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Full Length Research Paper

A review of remote sensing data change detection: Comparison of Faisalabad and Multan Districts, Punjab Province, Pakistan

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Vegetation is profoundly impacted by anthropogenic activities, particularly trampling. The ultimate effect of trampling is a reduction in amount of vegetation, often resulting in complete loss of vegetation cover. Satellite remote sensed data for land cover, landuse and its changes is a key to many diverse applications. Methods for monitoring vegetation change range from intensive field sampling with plot inventories to extensive analysis of remotely sensed data which has proven to be more cost effective for large regions, small site assessment and analysis. Remotely sensed change detection based on artificial neural networks presents a new technique using training algorithm. The trained neural network detected changes on a pixel-by-pixel basis in real time applications. The trained four-layered neural network (for example, decreased, some decrease, some increase and increased) provided complete categorical information about the nature of changes and detected complete land cover change "from-to" information, which is desirable in most change detection applications. This paper presents an application of the use of Landsat ETM+ images and MODIS EVI/NDVI time-series vegetation phenology algorithms of Faisalabad and Multan districts for evaluation of soil productivity and comparison of temporal change detection. The proposed method is successfully applied to actual multi-temporal and multi-spectral images.

Key words: Change detection, enhanced vegetation index (EVI), Landsat ETM+, normalized difference vegetation index (NDVI), remote sensing.

INTRODUCTION

Processing of multi-temporal images and change detection has been an active research field in remote sensing (Jianya et al., 2008). Although, successful application cases have been reported on the monitoring and detecting environmental change, there are enormous challenges on applying multi-temporal imagery to derive timely information on the earth's environment and human activities (Lillesand et al., 2004). In recent years, a great progress has been observed to overcome technological obstacles by the development of new platforms and sensors (Campbell, 1987; Jianya et al., 2008). Kerr and Ostrovsky (2003) and Pettorelli et al. (2005) have recently reviewed the numerous applications of satellite vegetation indices (VIs) in ecological studies. VIs is now indispensable tools in land cover classification, climate and landuse change detection, drought monitoring and habitat loss, to name just a few applications (Glenn et al., 2008). Change detection is a key task in remote sensing studies where temporal images acquired from spaceborne and airborne sensors are analyzed to detect changes over a period of time (Sundaresan et al., 2007). The wider availability of large archives of historical images also makes long-term change detection and modelling possible. Such a development stimulates further investigation in developing more advanced image processing methods and new approaches in handling image data in the time dimension (Richard et al., 2005; Jianya et al., 2008). Many techniques have been proposed in the last two decades for change detection using multi-temporal satellite data (Lu et al., 2004; Malpica and Alonso, 2008). Low-resolution satellite imagery commonly uses pixel-by-pixel change detection methods (Dai and Khorram, 1999). This cannot be applied to high-resolution satellite imagery due to the complexity of the scene; these images have greater detail, with many new signatures from different materials appearing in high-resolution images that were not detected in low-resolution images. For example, shadows present a problem in high-resolution imagery but not low-resolution imagery (Malpica and Alonso, 2008). The land cover changes occur naturally in a progressive and gradual way, however, it may be rapid and abrupt due to anthropogenic activities (Ramachandra and Kumar, 2004). Remote sensing data of better resolution at different time interval help in analyzing the rate of changes as well as the causal factors or drivers of changes (Dai and Khorram, 1999; Ramachandra and Kumar, 2004). Hence it has a significant role in planning at different spatial and temporal scales.

Change detection in agricultural planning helped in enhancing the capacity of local governments to implement sound environmental management (Prenzel and Treitz, 2004; Ramachandra and Kumar, 2004). This involved development of spatial and temporal database and analysis techniques. Efficiency of the techniques depends on several factors such as classification schemes, modelling, spatial and spectral resolution of remote sensing data, ground reference data and also an effective implementation of the result (Ramachandra and Kumar, 2004).

Study area

The District Faisalabad lies from 30° 42' to 31° 47' North latitude and 72° 40' to 73° 40' East longitude (GOP, 2000). It is bounded on the north by Jhang, Hafizabad and Nankana Sahib Districts, on the east by Nankana Sahib, Okara and Sahiwal districts, on the south by Sahiwal and Toba Tek Singh districts and on the west by Toba Tek Singh and Jhang districts, while the District Multan lies between 29° 22' to 30° 24' North latitude and 71° 03' to 72° 28' East longitude (GOP, 1999). It lies in a bend made by five confluent rivers and is bounded on the east by Lodhran and Khanewal districts, on the north by Khanewal district, on the south by Bahawalpur district dividing the two districts by Sutlej river in between and on the west by Chenab river across which Muzaffargarh district is situated.

RESEARCH DESIGN AND METHODS

Methods incorporated in this research paper included the application of an automated MODIS (Terra) EVI/NDVI time series to support multi-temporal imagery analysis. MODIS (Terra) EVI/NDVI data preprocessing was conducted to provide a filtered and cleaned uninterrupted data stream to support multi-temporal or phenological analysis.

MODIS (Terra) EVI/NDVI 16-days composite grid data in HDF format were acquired; February 2000 to February 2010 from the NASA Earth Observing System (EOS) data gateway. Details documenting the MODIS (Terra) EVI/NDVI compositing process and Quality Assessment Science Data Sets can be found at NASA's MODIS web site (MODIS, 1999; USGS, 2008).

In this research paper two Landsat ETM+ scenes 1999 and 2002 for District Faisalabad (path 149, row 38; 39 and path 150, row 38; 39), Landsat ETM+ scenes 1999 and 2002 for District Multan (path 150, row 39; 40) were used to implement the vegetation indices; the enhanced vegetation index (EVI), the normalized difference vegetation index (NDVI), the transformed normalized difference vegetation index (TNDVI) and the soil-adjusted vegetation index (SAVI).

In order to use these two scenes, several steps were followed to prepare for an accurate extraction and detection. These vital steps are: image registration, image enhancement and image mosaic as discussed by Macleod and Congalton (1998), Mahmoodzadeh (2007) and Al-Awadhi et al. (2011). These scenes were corrected and geo-referenced using projection UTM, zone 43 and datum WGS 84. Landsat has a long history of dataset, it is very helpful to map long-term vegetation cover and study the spatio-temporal vegetation changes (Schroeder et al., 2006; Xie, 2008).

ERDAS Imagine software have been used to generate the false colour composite by combining the near-infrared (NIR), red and green bands (4, 3, 2, respectively) for Landsat ETM+ images. Vegetation indices were applied upon 1999 and 2002 ETM+ images and further change detection technique was used to develop the EVI, NDVI, TNDVI and SAVI maps.

Data acquisition and change detection procedure

Remote sensing imagery offer unique possibilities for spatial and temporal characterization of the changes. The basic requirement is the availability of different dates of imagery which permits continuous monitoring of change and environmental developments over time. Change detection can be performed by restricting the analysis to a single sensor series or by using different satellite datasets (Lu et al., 2004; Nasr and Helmy, 2009).

The first step of the change detection procedures (Figure 1), involves data acquisition and a number of initial preprocessing steps prior to data analysis (Jensen et al., 1997). For instance, when acquiring imagery it is always necessary to preview the digital data to evaluate cloud cover conditions and data quality. In addition, the study area must be subset to conform to the outer boundaries of the area of interest (Lunetta, 1999; Nasr and Helmy, 2009).

