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*Keywords : Change detection, Landsat TM/ETM, land degradation, NDVI, remote sensing.*

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# Land Degradation Pattern Using Geo-Information Technology for Kot Addu, Punjab Province, Pakistan

Farooq Ahmad [α], Qurat-ul-ain Fatima [σ] & Kashif Shafique [ρ]

*Abstract* - One of the most important global phenomena that are currently threatening the ecosystem is land degradation and is mainly caused by the climatic changes and human influence. Land degradation is the reduction in the capability of the land to produce benefits from a particular land use under a specified form of land management. Land degradation is the consequence of important processes, which is active in arid and semi-arid ecosystems, where water is the original limiting factor in execution of land application. Remotely sensed data provide timely, accurate and reliable information on degraded lands at definite time intervals in a cost effective manner. In this research, the TM/ETM+ images were used to study changes occurred in the first decade of the new millennium; May 2001 to April 2011. In the present study, efforts have been made to identify and map areas affected by land degradation in Kot Addu *tehsil* of Muzaffargarh, Punjab province, Pakistan. The Normalized Difference Vegetation Index (NDVI), change detection technique was applied upon TM/ETM+ images and further unsupervised classification was used for extraction of information regarding the desert, bare soil, cultivatable land and cultivated land. The NDVIs properties help mitigate a large part of the variations that result from the overall remote-sensing system. The result shows that the desert is 458.73 km$^2$ (17%), bare soil is 1160.33 km$^2$ (43%), cultivated land is 647.62 km$^2$ (24%) and cultivatable land is 431.75 km$^2$ (16%) in April 2011. The values of the Kappa statistics were used to compare the performance of the classifiers. The data sets were analyzed using ArcGIS software in the Geographic Information System environment and can be implemented in the drylands of Pakistan.

*Keywords : Change detection, Landsat TM/ETM, land degradation, NDVI, remote sensing.*

## I. Introduction

Land degradation is an environmental problem that has major ecological-physical and social dimensions (Thomas, 1997), which has been contributing in number of ways. Land degradation or desertification has been high on the list of items of Global Environmental Agenda since 1970s, though the term was first conceived by Aubreville in 1949. Land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities (Glantz and Orlovsky, 1983; Warren and Agnew, 1988; Odingo, 1990; UNEP, 1992; Stiles, 1995; Ahmad, 2002; Kertész, 2009), and its proportion is increasing because of over-exploitation of premature meadows beyond quick rehabilitation (Babaev, 1999).

Remote sensing can offer unbiased view of large areas, with spatially explicit information distribution and time repetition, and has thus been widely used to monitor land degradation pattern and change detection at a regional scale (Quarmby et al., 1993; Baez-Gonzalez et al., 2002; Doraiswamy et al., 2003; Ruecker et al., 2007). Land degradation is usually detected efficiently by remote sensing analysis (Weismiller et al., 1977; Singh, 1989; Lu et al., 2004; Fadhil, 2009). Tappan et al. (1992) and Mout et al. (1997) used the Normalized Difference Vegetation Index (NDVI) as an indicator of land degradation or desertification since it related to vegetation greenness (Al-Bakri and Taylor, 2003).

The NDVI, spectral vegetation index which measures soil and vegetation moisture (Singh, 1989; Lyon et al., 1998; Mambo and Archer, 2007), has been widely used for environmental change monitoring (Young, 1998; Lillesand and Kiefer, 2000; Eastman, 2003; Lillesand et al., 2004; Mambo and Archer, 2007). The index can be used to identify areas showing distressed or degraded vegetation, leading to identification of possible degraded areas (Barrow, 1991; Booth et al., 1994; Mambo and Archer, 2007). The NDVI is used as a proxy; land degradation and improvement is inferred from long-term trends when other factors that may be responsible are accounted for. Rainfall effects may be accounted for by rain-use efficiency and residual trends of NDVI; temperature effects may be accounted for by energy-use efficiency (Bai and Dent, 2007; 2007a). Vegetation production and biomass have been successfully estimated with the NDVI derived from satellite data (Deering et al., 1975; Prince and Tucker, 1986; Tucker and Sellers, 1986; Prince, 1991; Jury et al., 1997; Myneni et al., 1997; Wessels et al., 2004).

The NDVI captures the marked contrast between the strong absorptance in the visible wavelengths and strong reflectance in the near-infrared wavelengths which uniquely characterizes the presence of photosynthetically active vegetation (Tucker, 1979; Wessels et al., 2004). The NDVI is an indicator of vegetation health, because degradation of ecosystem

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vegetation, or a decrease in green, would be reflected in a decrease in NDVI value (Meneses-Tovar, 2011).

The NDVI is highly correlated with vegetation parameters such as green leaf biomass and green leaf area (Justice et al., 1985), and it also is directly related to plant vigor, density, and growth conditions (Holben, 1986), now it is widely accepted as a primary tool for monitoring land degradation (Huang et al., 2010). In arid and semi-arid lands, seasonal sums of multi-temporal NDVI are strongly correlated with vegetation production (Prince and Tucker, 1986; Prince, 1991; Nicholson and Farrar, 1994; Nicholson et al., 1998; Wessels et al., 2004).

