation of soil influences in AVHRR red and near-infrared vegetation index imagery. International Journal of Remote Sensing, Vol. 12, pp. 1223-1242.
48. Huete, A.R., Didan, K., Miura, T., Rodriguez, E.P., Gao, X. and Ferreira, L.G. (2002). Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment, Vol. 83(1-2), pp.195-213.
49. Huete, A.R., Jackson, R.D. and Post, D.F. (1985). Spectral response of a plant canopy with different soil backgrounds. Remote Sensing of Environment, Vol. 17, pp.37-53.
50. Huete, A.R., Justice, C. and Leeuwen, van W. (1999). MODIS vegetation index (MOD 13) algorithm theoretical basis document version 3. URL: http://modis.gsfc.nasa.gov/data/atbd/atbd_mod13.pdf. (Accessed on September 17, 2011).
51. Huete, A.R., Liu, H.Q., Batchily, K. and Leeuwen, van W. (1997). A comparison of vegetation indices over a global set of TM images for EOS-MODIS. Remote Sensing of Environment, Vol. 59, pp.440-451.
52. Hurskainen, P. and Pellikka, P. (2004). Change detection of informal settlements using multi-temporal aerial photographs – The case of Voi, SE-Kenya, Proceedings of the 5th African Association of Remote Sensing of Environment Conference, 18-21 October 2004, Nairobi, Kenya. URL: http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.112.127 (Accessed on November 11, 2012).
53. Isaacman, A., Toller, G., Guenther, B., Barnes, W.L. and Xiong, X. (2003). MODIS level 1B calibration and data products. In: Huang, H., Lu, D. and Sasano, Y. (Eds.), Earth Observing Systems VIII, Proceedings of SPIE, Vol. 5151, pp.552-562.
54. Jakubauskas, M.E., David, R. and Kastens, J.H. (2002). Crop identification using harmonic analysis of time-series AVHRR NDVI data. Computers and Electronics in Agriculture, Vol. 37(1-3), pp.127-139.

55. James, M.E. and Kalluri, S.N.V. (1994). The Pathfinder AVHRR land dataset: An improved coarse resolution dataset for terrestrial monitoring. International Journal of Remote Sensing, Vol. 15(17), pp.3347-3363.
56. Jasinski, M.F. (1990). Sensitivity of the normalized difference vegetation index to sub-pixel canopy cover, soil albedo, and pixel scale. Remote Sensing of Environment, Vol. 32, pp.169-187.
57. Jensen, J.R. (1996). Introductory digital image processing: A remote sensing perspective. 2nd Edition, Englewood Cliffs, New Jersey, Prentice-Hall, pp.72-108.
58. Jensen, J.R. (2005). Introductory digital image processing: A remote sensing perspective. 3rd Edition, Englewood Cliffs, New Jersey, Prentice-Hall, pp.34-67.
59. Jensen, J.R., Cowen, D., Narumalani, S. and Halls, J. (1997). Principles of change detection using digital remote sensor data. In integration of Geographic Information Systems and Remote Sensing. Star, J.L., Estes, J.E. and McGwire, K.C (Eds.), Cambridge University Press, Cambridge, pp.37-54.
60. Jensen, J.R., Rutchey, K., Koch, M.S. and Narumalani, S. (1995). Inland wetland change detection in the everglades water conservation area 2A using a time series of normalized remotely sensed data. Photogrammetric Engineering & Remote Sensing, Vol. 61, pp.199-209.
61. Jianya, G., Haigang, S., Guorui, Ma. and Qiming, Z. (2008). A review of multi-temporal remote sensing data change detection algorithms. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII. Part B7, pp.757-762. URL: http://www.isprs.org/proceedings/XXXVII/congress/7_pdf/5_WG-VII-5/05.pdf. (Accessed on November 15, 2012).
62. Jin, S. and Sader, S.A. (2005). Comparison of time series tasseled cap wetness and the normalized difference moisture index in detecting forest disturbances. Remote Sensing of Environment, Vol. 94(3), pp.364-372.
63. Jolly, W.M., Nemani, R. and Running, S.W. (2005). A generalized, bioclimatic index to predict foliar phenology in response to climate. Global Change Biology, Vol. 11, pp.619-632.