Geometric distortions are normally introduced to satellite data during acquisition. These deficiencies may result from several sources including platform attitude (roll, pitch, and yaw), Earth’s rotation, scan skew and panoramic distortions (Mouat et al., 1993). Therefore, accurate geometric correction is particularly important for change detection analysis (Muchoney and Haack, 1994). The simultaneous analysis of multi-spectral data necessitates accurate spatial orientation of the input data sets. Because analysis is performed on a pixel-by-pixel basis, any mis-registration greater than one pixel will provide a false result for that pixel. To overcome this problem, the co-registration error between any two dates should not exceed 1 pixel. This is typically accomplished on the basis of uniformly well-distributed ground control points located on the images (Muchoney and Haack, 1994; Nasr and Helmy, 2009).

In the change detection process, when images of different types are comprised, with different spatial and spectral resolution, the number of difficulties increases. Different spatial resolution and differences in spectral resolution necessitate a different classification process for each, possibly with the result that comparison of their categories cannot be expected to yield high accuracies (Zee, 2006; Nasr and Helmy, 2009). Therefore, the direct multi-date classification is used, since it bypasses the difficulties associated with the analysis of images acquired by

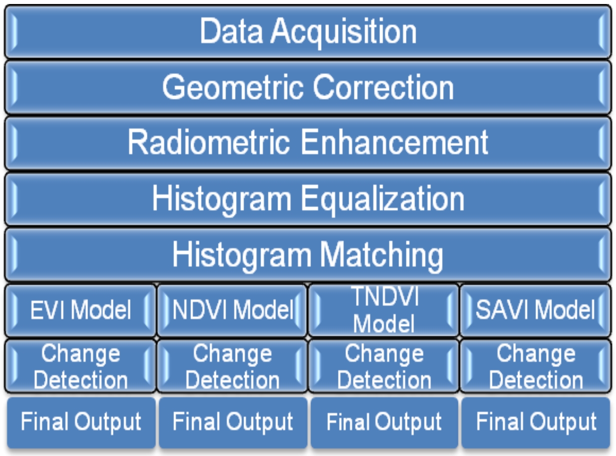

Figure 1. Scheme for change detection procedure.

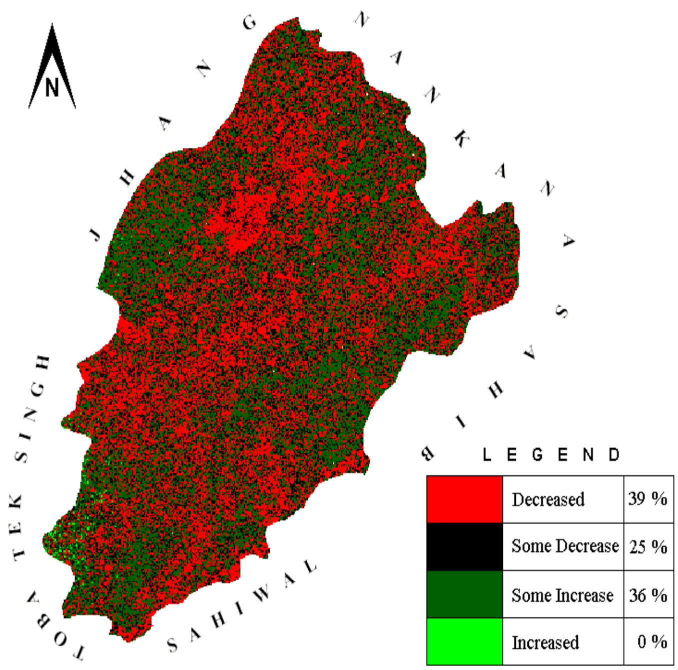

Figure 2. Map showing change detection (District Faisalabad) using EVI model.

different sensors (Muchoney and Haack, 1994). The main limitations are the higher dimensionality compared to the other approaches and the requirements of many classes (Coppin and Bauer, 1996; Nasr and Helmy, 2009).

Radiometric enhancement is performed to produce a homogenous radiometric set of data (Richard et al., 2005). So that, false changes are not introduced by factors such as: modification of the spectral distribution due to atmospheric conditions, different path radiance and seen angle variation (Ulbricht and Heckendorf, 1998). Ideally, all images would be calibrated to standard reflectance units (Nasr and Helmy, 2009). However, when comparing images to detect change, it is sufficient to convert raw digital counts to be consistent with a chosen reference image (Symeonakis et al., 2006). Histograms equalization and histogram matching were generated in order to identify the suitable contrast stretching level to optimize the balance (Singh, 1989) for both the Landsat ETM+ 1999 and 2002 images.

Image registration

Precise registration to the multi-temporal images is required by many change detection methods (Liu and Zhou, 2004). The importance of accurate spatial registration of multi-temporal imagery is obvious because largely spurious results of change detection will be produced if there is misregistration (Leonardo et al., 2006). If high registration accuracy is not available, a great deal of false change area in the scene will be caused by image displacement (Canty, 2007). It is generally agreed that geometrical registration accuracy of sub-pixel level is accepted (Jianya et al., 2008).

RESULTS

Figure 2 shows change detection using EVI model for District Faisalabad. Landsat ETM+ images for 1999 and 2002 were used to extract temporal changes in District Faisalabad. For balancing of an image, the geometric correction, radiometric enhancement, histogram equalization and histogram matching techniques were applied using ERDAS Imagine software. The EVI model was applied upon Landsat ETM+ 1999 and 2002 images and further change detection technique was used for extraction of land cover changes. The finding showed that during the period 1999 and 2002, the percentage of decreased vegetation was 39 while increased was zero. On the other hand, some increase > some decrease (Table 2). The result showed that the climatic variation was much higher in district Faisalabad and agricultural potential was decreasing during the period 1999 and 2002. Soil productivity can be seen in the western and north-western areas adjacent to district Jhang and Nankana Sahib, southern areas adjacent to district Toba Tek Singh and Sahiwal, and south-eastern part of district Faisalabad.

The EVI is an 'optimized index' designed to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences (Liu and Huete, 1995; Justice et al., 1998; Huete et al., 1999).

Figure 3 shows change detection using NDVI model for District Faisalabad. For this experiment, Landsat ETM+ images for 1999 and 2002 were used. After geometric correction, NDVI model was applied upon ETM+ images (Figure 4a and b) and further change detection technique was used for extraction of potential agricultural sites in district Faisalabad. The result showed that decreased > increased and some decrease > some increase (Table 2). A little soil potential can be seen in the western and north-western areas adjacent to district Jhang and Nankana Sahib, southern part adjacent to district

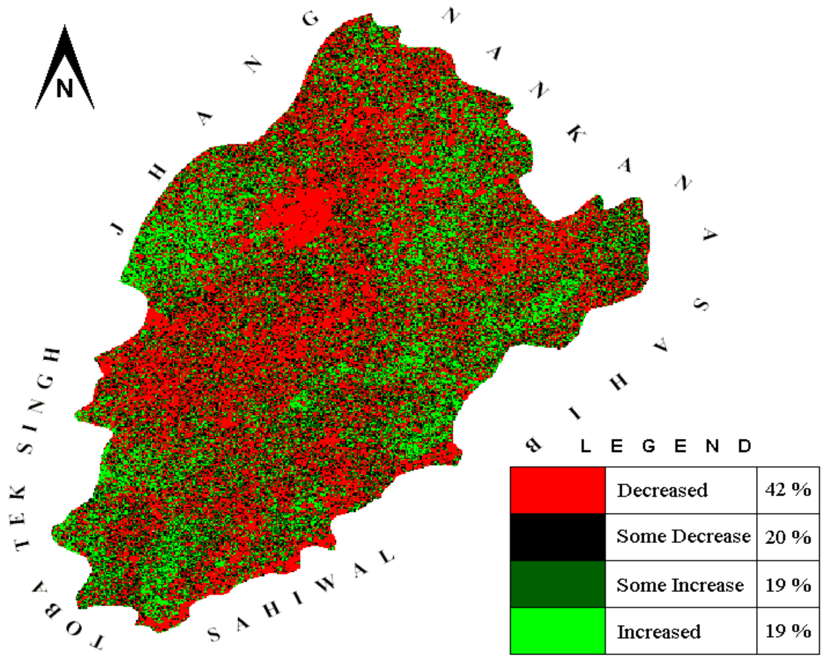

Figure 3. Map showing change detection (District Faisalabad) using NDVI model.