The Normalized Difference Vegetation Index (NDVI) is a normalized ratio of the NIR and red bands. The NDVI is computed following the equation:

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

Where, $\rho_{NIR}$ and $\rho_{red}$ are the surface bidirectional reflectance factors for their respective MODIS bands. The NDVI is referred to as the 'continuity index' to the existing 20+ year NOAA-AVHRR derived NDVI (Rouse et al., 1973) time series (Moran et al., 1992; Verhoef et al., 1996; Jakubauskas et al., 2001; Huete et al., 2002; Zoran and Stefan, 2006; USGS, 2010; Ahmad, 2012; 2012a; 2012b), which could be extended by MODIS data to provide a longer term data record for use in operational monitoring studies (Chen et al., 2003).

The NDVI (Figure 1) 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; Ahmad, 2012c; 2012d; Zaeen, 2012). The NDVI provides useful information for detecting and interpreting vegetation land cover it has been widely used in remote sensing studies (Dorman and Sellers, 1989; Myneni and Asrar, 1994; Gao, 1996; Sesnie et al., 2008; Karaburun, 2010; Ahmad, 2012e).

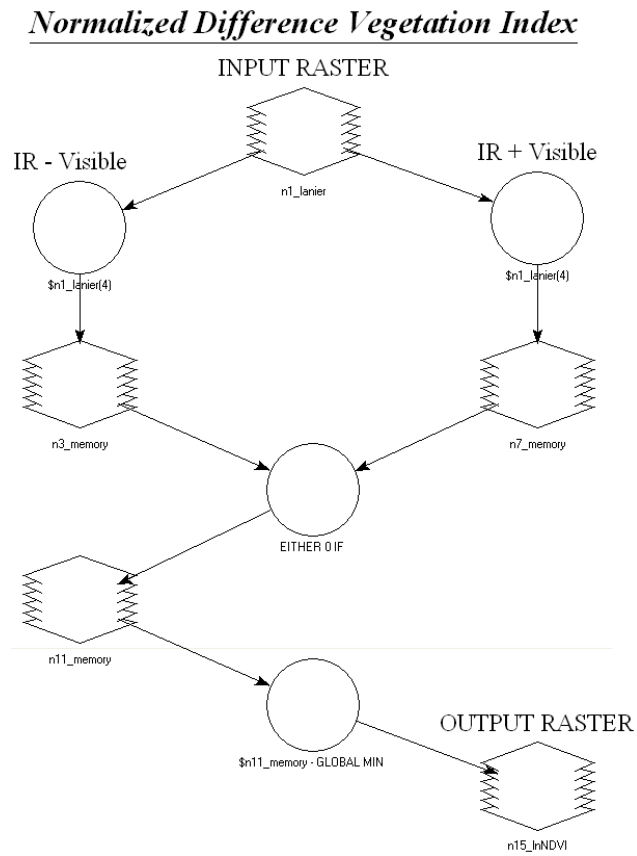


*Figure 1 :* Schematic view of the Model Maker window, illustrating the calculation of the NDVI

*Source: http://geospatial.intergraph.com/products/ERDASIMAGINE/ERDASIMAGINE/Downloads.aspx*

## II. Study Area

The study area (Figure 2) lies in the southern Punjab province of Pakistan from 30° 05' 39" to 30° 45' 57" North latitude and 70° 47' 35" to 71° 33' 37" East longitude.

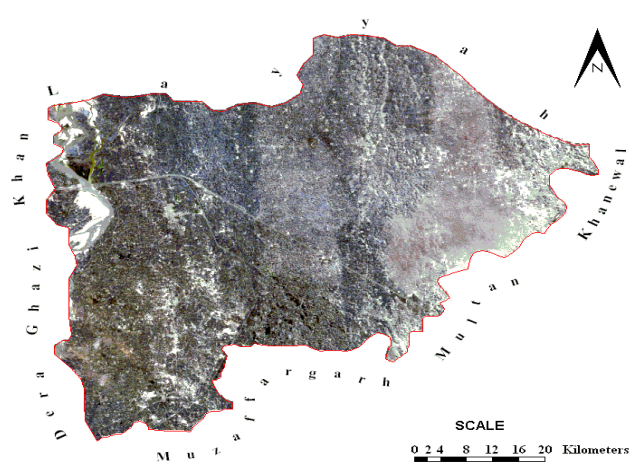


*Figure 2 :* Kot Addu - Landsat TM 25th April, 2011 image

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



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## III. Research Design and Methods

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, 2012e). The NDVI is based on differences in reflectance in the red region and maximum reflectance in the near infrared; it is the most widely used index in remote sensing (Aguilar et al., 2012; Ahmad, 2012b).

The NDVI values range from -1 to +1; because of high reflectance in the NIR portion of the EMS, healthy vegetation is represented by high NDVI values between 0.1 and 1 (Liu and Huete, 1995; USGS, 2008; 2010). Conversely, non-vegetated surfaces such as water bodies yield negative values of NDVI because of the electromagnetic absorption property of water. Bare soil areas represent NDVI values which are closest to 0 due to high reflectance in both the visible and NIR portions of the EMS (Townshend, 1992; 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; Ahmad, 2012e). Because of these properties, the NDVI has become the primary tool for mapping changes in vegetation cover and analysis of the impacts of environmental phenomena. The NDVI can be used not only for accurate description of vegetation classification and vegetation phenology (Tucker et al., 1982; Tarpley et al., 1984; Justice et al., 1985; Lloyd, 1990; Singh et al., 2003; Los et al., 2005) but also effective for monitoring rainfall and drought, estimating net primary production of vegetation, crop growth conditions and crop yields, detecting weather impacts and other events important for agriculture and ecology (Kogan, 1987; Dabrowska-Zielinska et al., 2002; Singh et al., 2003; Chris and Molly, 2006; Baldi et al., 2008; Glenn et al., 2008; Ahmad, 2012e). The NDVI is the most commonly used index (Ahmad, 2012) and serves as a measure of photosynthetic activity within a certain area (Fontana, 2009; Ahmad, 2012b).