64. Justice, C.O., Townshend, J.R.G., Holben, B.N. and Tucker, C.J. (1985). Analysis of the phenology of global vegetation using meteorological satellite data. International Journal of Remote Sensing, Vol. 6, pp.1271-1318.
65. Justice, C.O., Townshend, J.R.G., Vermote, E.F., Masuoka, E., Wolfe, R.E., Saleous, N., Roy, D.P. and Morisette, J.T. (2002). An overview of MODIS land data processing and product status. Remote Sensing of Environment, Vol. 83, pp.3-15.
66. Kaiser, M.F. (2009). Environmental changes, remote sensing, and infrastructure development: The case of Egypt's East Port Said Harbour. Applied Geography, Vol. 29, pp.280-288.
67. Karaburun, A. (2010). Estimation of C factor for soil erosion modeling using NDVI in Büyükçekmece watershed. Ozean Journal of Applied Sciences, Vol. 3(1), pp.77-85. URL: http://ozelacademy.com/OJAS_v3n1_8.pdf. (Accessed on November 10, 2011).
68. Kidwell, K.B. (1991). NOAA polar orbiter data (TIROS-N, NOAA-6, NOAA-7, NOAA-8, NOAA-9, NOAA-10, NOAA-11, NOAA-12 and NOAA-14) users' guide: NOAA/NESDIS-National Environmental Satellite, Data, and Information Service. URL: http://www.nesdis.noaa.gov/ (Accessed on January 06, 2012).
69. Koutsias, N., Mallinis, G. and Karteris, M. (2009). A forward/backward principal component analysis of Landsat-7 ETM+ data to enhance the spectral signal of burnt surfaces. ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 64, pp.37-46.
70. Lee, T.M. and Yeh, H.C. (2009). Applying remote sensing techniques to monitor shifting wetland vegetation: A case study of Danshui River estuary mangrove communities, Taiwan. Ecological Engineering, Vol. 35, pp.487-496.
71. Li, Z., and Guo, X. (2012). Detecting climate effects on vegetation in northern mixed prairie using NOAA AVHRR 1-km time-series NDVI data. Remote Sensing, Vol. 4, pp.120-134.
72. Lillesand, T.M. and Kiefer, R.W. (1994). Remote Sensing and Image Interpretation. 3rd Edition, John Wiley & Sons, Inc., New York, pp.203-210.
73. Lillesand, T.M. and Kiefer, R.W. (2000). Remote sensing and image interpretation. 4th Edition, John Wiley & Sons, Inc., New York, pp.124-156.
74. Lillesand, T.M., Kiefer, R.W. and Chipman, J.W. (2004). Remote Sensing and Image Interpretation. 5th Edition, John Wiley & Sons, Inc., New York, pp.178-198.
75. Linkosalo, T., Häkkinen, R. and Hänninen, H. (2006). Models of the spring phenology of boreal and temperate trees: Is there something missing? Tree Physiology, Vol. 26(9), pp.1165-1172.
76. Los, S.O. (1993). Calibration adjustment of the NOAA Advanced Very High Resolution Radiometer without recourse to component channel-1 and channel-2 data. International Journal of Remote Sensing, Vol. 14(10), pp.1907-1917.
77. Los, S.O. (1998). Estimation of the ratio of sensor degradation between NOAA-AVHRR channels 1 and 2 from monthly NDVI composites. IEEE Transactions on Geoscience and Remote Sensing, Vol. 36, pp.206-213.

78. Los, S.O. (2010). ISLSCP II FASIR-adjusted NDVI 1982-98. In: Hall, F.G., Collatz, G., Meeson, B., Los, S.O., Brown, de C.E. and Landis, D. (Eds.), Department of Geography, University of Wales at Swansea, United Kingdom. URL: ftp://daac.ornl.gov/data/islscp_ii/vegetation/fasir_ndvi_monthly_xdeg/comp/1_fasir_ndvi_doc.pdf. (Accessed on January 10, 2012).