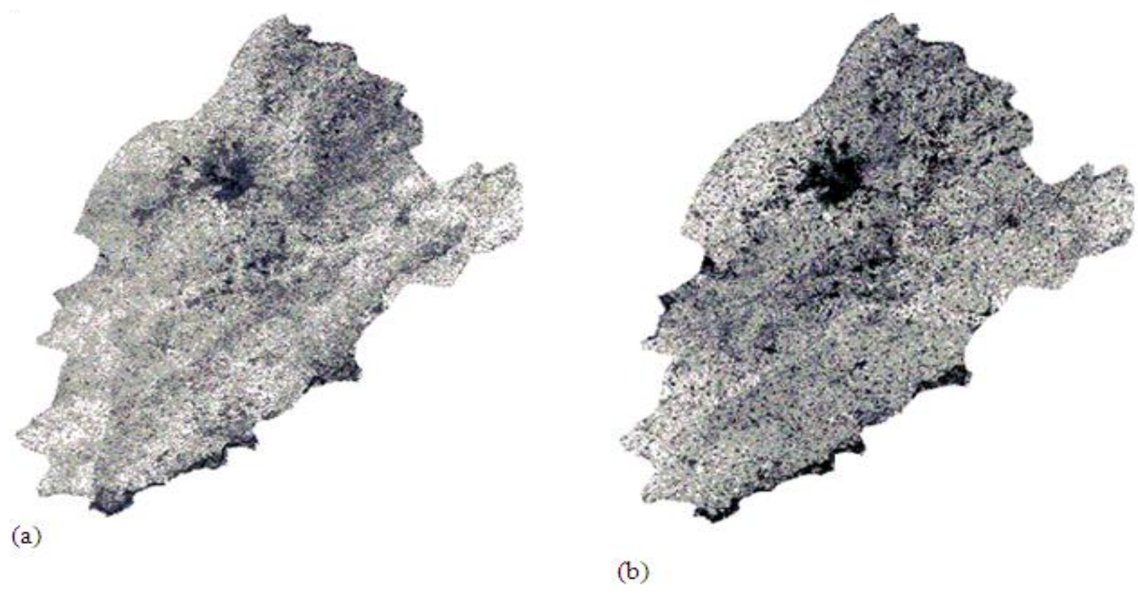

Figure 4. The NDVI image (a) 1999; (b) 2002 (District Faisalabad).

Toba Tek Singh and Sahiwal, and eastern and south-eastern part of district Faisalabad.

Rouse et al. (1973) suggested the most widely used NDVI to improve identifying the vegetated areas and their condition (Rouse et al., 1973; Yang et al., 2008). However, the NDVI index is saturated in high biomass and it is sensitive to a number of perturbing factors, such as atmospheric effects, cloud, soil effects, and anisotropic effects *etc.* Therefore, a number of derivatives and alternatives to NDVI have been proposed in the scientific literature to address these limitations (Yang et al., 2008).

The NDVI has been used widely in remote sensing studies since its development (Jensen, 2005). The NDVI values range from -1.0 to 1.0, where higher values are for green vegetation and low values for other common

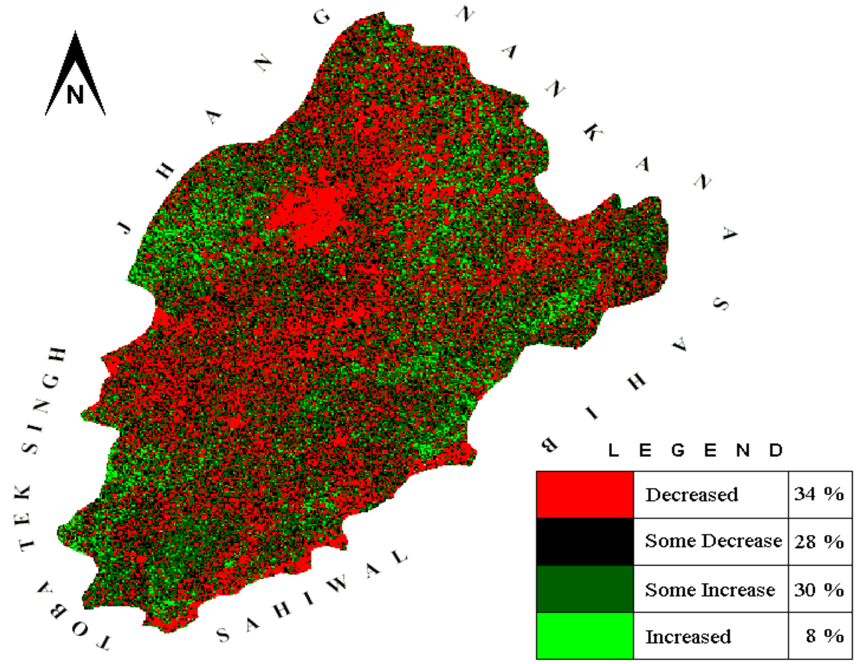

Figure 5. Map showing change detection (District Faisalabad) using TNDVI model.

Table 1. Vegetation indices evaluated in this research paper.

Vegetation index	Formula	Reference
EVI	(NIR–R)/(NIR + (C1*R) – (C2*B) + L)*(1 + L) C1=6.0, C2=7.5, L=1.0	Liu and Huete, 1995; Justice et al., 1998; Huete et al., 1999
NDVI	(NIR–R)/(NIR+R) NIR is ETM+ Band 4, R is ETM+ Band 3	Rouse et al., 1973
TNDVI	Sqrt ((NIR–R/NIR+R) +0.5)	Tucker, 1979
SAVI	(1 + L)*(NIR - R) / (NIR + R + L) with L = 0.5	Huete, 1988

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), 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).

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). The strength of the NDVI is in its ratioing concept (Moran et al., 1992), which reduces many forms of multiplicative noise (illumination differences, cloud shadows, atmospheric attenuation, and certain topographic variations) present in multiple bands (Chen et al., 2002).

Figure 5 shows change detection using TNDVI model for District Faisalabad. For this experiment, Landsat ETM+ images for 1999 and 2002 were used. After geometric correction, radiometric enhancement and histogram equalization TNDVI model was applied upon ETM+ images and further change detection technique was used for extraction of potential agricultural sites in district Faisalabad. The result showed that decreased was much higher than increased and some decrease < some increase (Table 2). The result showed that the climatic variation was much higher and agricultural potential was decreasing due to industrialization in urban and sub-urban areas in the District Faisalabad.

Tucker (1979) presented a TNDVI by adding a constant 0.5 to NDVI and taking the square root (Table 1). It always has positive values and the variance of the ratio is proportional to mean values. The TNDVI indicates a slight better correlation between the amounts of green biomass and is found in a pixel (Senseman et al., 1996a; Sandham and Zietsman, 1997; Yang et al., 2008).