The NDVI can be a useful tool to couple climate and vegetation distribution and performance at large spatial and temporal scales (Pettorelli et al., 2005; Aguilar et al., 2012; Ahmad, 2012b) because vegetation vigor and productivity are related to temperature-precipitation and evapotranspiration. The NDVI serves as a surrogate measure of these factors at the landscape scale (Wang et al., 2003; Groeneveld and Baugh, 2007; Aguilar et al., 2012; Ahmad, 2012b).

Remotely sensing derived NDVI data have been successfully used for monitoring of vegetation activity and environmental changes at regional and global scales (Kowabata et al., 2001; Tucker et al., 2001; Xiao and Moody, 2004; 2005; Propastin and Kappas, 2008), detection of droughts (Kogan, 1997; Propastin and Kappas, 2008), land degradation and desertification studies (Thiam, 2003; Wessels et al., 2004; Propastin and Kappas, 2008).

The NDVI product works optimally with cloud filtering, radiometric calibration, precise geolocation, and a snow mask. In addition, the product performs best using top-of-canopy reflectance inputs, corrected for atmospheric ozone, molecular scattering, aerosol, and water vapour (Huete et al., 2006; Ahmad, 2012b). Various methods using daily NDVI data have been developed for monitoring natural vegetation (Akiyama et al., 2002; Saito et al., 2002; Xiao et al., 2002; Sakamoto et al., 2005; Ahmad, 2012b).

ERDAS imagine 2011 and ArcGIS 10 software were used for application of NDVI model and calculation upon Landsat TM/ETM+ images (path 151, row 39); May 2001, April 2003, May 2009 and April 2011 respectively and change detection technique was applied to explore land degradation pattern for the period of 2001 to 2011 and 2003 to 2009 at Kot Addu (Figure 3). Unsupervised classification was applied upon NDVI images for calculation the area of the desert, cultivatable land, cultivated land and bare soil classes. Further, comparative analysis of unsupervised classification using NDVI images were performed for description and evaluation of land degradation pattern at Kot Addu, Punjab province of Pakistan.

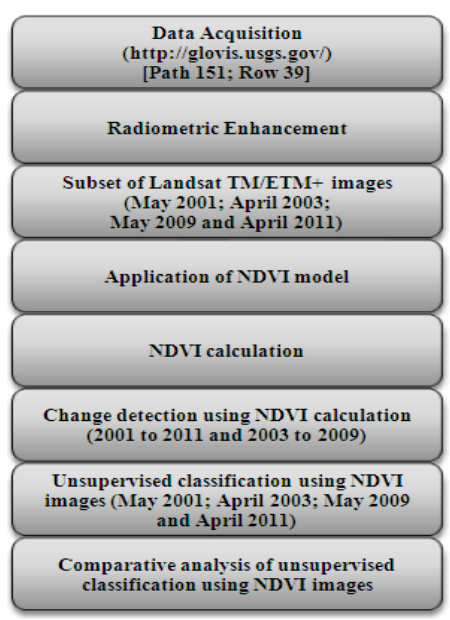


*Figure 3 :* Scheme for research design and methods



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## IV. Results

Figure 4, 5, 6, 7 (Table 1) shows NDVI values of Landsat TM/ETM+ images for May 2001; April 2003; May 2009 and April 2011 respectively. The NDVI index was applied upon the Landsat TM/ETM+ using ERDAS imagine 2011 software while ArcGIS 10 was used for NDVI calculation. The findings showed that there was a relationship between desert, cultivatable land, cultivated land and bare soil and NDVI values. The NDVI is a measurement of the balance between energy received and energy emitted by objects on Earth. When applied to plant communities, this index establishes a value for how green the area is, that is, the quantity of vegetation present in a given area and its state of health or vigor of growth (Meneses-Tovar, 2011). The significance of NDVI index may vary according to habitat type (Pettorelli et al., 2005; Hamel et al., 2009).

Figure 8 shows change detection during 2001-2011 at Kot Addu, Punjab province, Pakistan. The findings showed that decreased in the desert was 978.55 $km^2$ (36%), some decrease was 1601.45 $km^2$ (59%), unchanged was 0.45 $km^2$, some increase was 96.17 $km^2$ (4%), while increased was 21.81 $km^2$ (1%). Decreased and some decrease > some increase and increased while unchanged was negligible. The change detection technique was performed upon NDVI images; May 2001 and April 2011. The results and accuracy assessment is given in Table 2.

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; Ahmad, 2012c).

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; Ahmad, 2012c). 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; Ahmad, 2012c).

Figure 9 shows change detection during 2003-2009 at Kot Addu, Punjab province, Pakistan. The findings showed that decreased in the desert was 230.72 $km^2$ (9%), some decrease was 2300.76 $km^2$ (85%), unchanged was 2.35 $km^2$, some increase was 150.12 $km^2$ (6%), while increased was 14.48 $km^2$. Decreased and some decrease > some increase and increased while unchanged was negligible. The change detection technique was performed upon NDVI images; April 2003 and May 2009. The results and accuracy assessment is given in Table 2.