79. Los, S.O., Collatz, G.J., Sellers, P.J., Malmström, C.M., Pollack, N.H., DeFries, R.S., Bounoua, L., Parris, M.T., Tucker, C.J. and Dazlich, D.A. (2000). A Global 9-yr biophysical land surface dataset from NOAA- AVHRR data. Journal of Hydrometeorology, Vol. 1, pp.183-199.
80. Los, S.O., Justice, C.O. and Tucker, C.J. (1994). A global 1° by 1° NDVI data set for climate studies derived from the GIMMS continental NDVI data. International Journal of Remote Sensing, Vol. 15(17), pp.3493-3518.
81. Los, S.O., North, P.R.J., Grey, W.M.F. and Barnsley, M.J. (2005). A method to convert AVHRR normalized difference vegetation index time series to a standard viewing and illumination geometry. Remote Sensing of Environment, Vol. 99(4), pp.400-411.
82. Los, S.O., Weedon, G.P., North, P.R.J., Kaduk, J.D., Taylor, C.M. and Cox, P.M. (2006). An observation-based estimate of the strength of rainfall-vegetation interactions in the Sahel. Geophysical Research Letters, Vol. 33(L16402), 5 p. URL: http://www.agu.org/pubs/crossref/2006/2006GL027065.shtml. (Accessed on January 10, 2012).
83. Lotsch, A., Friedl, M.A. and Pinzon, J.E. (2003). Spatio-temporal deconvolution of NDVI image sequences using independent component analysis. IEEE Transactions on Geoscience and Remote Sensing, Vol. 41, pp.2938-2942.
84. Lu, D., Mausel, P., Brondízio, E. and Moran, E. (2004). Change detection techniques. International Journal of Remote Sensing, Vol. 25(12), pp. 2365-2407.
85. Lunetta, R.L., Johnson, D.M., Lyon, J.G. and Crotwell, J. (2004). Impacts of imagery temporal frequency on land-cover change detection monitoring. Remote Sensing of Environment, Vol. 89(4), pp.444-454.
86. Lunetta, R.S., Alvarez, R., Edmonds, C.M., Lyon, J.G., Elvidge, C.D. and Bonifaz, R. (2002). An assessment of NALC/Mexico land-cover mapping results: Implications for assessing landscape change. International Journal of Remote Sensing, Vol. 23(16), pp.3129-3148.
87. Lunetta, R.S., Ediriwickrema, J., Johnson, D.M., Lyon, J.G. and McKerrow, A. (2002a). Impacts of vegetation dynamics on the identification of land-cover change in a biologically complex community in North Carolina USA. Remote Sensing of Environment, Vol. 82, pp.258-270.
88. Lunetta, R.S., Knight, J.F., Ediriwickrema, J., Lyon, J.G. and Worthy, L.D. (2006). Land-cover change detection using multi-temporal MODIS NDVI data. Remote Sensing of Environment, Vol. 105, pp.142-154.
89. Maselli, F., Conese, C., Petkov, L. and Maracchi, G. (1996). Eco-climatic classification of Tuscany through NOAA-AVHRR data. International Journal of Remote Sensing, Vol. 17, pp.2369-2384.
90. Menzel, A., Estrella, N. and Fabian, P. (2001). Spatial and temporal variability of the phenological seasons in Germany from 1951 to 1996. Global Change Biology, Vol. 7, pp.657-666.
91. Matthews, E. (1983). Global vegetation and land use: New high-resolution data bases for climate studies. Journal of Climate and Applied Meteorology, Vol. 22, pp.474-487.
92. Meneses-Tovar, C.L. (2011). NDVI as indicator of degradation. Unasylva, Vol. 62(238), pp. 39-46.
93. Mikkola, K. (1996). A remote sensing analysis of vegetation damage around metal smelters in the Kola Peninsula, Russia. International Journal of Remote Sensing, Vol. 17(18), pp.3675-3690.
94. MODIS (1999). MODIS Vegetation Index (MOD 13): Algorithm theoretical basis document (version 3), pp.26-29. URL: http://modis.gsfc.nasa.gov/data/atbd/atbd_mod13.pdf. (Accessed on November 14, 2012).
95. Mouat, D.A., Mahin, G.C. and Lancaster, J. (1993). Remote sensing techniques in the analysis of change detection. Geocarto International, Vol. 2, pp.39-50.