Figure 6 shows change detection using SAVI model for

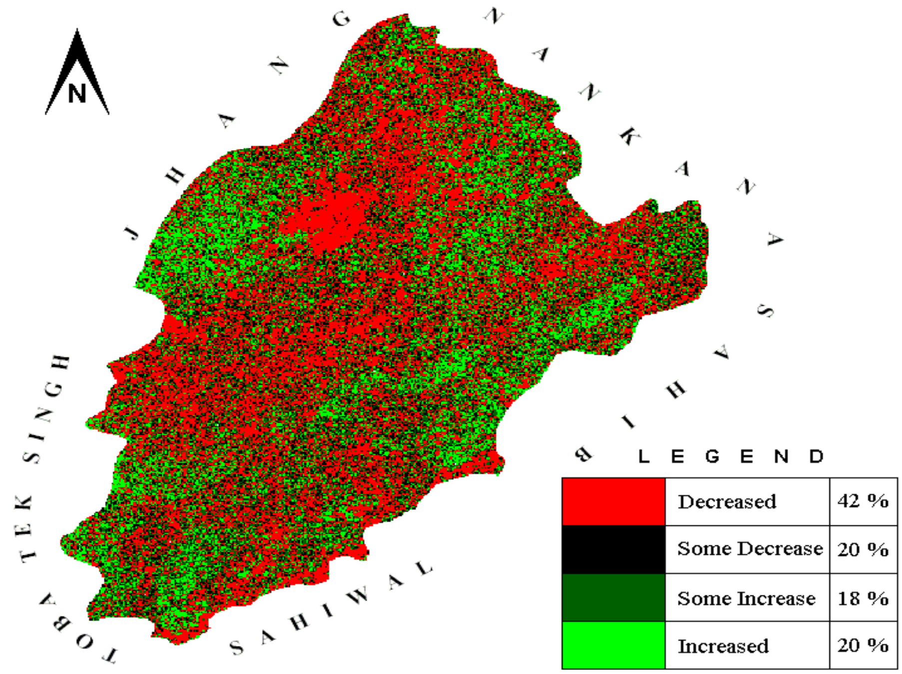

Figure 6. Map showing change detection (District Faisalabad) using SAVI model.

Table 2. Vegetation matrix percentage for individual change classification.

Vegetation indices	Faisalabad				Multan			
	Decreased %	Some decrease %	Some Increase %	Increased %	Decreased %	Some decrease %	Some increase %	Increased %
EVI	39	25	36	0	51	35	11	3
NDVI	42	20	19	19	61	25	11	3
TNDVI	34	28	30	8	34	52	13	1
SAVI	42	20	18	20	61	25	11	3

District Faisalabad. In this experiment, Landsat ETM+ images for 1999 and 2002 were used. For balancing of an image, the geometric correction, radiometric enhancement, histogram equalization and histogram matching techniques were applied using ERDAS imagine software. The SAVI model was applied upon ETM+ images and further change detection technique was used for extraction of potential agricultural sites in the District Faisalabad. The result showed that decreased was much higher than increased and some decrease > some increase (Table 2). To reduce the impact to the NDVI from the soil variations in lower vegetation cover areas, Huete (1988) proposed the SAVI by introducing a correction factor *L* (Yang et al., 2008). The SAVI was found to be an important step toward the establishment of simple "global" model that can describe dynamic soil-vegetation systems from remotely sensed data (Huete, 1988).

Figure 7 shows comparative analysis of vegetation indices for district Faisalabad. The EVI model showed almost zero increased while NDVI showed 19%, TNDVI 8% and SAVI 20%. The vegetation indices showed much higher decreased and some decrease, while in some increase class; the EVI showed 36%, NDVI 19%, TNDVI 30% and SAVI 18% (Table 2).

Due to scanty and erratic rainfall, successful agriculture is only possible in the district through irrigation. Presently, almost 2/3 of the district is fed by a perennial canal system; that is, the water flows constantly into a secondary and tertiary canal system as long as there is need for water and sufficient flow in the rivers. The outlets from the distributaries are not gated and are designed to deliver a fixed quantity of water when the canals are flowing at full capacity. The design flows in the distributaries are based on the historical size of the command area. This system was designed to spread a

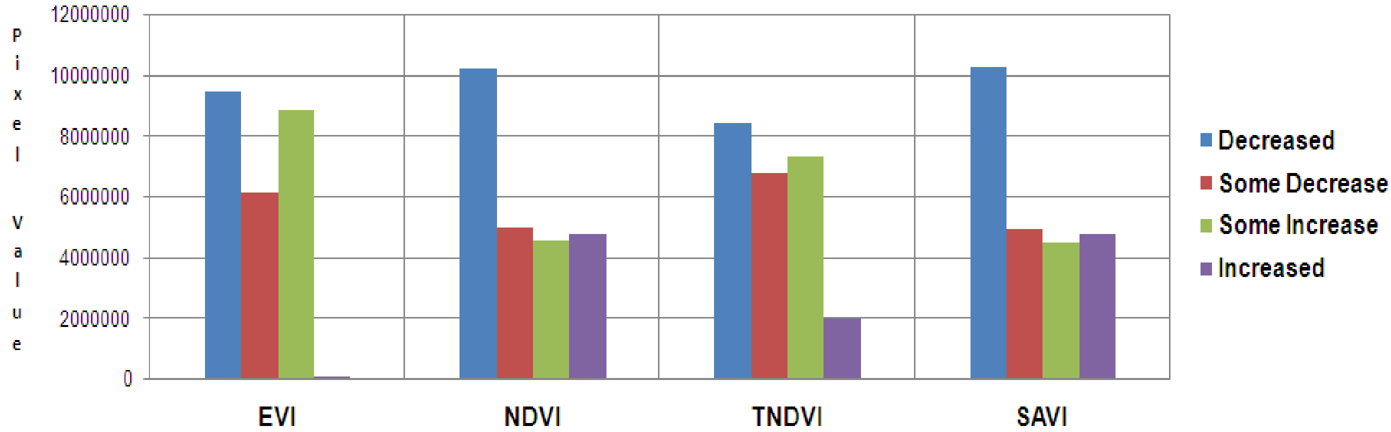

Figure 7. Comparative analysis of vegetation indices, District Faisalabad.

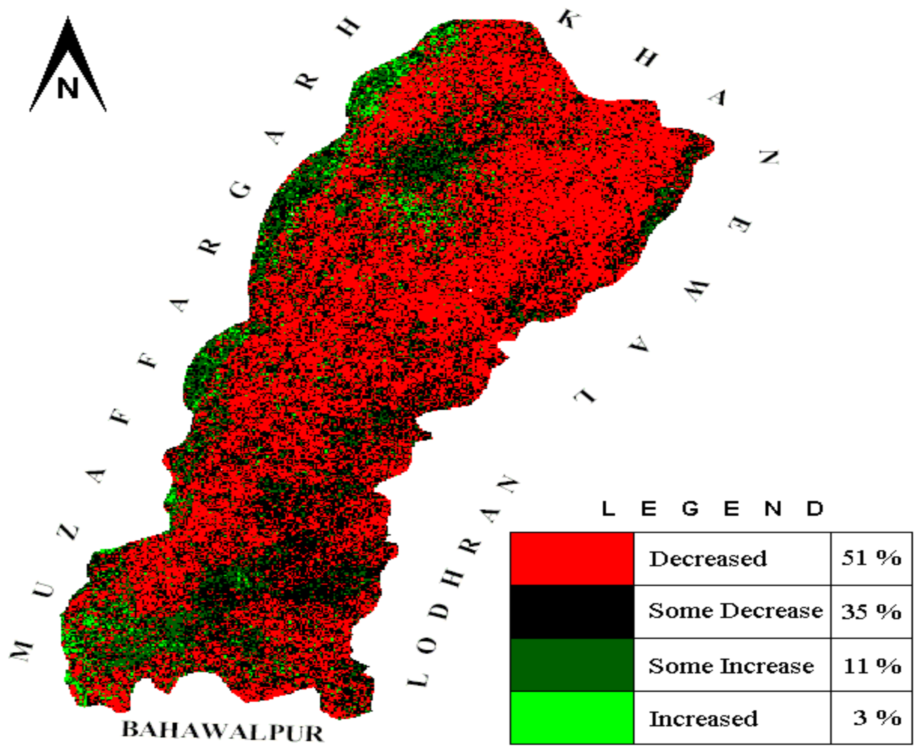

Figure 8. Map showing change detection (District Multan) using EVI model.

limited amount of canal water to support a cropping intensity of approximately 65%. The original design objective of the irrigation development was to protect against crop failure and prevent famine. However, the cropping intensities have increased up to 150% in the last two to three decades, enabled by additional supplies from groundwater extraction (Ahmad, 2002).