Remote sensing provides a viable source of data from which updated land-cover information can be extracted efficiently and cheaply in order to inventory and monitor these changes effectively (Mas, 1999). Remote sensing change detection is a hot issue in recent years (Yan and Xiao-xia, 2010). Change detection is an important application of remote sensing technology. It is a technology ascertaining the changes of specific features within a certain time interval. It provides the spatial distribution of features and qualitative and quantitative information of features changes (Shaoqing and Lu, 2008).

Prior to any change detection, it is imperative that the imagery be geometrically rectified so that the same pixel at one date overlaps the same pixel for the other date (Townshend et al., 1992; Macleod and Congalton, 1998). Usually, change detection involves two or more registered remotely sensed images acquired for the same ground area at different times (Dal and Khorram, 1999). Change detection using remote sensing data is the process of identifying and examining temporal, spatial and spectral changes of pixel signal (Wen and Yang, 2009). Long-term change detection results can provide insight into the stressors and drivers of change, potentially allowing for management strategies targeted toward cause rather than simply the symptoms of the cause (Kennedy et al., 2009).

Digital change detection essentially comprises the quantification of temporal phenomena from multi-date imagery that is most commonly acquired by satellite-based multispectral sensors (Coppin and Bauer, 1996). The critical requirement for successful change detection is that a common radiometric response is required for quantitative analysis of multiple images acquired on different dates (Hall et al., 1991; Coppin and Bauer, 1996). Radiometric correction is to remove or reduce the inconsistency between the values surveyed by sensors and the spectral reflectivity and spectral radiation brightness of the objects (Jianya et al., 2008).



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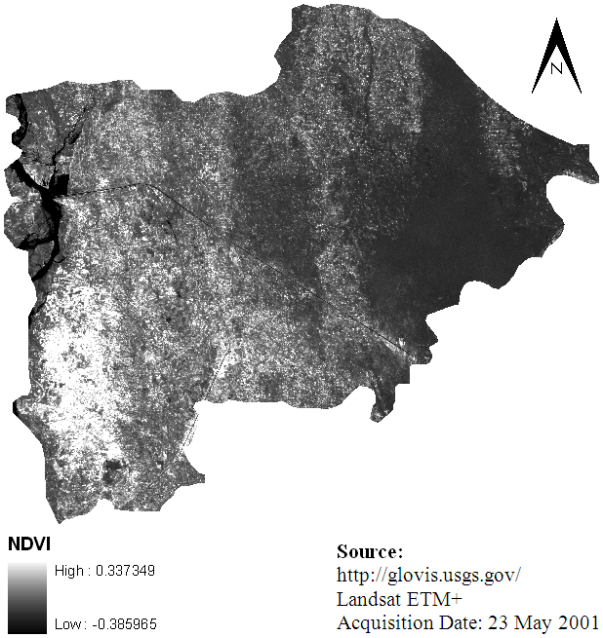



*Figure 4 :* NDVI 2001, Kot Addu, Pakistan

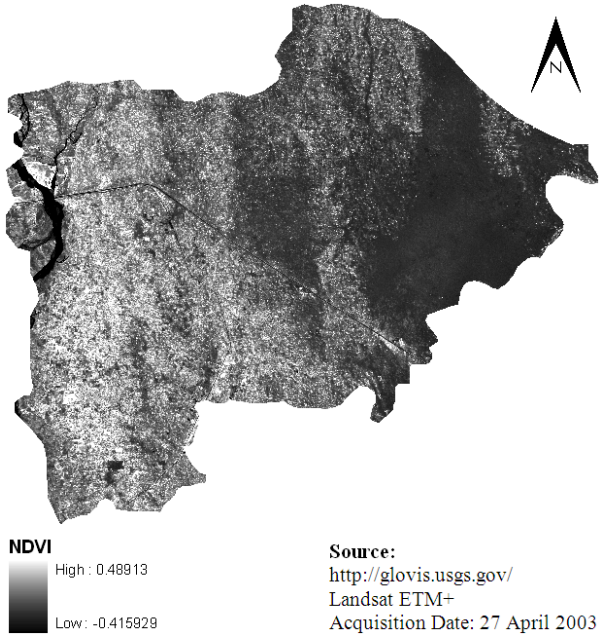
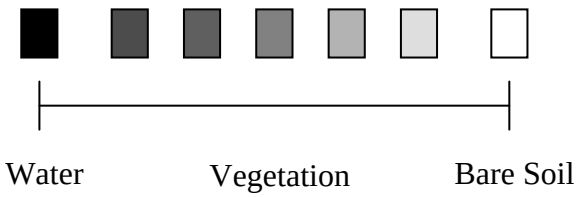