96. Muchoney, D.M. and Haack, B.N. (1994). Change detection for monitoring forest defoliation. Photogrammetric Engineering & Remote Sensing, Vol. 60, pp.1243-1251.
97. Myneni, R.B. and Asrar, G. (1994). Atmospheric effects and spectral vegetation indices. Remote Sensing of Environment, Vol. 47, pp.390-402.
98. Nicandrou, A. (2010). Hydrological assessment and modelling of the river Fani catchment, Albania. Faculty of Advanced Technology, University of Glamorgan. URL: http://dspace1.isd.glam.ac.uk/dspace/handle/10265/461 (Accessed on November 11, 2012).
99. Nightingale, J.M., Esaias, W.E., Wolfe, R.E., Nickeson, J.E. and Pedelty, J.A. (2008). Assessing the effect of climate change on honey bees using scale hive records and satellite derived vegetation phenology products. URL: http://www.igarss08.org/Abstracts/pdfs/2282.pdf. (Accessed on November 10, 2011).
100. Pal, S.K., Majumdar, T.J. and Bhattacharya, A.K. (2007). ERS-2 SAR and IRS-1C LISS III data fusion: A PCA approach to improve remote sensing based

geological interpretation. ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 61, pp.281-297.

101. Pesaresi, M. (2000). Texture analysis for urban pattern recognition using fine-resolution panchromatic satellite imagery. Geographical and Environmental Modelling, Vol. 4(1), pp.43-63.
102. Pettorelli, N., Vik, J.O., Mysterud, A., Gaillard, J-M., Tucker, C.J. and Stenseth, N.C. (2005). Using the satellite-derived NDVI to assess ecological responses to environmental change. Trends in Ecology & Evolution, Vol. 20(9), pp.503-510.
103. Prentice, K.C. (1990). Bioclimatic distribution of vegetation for general circulation model studies. Journal of Geophysical Research, Vol. 95, pp.11811-11830.
104. Prenzel, B. and Treitz, P. (2004). Remote sensing change detection for a watershed in north Sulawesi, Indonesia. Progress in Planning, Vol. 61, pp.349-363.
105. Rahman, Md.R., Islam, A.H.M.H., and Rahman, Md.A. (2004). NDVI derived sugarcane area identification and crop condition assessment. Planplus, Vol. 1(2), pp.1-12.
106. Ramachandra, T.V. and Kumar, U. (2004). Geographic resources decision support system for land use, land cover dynamics analysis. Proceedings of the FOSS/GRASS Users Conference, 12-14 September 2004, Bangkok, Thailand. URL: http://wgbis.ces.iisc.ernet.in/energy/paper/grdss/viewpaper.pdf. (Accessed on November 15, 2012).
107. Rao, C.R.N. and Chen, J. (1995). Inter-satellite calibration linkages for the visible and near infrared channels of the Advanced Very High Resolution Radiometer on NOAA-7, -9, -11 spacecraft. International Journal of Remote Sensing, Vol. 16, pp.1931-1942.
108. Reed, B.C., Brown, J.F., Vanderzee, D., Loveland, T.R., Merchant, J.W. and Ohlen, D.O. (1994). Measuring phenological variability from satellite imagery. Journal of Vegetation Science, Vol. 5(5), pp.703-714.
109. Rouse, J.W., Haas, R.H., Schell, J.A. and Deering, D.W. (1973). Monitoring vegetation systems in the Great Plains with ERTS. 3rd ERTS Symposium, NASA SP-351 I, pp.309-317. URL: http://geol.hu/data/online_help/Vegetation_Indices.html. (Accessed on January 10, 2012).
110. Running, S.W., Loveland, T.R. and Pierce, L.L. (1994). A vegetation classification logic based on remote sensing for use in global biogeochemical models. Ambio, Vol. 23, pp.77-81.
111. Sader, S.A. and Winne, J.C. (1992). RGB-NDVI colour composites for visualizing forest change dynamics. International Journal of Remote Sensing, Vol. 13, pp.3055-3067.