Figure 8 shows change detection using EVI model in the District Multan. Landsat ETM+ images for 1999 and 2002 were used to extract temporal changes in the district. The finding showed that during 1999 and 2002, the percentage of decreased was much higher than increased. Some decrease > some increase (Table 2). The result showed that the climatic variation was much higher in the district and agricultural potential was decreasing during the period 1999 and 2002. Soil productivity can be seen in western areas adjacent to the Chenab River and southern part of the district, while soil

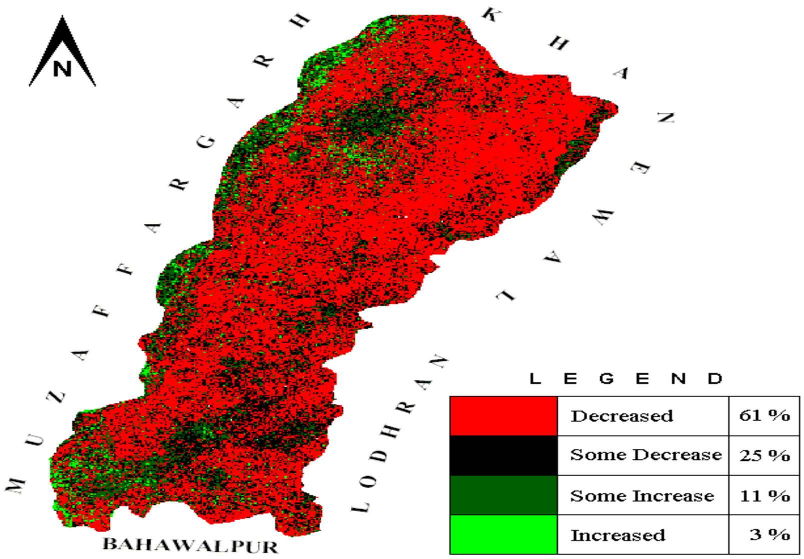

Figure 9. Map showing change detection (District Multan) using NDVI model.

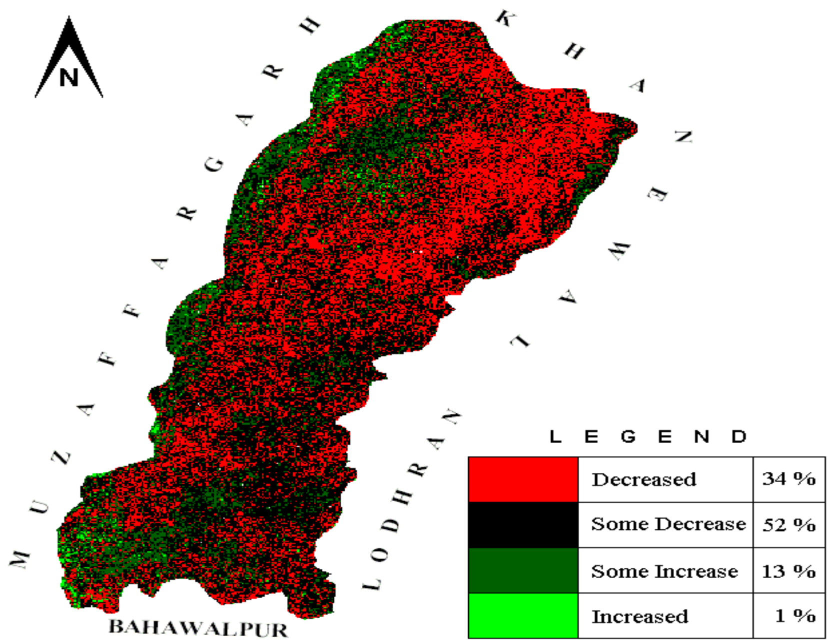

Figure 10. Map showing change detection (District Multan) using TNDVI model.

productivity decreased in northern and north-eastern part of the district.

Figure 9 shows change detection using NDVI model in the District Multan. Landsat ETM+ images for 1999 and 2002 were used to extract temporal change detection in the district. The finding showed that during 1999 and 2002, the percentage of decreased vegetation was 61% and increased was 3%. Some decrease > some increase (Table 2). Soil productivity can be seen in western areas adjacent to the Chenab River and southern part of the district.

The NDVI seems still to be the leading index in remote sensing applications. The reason for this may be either the other indices' more complex formulation or the fact that they have not been convincingly demonstrated to improve on the NDVI in the assessment of vegetation parameters (Rondeaux et al., 1996).

Figure 10 shows change detection using TNDVI model

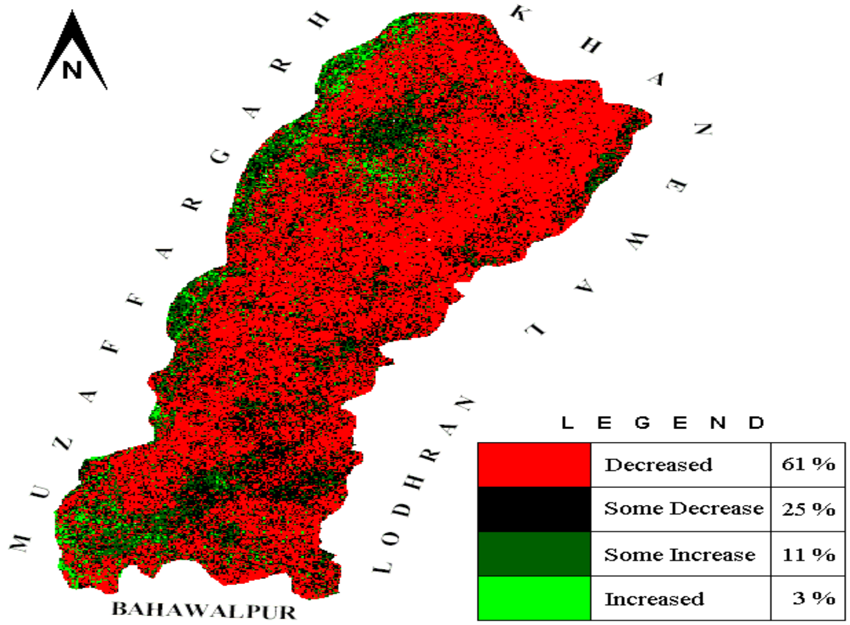

Figure 11. Map showing change detection (District Multan) using SAVI model.