*Figure 5 :* NDVI 2003, Kot Addu, Pakistan

## Legend



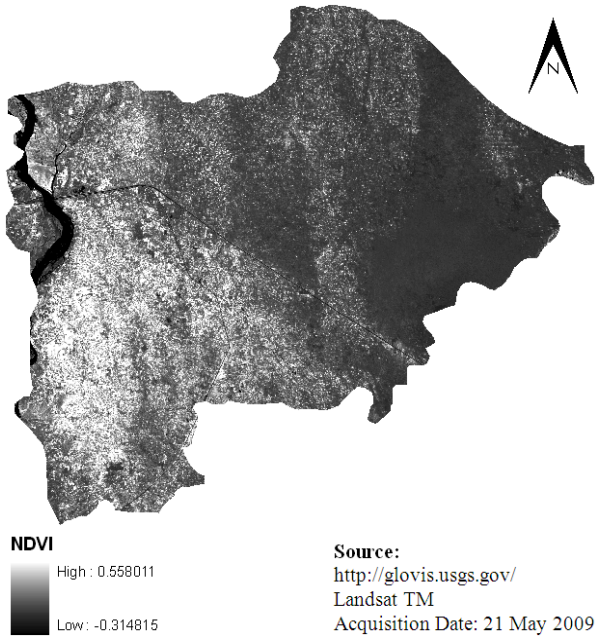




*Figure 6 :* NDVI 2009, Kot Addu, Pakistan

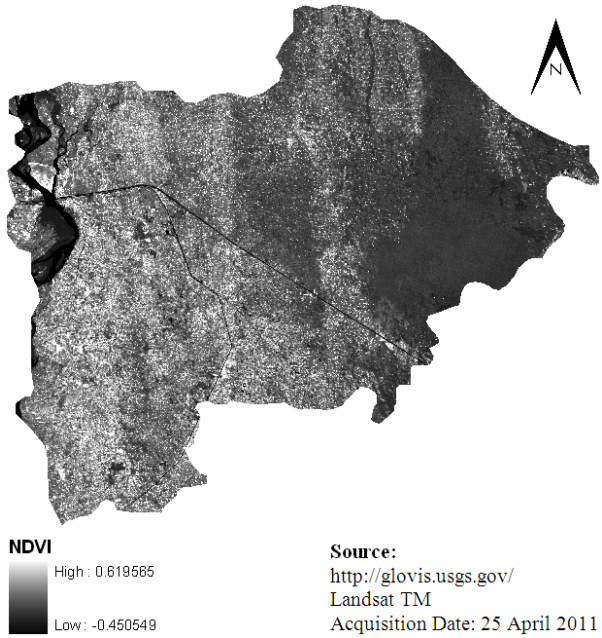



*Figure 7 :* NDVI 2011, Kot Addu, Pakistan



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*Table 1 :* NDVI values of Landsat images

| Image Acquisition Date | Maximum NDVI | Minimum NDVI | Mean NDVI | Standard Deviation |
|---|---|---|---|---|
| 23 May, 2001 (Landsat ETM+) | 0.34 | -0.39 | -0.09 | 0.08 |
| 27 April, 2003 (Landsat ETM+) | 0.49 | -0.42 | -0.05 | 0.08 |
| 21 May, 2009 (Landsat TM) | 0.56 | -0.31 | 0.05 | 0.10 |
| 25 April, 2011 (Landsat TM) | 0.62 | -0.45 | 0.06 | 0.09 |

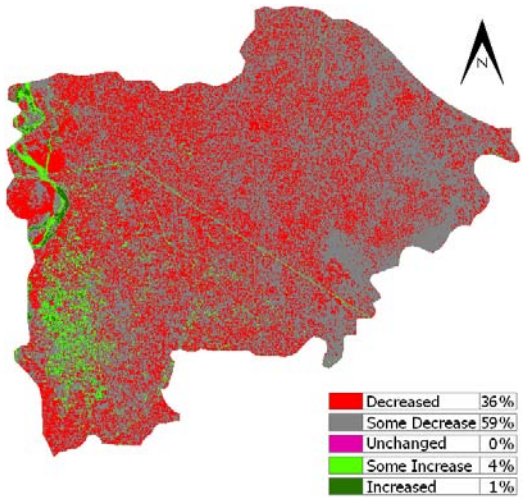


*Figure 8 :* Change detection during 2001-2011 at Kot Addu, Pakistan

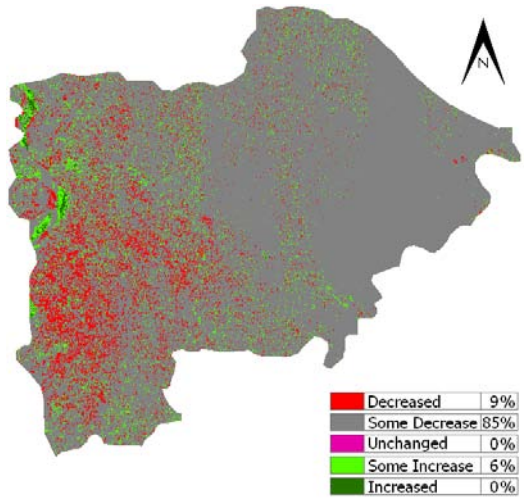


*Figure 9 :* Change detection during 2003-2009 at Kot Addu, Pakistan

*Table 2 :* Change detection using NDVI calculation

| Classes | During 2001 to 2011 | | | During 2003 to 2009 | | |
|---|---|---|---|---|---|---|
| | Area ($km^2$) | Area (%) | Accuracy Assessment (%) | Area ($km^2$) | Area (%) | Accuracy Assessment (%) |
| Decreased | 978.55 | 36 | 85.79 | 230.72 | 9 | 87.31 |
| Some Decrease | 1601.45 | 59 | 92.14 | 2300.76 | 85 | 90.19 |
| Unchanged | 0.45 | Negligible | 89.32 | 2.35 | Negligible | 87.22 |
| Some Increase | 96.17 | 4 | 85.16 | 150.12 | 6 | 88.45 |
| Increased | 21.81 | 1 | 91.47 | 14.48 | Negligible | 92.21 |
| SUM | 2698.43 | 100 | - | 2698.43 | 100 | - |