112. Sekhon, N.S., Hassan, Q.K. and Sleep, R.W. (2010). Evaluating potential of MODIS-based indices in determining “Snow Gone” stage over forest-dominant regions. Remote Sensing, Vol. 2, pp.1348-1363.
113. Sellers, P.J. (1985). Canopy reflectance, photosynthesis and transpiration. International Journal of Remote Sensing, Vol. 6, pp.1335-1372.
114. Sellers, P.J., Los, S.O., Tucker, C.J., Justice, C.O., Dazlich, D.A., Collatz, G.J. and Randall, D.A. (1996). A revised land surface parameterization (SiB-2) for atmospheric GCMs. Part 2: The generation of global fields of terrestrial biophysical parameters from satellite data. Journal of Climate, Vol. 9(4), pp.706-737.
115. Sellers, P.J., Tucker, C.J., Collatz, G.J., Los, S.O., Justice, C.O., Dazlich, D.A. and Randall, D.A. (1994). A global 1° by 1° NDVI data set for climate studies. Part 2: The generation of global fields of terrestrial biophysical parameters from the NDVI. International Journal of Remote Sensing, Vol. 15(17), pp.3519-3545.
116. Serpico, S.B. and Bruzzone, L. (1999). Change detection. In information processing for remote sensing. Chen, C.H. (Ed.), World Scientific Publishing, Singapore, pp.319-336.
117. Sesnie, S.E., Gessler, P.E., Finegan, B. and Thessler, S. (2008). Integrating Landsat TM and SRTM-DEM derived variables with decision trees for habitat classification and change detection in complex neotropical environments. Remote Sensing of Environment, Vol. 112, pp.2145-2159.
118. Singh, A. (1989). Digital change detection techniques using remotely-sensed data. International Journal of Remote Sensing, Vol. 10, pp.989-1003.
119. Spruce, J.P., Hargrove, W., Norman, S., Gasser, J., Smoot, J. and Kuper, P.D. (2012). Role of MODIS vegetation phenology products in the ForWarn system for monitoring of forest disturbances in the Conterminous United States. NASA Stennis Space Center, USA. URL: http://ntrs.nasa.gov/search.jsp?R=20120013471 (Accessed on November 18, 2012).
120. Stowe, L.L., Jacobowitz, H., Ohring, G., Knapp, K.R. and Nalli, N.R. (2002). The advanced very high resolution radiometer (AVHRR) pathfinder atmosphere (PATMOS) climate dataset: Initial analyses and evaluations. Journal of Climate, Vol. 15(11), pp.1243-1260.
121. Tan, B., Morisette, J.T., Wolfe, R.E., Gao, F., Ederer, G.A., Nightingale, J.M. and Pedelty, J.A. (2008). Vegetation phenology metrics derived from temporally smoothed and gap-filled MODIS data. URL: www.igarss08.org/Abstracts/pdfs/2347.pdf. (Accessed on November 10, 2011).

122. Teillet, P.M., Slater, P.N., Ding, Y., Santer, R.P., Jackson, R.D. and Moran, M.S. (1990). Three methods for the absolute calibration of the NOAA AVHRR sensors in-flight. Remote Sensing of Environment, Vol. 31, pp.105-120.
123. Teng, S.P., Chen, Y.K., Cheng, K.S. and Lo, H.C. (2008). Hypothesis-test-based land cover change detection using multi-temporal satellite images – A comparative study. Advances in Space Research, Vol. 41, pp.1744-1754.
124. Townshend, J., Justice, C., Li, W., Gurney, C. and McManus, J. (1991). Global land cover classification by remote sensing: present capabilities and future possibilities. Remote Sensing of Environment, Vol. 35(2-3), pp.243-255.
125. Tucker, C.J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment, Vol. 8, pp.127-150.
126. Tucker, C.J. and Sellers, P.J. (1986). Satellite remote sensing of primary production. International Journal of Remote Sensing, Vol. 7, pp.1396-1416.
127. Tucker, C.J., Pinzon, J.E., Brown, M.E., Slayback, D.A., Pak, E.W., Mahoney, R., Vermote, E.F. and El-Saleous, N.Z. (2005). An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data. International Journal of Remote Sensing, Vol. 26(20), pp.4485-4498.