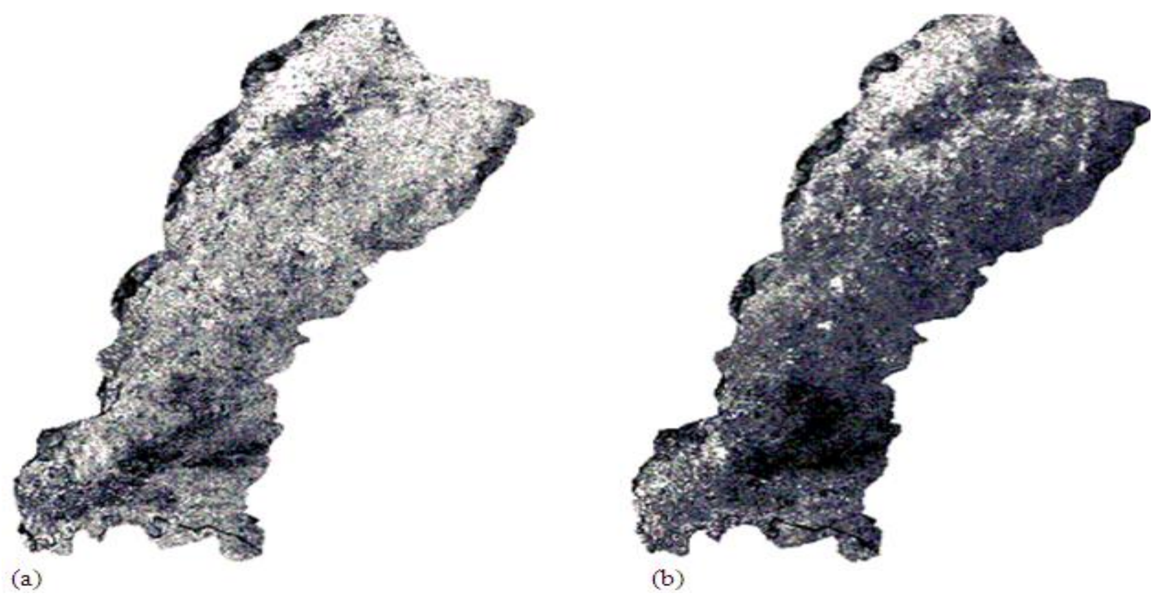

Figure 12. The SAVI image (a) 1999; (b) 2002 (District Multan).

in the District Multan.Landsat ETM+ images for 1999 and 2002 were used to extract temporal change detection in the district. The result showed that during the period 1999 and 2002, the percentage of decreased vegetation was 34% and increased was 1%. Some decrease > some increase (Table 2). Soil productivity can be seen in the western part adjacent to the Chenab River and southern part of the district.

Figure 11 shows change detection using SAVI model in the District Multan. For this experiment, Landsat ETM+ images for 1999 and 2002 were used. After geometric correction, SAVI model was applied upon ETM+ images (Figure 12a and b) and further change detection technique was used for extraction of potential agricultural sites in the district. In this experiment SAVI=NDVI (Huete, 1988). When L=0 makes SAVI equivalent to NDVI (Huete, 1988; Rondeaux et al., 1996). The NDVI (USGS, 2010) approach is based on the fact that healthy

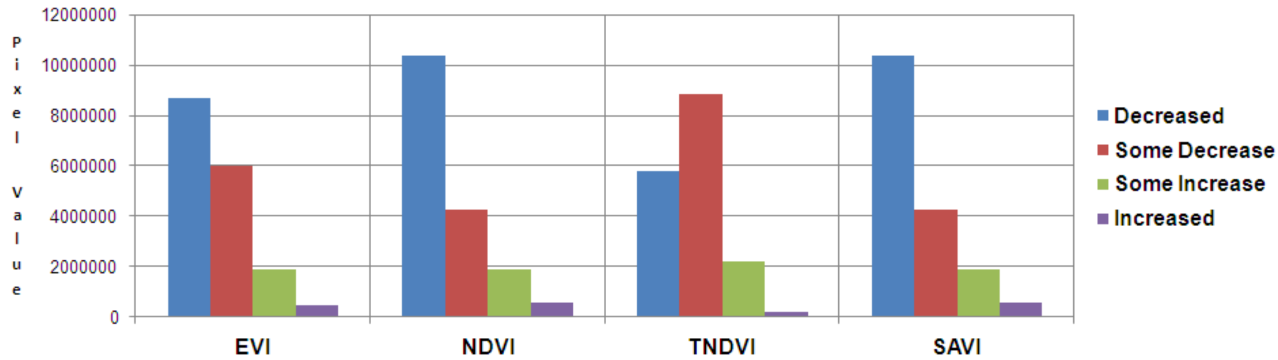

Figure 13. Comparative analysis of vegetation indices, District Multan.

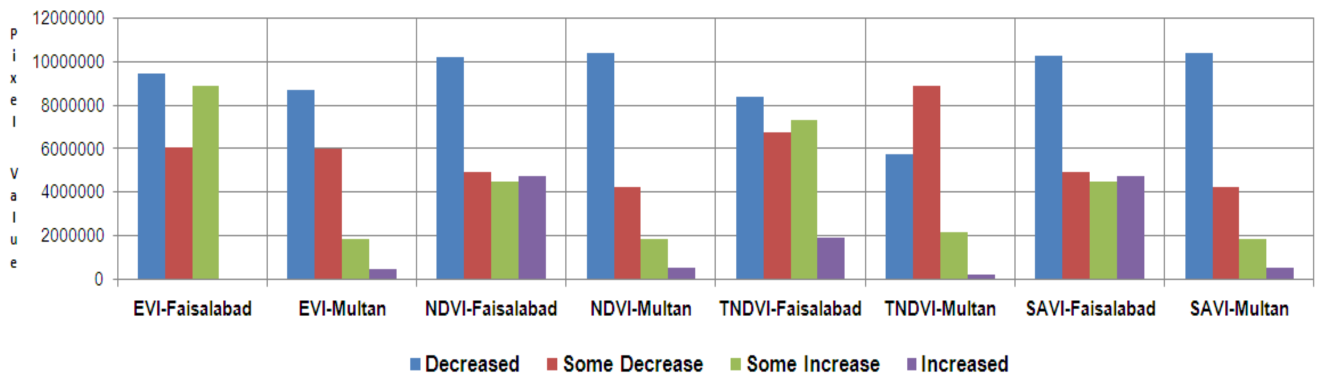

Figure 14. Comparative analysis of vegetation indices, District Faisalabad and Multan.

vegetation has low reflectance in the visible portion of the EMS due to chlorophyll and other pigment absorption and has high reflectance in the NIR because of the internal reflectance by the mesophyll spongy tissue of green leaf. The NDVI can be calculated as a ratio of red and the NIR bands of a sensor system (Huete, 2005). The result showed that during the period 1999 and 2002, the percentage of decreased vegetation was 61% while increased was 3% and some decrease > some increase.

In areas where vegetative cover is low and the soil surface is exposed, the reflectance of light in the red and near-infrared (NIR) spectra can influence vegetation index values (Huete, 1988). This is especially problematic when comparisons are being made across different soil types that may reflect different amounts of light in the red and near infrared wavelengths (Huete et al., 2002). The soil-adjusted vegetation index (SAVI) was developed as a modification of the normalized difference vegetation index (NDVI) to correct for the influence of soil brightness when vegetative cover is low (Huete, 1988; Richardson and Everitt, 1992; Rondeaux et al., 1996; Senseman et al., 1996; Lyon et al., 1998). The SAVI is structured similar to the NDVI but with the addition of a “soil brightness correction factor” (Huete, 1988).