Figure 10 shows comparative change detection, during 2001 to 2011 and during 2003 to 2009. The findings showed that sufficient decrease in desert area at Kot Addu, Punjab province, Pakistan. The area of the desert decreased from 1376.20 $km^2$, May 2001 to 458.73 $km^2$, April 2011 (Table 3). 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; Ahmad, 2012c). The wider availability of large archives of historical images also makes long-term change detection and modelling possible (Jianya et al., 2008). Change detection has become a major application of remotely sensed data because of repetitive coverage at short intervals and consistent image quality (Mas, 1999). Over the past years, researchers have put forward large numbers of change detection techniques of remote sensing image and summarized or classified them from different viewpoints (Singh, 1989; Lu et al., 2004; Jianya et al., 2008). The problem of availability of cloud-free images in sub-tropical regions is very common and has been reported by many authors (Ducros-Gambart and Gastellu-Etchegorry, 1984; Nelson and Holben, 1986; Pilon et al., 1988; Alwashe and Bokhari, 1993; Jha and Unni, 1994; Mas,1999).



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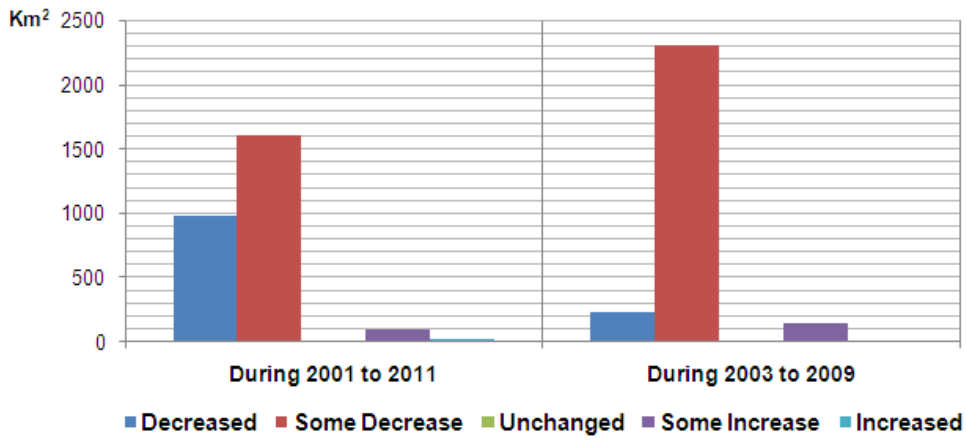


*Figure 10 :* Comparative change detection at Kot Addu, Pakistan

Figure 11 shows unsupervised classification using NDVI image 2001. The findings showed that the desert was 1376.20 km$^2$ (51%), bare soil 1241.28 km$^2$ (46%), and cultivated land 53.97 km$^2$ (2%) while the cultivatable land was 26.98 km$^2$ (1%). The accuracy assessment is given in Table 3.

The approach unsupervised classification which is part of post classification comparison method or direct classification method. This approach is based on the natural groupings of the spectral properties of the pixels which are usually selected by the RS software without any influence from the users (Al-Awadhi et al., 2011).

Figure 12 shows unsupervised classification using NDVI image 2003. The findings showed that the desert was 1214.29 km$^2$ (45%), bare soil 1268.27 km$^2$ (47%), and cultivated land 188.89 km$^2$ (7%) while the cultivatable land was 26.98 km$^2$ (1%). The accuracy assessment is given in Table 3. The accurate assessment of land degradation, their vulnerability to drought, or degree of degradation, requires information about the dominant vegetation types including spatial variations in coverage (Le Houérou, 1996; Geerken et al., 2005). This clearly emphasizes the need for a classification technique that gives more consideration to the biophysical information contained in NDVI time series, incorporating both vegetation type and spatial intra-class coverage variability (Geerken et al., 2005).

Figure 13 shows unsupervised classification using NDVI image 2009. The findings showed that the desert was 782.54 km$^2$ (29%), bare soil 1295.25 km$^2$ (48%), and cultivated land 269.84 km$^2$ (10%) while the cultivatable land was 350.80 km$^2$ (13%). The accuracy assessment is given in Table 3.

Unsupervised context-sensitive technique for change-detection in multitemporal remote sensing images (Patra et al., 2007). Automated classification can be performed upon NDVI by unsupervised cluster analysis (Sader and Winne, 1992; Sader et al., 2003).

Figure 14 shows unsupervised classification using NDVI image 2011. The findings showed that the desert was 458.73 km$^2$ (17%), bare soil 1160.33 km$^2$ (43%), and cultivated land 647.62 km$^2$ (24%) while the cultivatable land was 431.75 km$^2$ (16%). The accuracy assessment is given in Table 3.