128. USGS (2008). Earth Resources Observation and Science Center. URL: http://glovis.usgs.gov/ (Accessed on November 12, 2012).
129. USGS (2010). What is NDVI? United States Geological Survey: Science for Changing World. URL: http://ivm.cr.usgs.gov/ (Accessed on September 10, 2011).
130. Vermote, E.F. and Kaufman, Y.J. (1995). Absolute calibration of AVHRR visible and near-infrared channels using ocean and cloud views. International Journal of Remote Sensing, Vol. 16(13), pp.2317-2340.
131. Vermote, E.F. and Vermeulen, A. (1999). Atmospheric correction algorithm: Spectral reflectances (MOD09) algorithm technical background document. URL: http://modis.gsfc.nasa.gov/data/atbd/atbd_mod08.pdf. (Accessed on November 18, 2012).
132. Vermote, E.F., El-Saleous, N.Z. and Justice, C.O. (2002). Atmospheric correction of MODIS data in the visible to middle infrared: First results. Remote Sensing of Environment, Vol. 83, pp.97-111.
133. Weinreb, M.P., Hamilton, G., Brown, S. and Koczor, R.J. (1990). Nonlinearity corrections in calibration of Advanced Very High Resolution Radiometer infrared channels. Journal of Geophysical Research, Vol. 95(C5), pp.7381-7388. URL: http://www.agu.org/pubs/crossref/1990/JC095iC05p07381.shtml. (Accessed on January 10, 2012).
134. Weishou, S., Di, J., Hui, Z., Shouguang, Y., Haidong, L. and Naifeng, L. (2011). The response relation between climate change and NDVI over the Qinghai-Tibet plateau. World Academy of Science, Engineering and Technology, Vol. 59, pp.2216-2222.
135. Westerling, A.L., Hidalgo, H.G., Cayan, D.R. and Swetnam, T.W. (2006). Warming and earlier spring increase Western U.S. forest wildfire activity. Science, Vol. 313(5789), pp.940-943.
136. White, A., Hoffman, F. and Hargrove, W. (2005). A global framework for monitoring phenological response to climate change. Geophysical Research Letters, Vol. 32, pp.694-703.
137. Xiong, J., Toller, G., Chiang, V., Sun, J., Esposito, J.A. and Barnes, W.L. (2005). MODIS level 1B algorithm theoretical basis document. URL: http://modis.gsfc.nasa.gov/ (Accessed on November 12, 2012).
138. Xiong, X., Chiang, K., Guenther, B. and Barnes, W.L. (2003). MODIS thermal emissive bands calibration algorithm and on-orbit performance. In: Huang, H., Lu, D. and Sasano, Y. (Eds.), Optical Remote Sensing of the Atmosphere and Clouds III, Proceedings of the SPIE, Vol. 4891, pp.392-401.
139. Xiong, X., Sun, J., Esposito, J.A., Guenther, B. and Barnes, W.L. (2003a). MODIS reflective solar bands calibration algorithm and on-orbit performance. In: Huang, H., Lu, D. and Sasano, Y. (Eds.), Optical Remote Sensing of the Atmosphere and Clouds III, Proceedings of the SPIE, Vol. 4891, pp.95-104.
140. Yuan, D., Elvidge, C.D. and Lunetta, R.S. (1998). Survey of multispectral methods for land cover change analysis. In remote sensing change detection: Environmental monitoring methods and applications. Lunetta, R.S. and Elvidge, C.D. (Eds.), Ann Arbor Press, Chelsea, Michigan, pp.21-39.
141. Zaeen, A.A. (2012). Remote sensing technique to monitoring the risk of soil degradation using NDVI. International Journal of Geographical Information System Applications and Remote Sensing, Vol. 3(1), pp.1-8.
142. Zeng, N., Neelin, J.D. and Lau, W.K.M. (1999). Enhancement of inter-decadal climate variability in the Sahel by vegetation interaction. Science, Vol. 286, pp.1537-1540.
143. Zoran, M. and Stefan, S. (2006). Climatic changes effects on spectral vegetation indices for forested areas analysis from satellite data. Proceedings of the 2nd Environmental Physics Conference, 18-22 February 2006, Alexandria, Egypt, pp.73-83.