Figure 13 shows comparative analysis of vegetation indices, District Multan. The vegetation indices showed very low increased; the decreased was maximum. Some decrease > some increase. The finding showed that the climatic variation was much higher and agricultural potential was decreasing during the period 1999 and 2002 in the district. The result of SAVI and NDVI was same (Table 2). The main disadvantage of the NDVI is the inherent non-linearity of ratio-based indices and the influence of additive noise effects, such as atmospheric path radiances. The NDVI also exhibits scaling problems, asymptotic signals over high biomass conditions, and is very sensitive to canopy background variations with NDVI values particularly high with darker canopy backgrounds (Vermote and Vermeulen, 1999; Vermote et al., 2002). The modeling process is effective to estimate land cover from satellite images, even using a limited number of data (Bocco et al., 2007).

Figure 14 shows comparative analysis of vegetation indices, District Faisalabad and Multan. The finding showed that the climatic variation was much higher and agricultural potential was decreasing during the period 1999 and 2002 in the district Faisalabad and Multan.

Agriculture has been seen in its multiple roles like

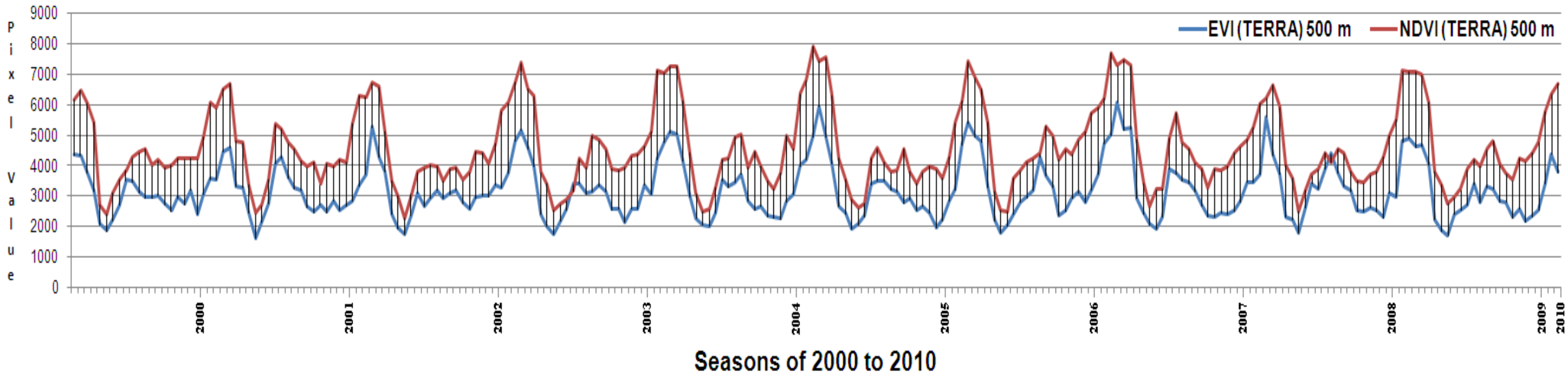

Figure 15. Comparative time-series vegetation phenology metrics for Chak 247 RB Miani, District Faisalabad.

contributing to development as an economic activity, source of livelihood, provider of environmental services and a unique instrument to overall development. As an economic activity, it is a source of growth for national economy, food security, foreign exchange as well as provider of investment opportunities for agro-based industries and rural non-farm economy. As source of livelihood, it provides jobs to majority of the people, especially the small holders, landless and the poor. In terms of environmental services, being the major player in underground water depletion, agrochemical pollution, soil exhaustion and global climate change due to greenhouse gas emissions (Farooq et al., 2007). Disturbance of the natural equilibrium ultimately results in economical losses, social problems and general moral decline of the society. Degradation of natural and agricultural ecosystem has led to a deep environmental crisis (Ahmad, 2003; 2007).

Figure 15 shows comparative time-series vegetation phenology metrics for Chak 247 RB Miani, District Faisalabad. In this vegetation phenology metrics EVI (Terra) 500 m and NDVI (Terra) 500 m data products for the seasons of 2000 to 2010 at 16-days interval have been evaluated for green cover fraction and biomass at the same location. The result showed that EVI differs from NDVI by attempting to correct for atmospheric and background effects. The EVI appears to be superior in discriminating subtle differences in areas of high vegetation density, situations in which NDVI tends to saturate. The NDVI has been used for several decades, which is advantageous for studying historical changes (Trishchenko et al., 2002). The findings showed that climate was stable (start/end) and land degradation cannot be seen during the seasons of 2000 to 2010. Variation in biomass and soil productivity can be seen due to summer monsoon and winter depression.

Figure 16 shows comparative time-series vegetation phenological variation profile for Bedianwala, District Faisalabad. In this vegetation index EVI (Terra) 250 m data product for the period 2006 to 2009 at 16-days interval have been evaluated for green cover fraction and biomass at the same location. The result showed that the impact of winter depression was strong as compared to summer monsoon in the district. Year 2009 showed the maximum while the year 2006 showed minimum soil productivity. The climate was stable during the period 2006 to 2009 and land degradation cannot be seen.

Phenology is the study of the times of recurring natural phenomena. One of the most successful of the approach is based on tracking the temporal change of a vegetation index such as NDVI or EVI. The evolution of vegetation index exhibits a strong correlation with the typical green vegetation growth stages. The results (temporal curves) can be analyzed to obtain useful information such as the start/end of vegetation growing season (Gao and Mas, 2008). 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

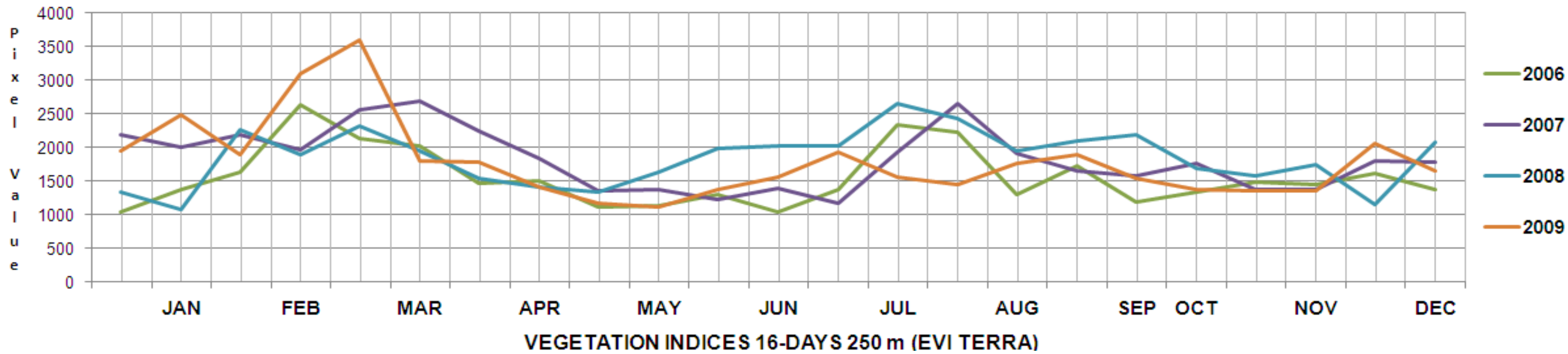

Figure 16. Comparative time-series vegetation phenological variation profile for Bedianwala, District Faisalabad.