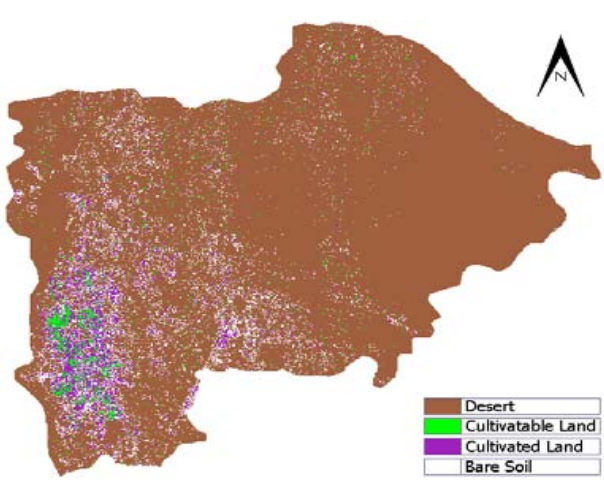


*Figure 11 :* Unsupervised classification using NDVI image 2001

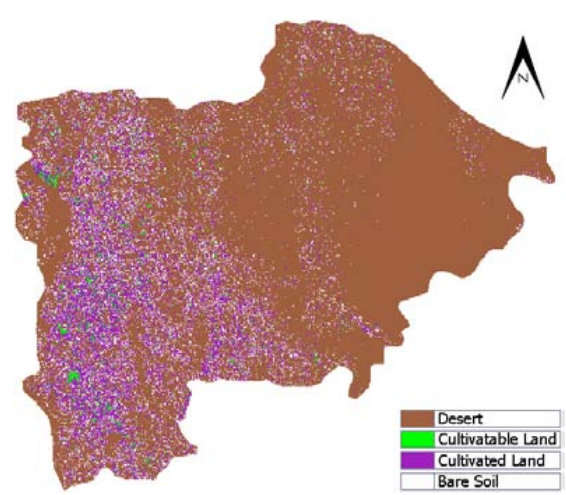


*Figure 12 :* Unsupervised classification using NDVI image 2003



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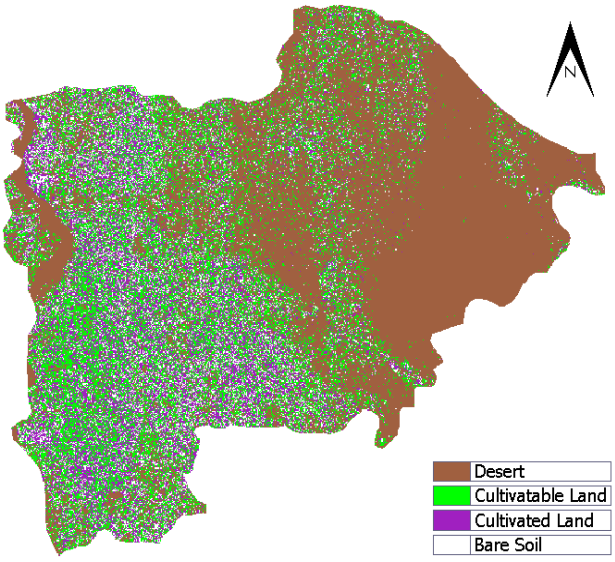


*Figure 13 :* Unsupervised classification using NDVI image 2009

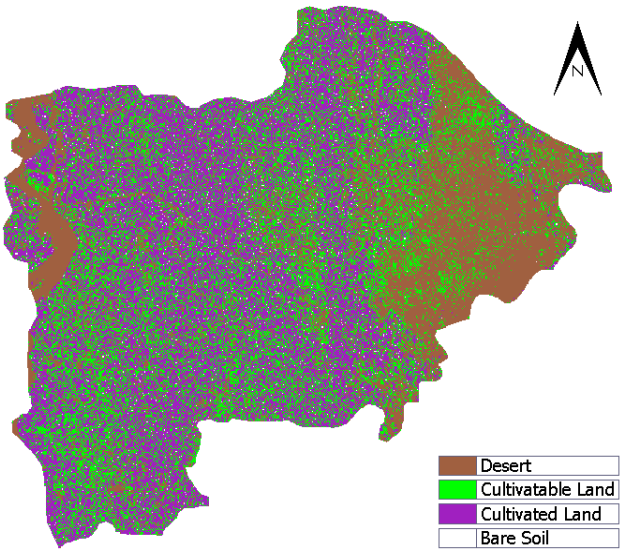


*Figure 14 :* Unsupervised classification using NDVI image 2011

*Table 3 :* Unsupervised classification using NDVI images

| Image Acquisition Date | Classes | Area ($km^2$) | Area (%) | Accuracy Assessment (%) |
|---|---|---|---|---|
| 23 May, 2001 (Landsat ETM+) | Desert | 1376.20 | 51 | 91.23 |
| | Bare Soil | 1241.28 | 46 | 87.65 |
| | Cultivated Land | 53.97 | 2 | 85.42 |
| | Cultivatable Land | 26.98 | 1 | 87.39 |
| | SUM | 2698.43 | 100 | - |
| 27 April, 2003 (Landsat ETM+) | Desert | 1214.29 | 45 | 89.61 |
| | Bare Soil | 1268.27 | 47 | 90.73 |
| | Cultivated Land | 188.89 | 7 | 87.94 |
| | Cultivatable Land | 26.98 | 1 | 86.92 |
| | SUM | 2698.43 | 100 | - |
| 21 May, 2009 (Landsat TM) | Desert | 782.54 | 29 | 92.13 |
| | Bare Soil | 1295.25 | 48 | 88.76 |
| | Cultivated Land | 269.84 | 10 | 86.14 |
| | Cultivatable Land | 350.80 | 13 | 89.63 |
| | SUM | 2698.43 | 100 | - |
| 25 April, 2011 (Landsat TM) | Desert | 458.73 | 17 | 90.81 |
| | Bare Soil | 1160.33 | 43 | 92.37 |
| | Cultivated Land | 647.62 | 24 | 87.71 |
| | Cultivatable Land | 431.75 | 16 | 85.49 |
| | SUM | 2698.43 | 100 | - |