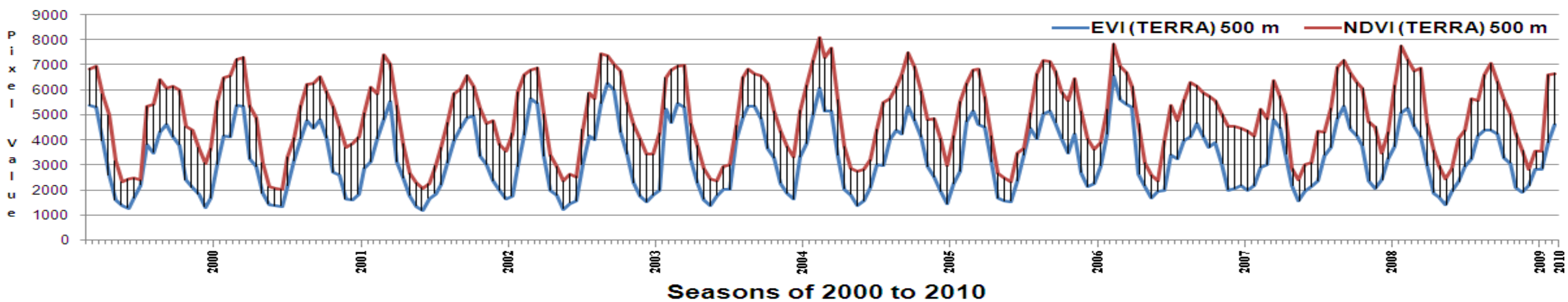

Figure 17. Comparative time-series vegetation phenology metrics for Kotla Maharan, District Multan.

(Nightingale et al., 2008) is therefore useful for studies of seasonal and inter-annual variability in carbon exchange and vegetation-climate interactions. 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). Figure 17 shows comparative time-series vegetation phenology metrics for Kotla Maharan, District Multan. In this vegetation phenology metrics EVI (Terra) 500 m and NDVI (Terra) 500 m data products for the seasons of 2000 to 2010 at 16-days interval have been evaluated for green cover fraction and biomass at the same location. The findings showed significant seasonal variation in the district. This variation was due to summer monsoon and winter depression. The scarcity of water is the major problem of the district. The result showed that climate was stable (start/end) during 2000 to 2010. Variation in biomass and soil productivity can be seen due to summer monsoon and winter depression. Figure 18 shows comparative time-series vegetation phenological variation profile for Gopalpur, District Multan. In this vegetation index EVI (Terra) 250 m data product for the period 2006 to 2009 at 16-days interval have been evaluated for green cover fraction and biomass at the same location. The impact of winter

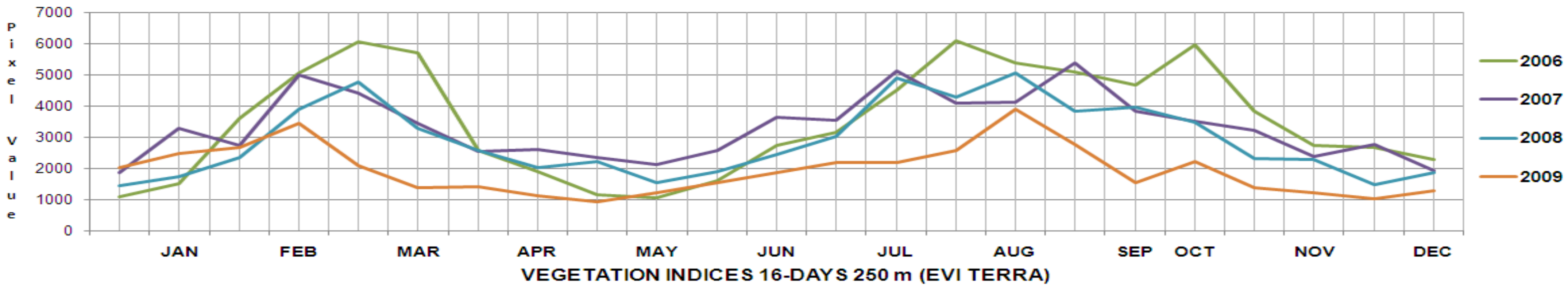

Figure 18. Comparative time-series vegetation phenological variation profile for Gopalpur, District Multan.

depression was stronger as compared to summer monsoon. Year 2006 showed the maximum while the year 2009 showed minimum soil productivity. The vegetation phenological variation profile showed that scarcity of water is the major problem for enhancement of agriculture in the district.

Water is a source of life but unfortunately, the Punjab is in the grip of its scarcity, which has disturbed the whole national life. The aggravating crisis is gnawing at the public mind and, regrettably, it has considerably contributed towards straining national harmony and there are no signs of tiding over this grim situation (Gazdar, 1987). The shortage is threatening to create famine like condition across the province.

DISCUSSION AND CONCLUSIONS

The performance of a change detection algorithm can be evaluated visually and quantitatively based on application needs. Components of change detection algorithms can also be evaluated individually (Radke et al., 2004). In particular, recent advances in remote sensing technology suggest that satellite based earth observation has great potential for providing and updating spatial information in a timely and cost effective manner (Pacifici, 2007; Pacifici et al., 2007). Moreover, the availability of remote sensing data is guaranteed for decades to come, making earth observation a powerful long term change detection instrument (Smits and Annoni, 1999). This kind of change analysis, however, has the following problems (Yamamoto et al., 2001; Bruzzone and Prieto, 2002; Pacifici, 2007; Pacifici et al., 2007).

1) A huge volume of data must be processed for detecting only few change areas,
2) Many types of satellite sensors are available, but their spectral bands are not always identical in center wavelength and band width,
3) Noise due to differences in light conditions, atmospheric conditions, sensor calibration and ground moisture at the two acquisition dates considered causes apparent changes,
4) Each image has own geometrical distortion and problems of alignment of multi-temporal images.

Concerning this last issue, two images should be registered so that pixels with the same coordinates in the images may be associated with the same area on the ground. This is a very critical step in very high resolution satellite and airborne imagery, especially when the angle of acquisition varies greatly, rendering change detection results unreliable (Pacifici, 2007; Pacifici et al., 2007).

Vegetation phenology derived from remote sensing is important for a variety of scientific applications (Hufkens et al., 2010). Vegetation phenology can provide a useful signal for classifying vegetated land cover (Dennison and Roberts, 2003). Changes in vegetation spectral response caused by phenology can conceal longer term changes in the landscape (Hobbs, 1989; Lambin, 1996; Dennison and Roberts, 2003). Multi-temporal data that captures these spectral differences can improve reparability of vegetation types over classifications based on single date imagery (DeFries et al., 1995). Global-scale land cover classifications have utilized differences in vegetation phenology derived from multi-temporal data to map the distribution of ecoregions (DeFries and Townshend, 1994; Loveland et al., 2000; Dennison and Roberts, 2003). While global scale monitoring of phenology has been successful, hyperspectral analyses of seasonal changes in vegetation have been limited due to the restricted abilities of aerial platforms to repeatedly sample large areas (Elvidge and

Portigal, 1990; Roberts et al., 1997; Merton, 1998; Garcia and Ustin, 2001; Dennison and Roberts, 2003). With the continuous development of computer network, space technology and remote sensing, demand on automated, real-time and in-orbit processing become more urgent than ever before for change detection (Mouat et al., 1993). To achieve this, the challenges to the technology include the full automation for image registration, image matching, feature extraction, image interpretation, image fusion, data-cleaning, image classification, and data mining and knowledge discovery from GIS database (Liu and Zhou, 2004; Jianya et al., 2008).

Different change detection algorithms have their own strong points and no single approach can be considered the best for all cases (Malpica and Alonso, 2008). In practice, different algorithms are often compared to find the optimal change detection algorithm for a specific application.

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