Figure 15 shows comparative analysis of unsupervised classification using NDVI images for the period May 2001 to April 2011. The findings showed that the area of the desert was decreased from 1376.20 $km^2$ (51%) in May 2001 to 458.73 $km^2$ (17%) in April 2011, the bare soil decreased from 1241.28 $km^2$ (46%) in May 2001 to 1160.33 $km^2$ (43%) in April 2011, while cultivated land increased from 53.97 $km^2$ (2%) in May 2001 to 647.62 $km^2$ (24%) in April 2011, cultivatable land also increased from 26.98 $km^2$ (1%) in May 2001 to 431.75 $km^2$ (16%) in April 2011 (Table 3).

As the use of space and computer technology developed, humankind has a great advantage of produce this much important research projects with the help of technology in an easier, more accurate way within less time than other ways. As a result all these can have a very effective role in helping the country to increase the amount and the quality of agricultural products (Akkartala et al., 2004; Ahmad, 2012).



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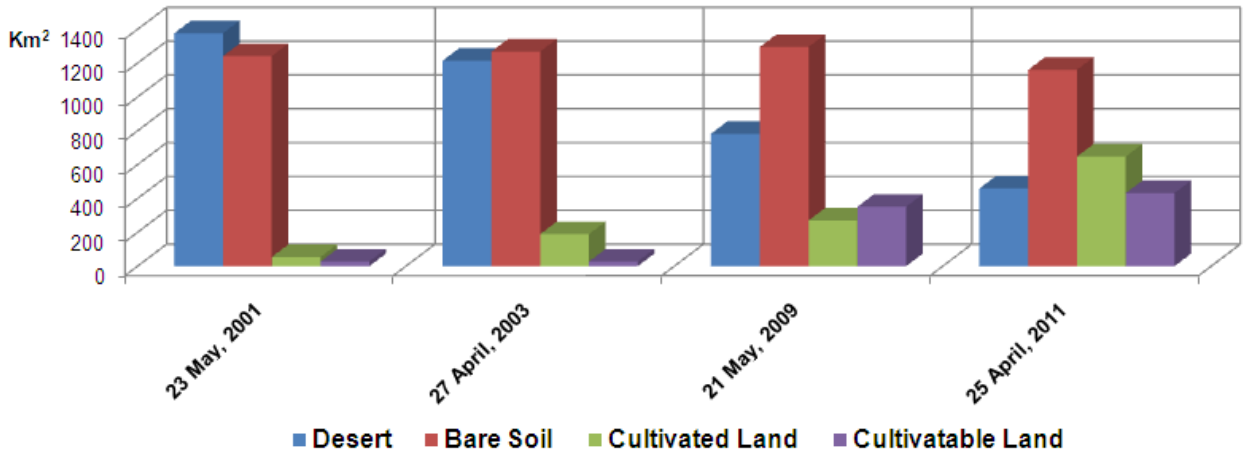


*Figure 15 :* Comparative analysis of unsupervised classification using NDVI images

## V. Discussion and Conclusions

Remote sensing change detection techniques can be broadly classified as either pre or post classification change methods (Lunetta et al., 2006). The NDVI is the most commonly used of all the VIs tested and its performance, due to non-systematic variation as described by Huete and Liu (1994) and Liu and Huete (1995). The NDVI suppresses differential solar illumination effects of slope and aspect orientation (Lillesand and Kiefer, 1994; Sader et al., 2001) and helps to normalize differences in brightness values when processing multiple dates of imagery (Singh, 1986; Lyon et al., 1998; Sader et al., 2001).

Many studies have found the NDVI to be unstable, varying with soil, sun-view geometry, atmospheric conditions, and the presence of dead material, as well as with changes within the canopy itself (Sellers, 1985; Jackson and Pinter, 1986; Jackson and Huete, 1991; Myneni et al., 1992; Huete and Liu, 1994). As a result, several studies and developments have sought to improve upon the NDVI by correcting for soil and atmospheric sources of variance (Huete and Liu, 1994). The improved variants to the NDVI equation attempt to either incorporate a "soil" adjustment factor or a "blue" band for atmospheric normalization (Huete and Liu, 1994). The soil adjusted vegetation index (SAVI) introduced a soil calibration factor $L$ to the NDVI equation to account for first-order soil-vegetation optical interactions and differential red and NIR extinction through the canopy (Huete, 1988; Huete and Liu, 1994).

Land cover classification techniques can be straightforward but at the same time very complicated. Depending on the methodology used, each classification technique can give different results. If attention is not given, the classification results could be misleading and erroneous (Nicandrou, 2010). 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; Li and Guo, 2012; Ahmad, 2012c). In practice, different algorithms are often compared to find the optimal change detection algorithm for a specific application. A limitation of image differencing or ratio image differencing as a change detection method is that it does not specify the 'from-to' land cover type change information (Jensen, 1996; Sader et al., 2001), but only detects that a change did or did not occur (Sader et al., 2001). The overall accuracy of the change detection results exceeded 85%, the level that the US Geological Survey (Anderson et al., 1976; Sader et al., 2001) uses as a threshold to define acceptability (Sader et al., 2001). The approaches used in this study can be applied to other areas to examine land degradation pattern in Pakistan.

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