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Phenologically-Tuned MODIS NDVI-Based Time Series (2000-2012) for Monitoring of Vegetation and Climate Change in North-Eastern Punjab, Pakistan

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GJHSS-C Classification : FOR Code : 630205p, 770101p



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Phenologically-Tuned MODIS NDVI-Based Time Series (2000-2012) for Monitoring of Vegetation and Climate Change in North-Eastern Punjab, Pakistan

Farooq Ahmad ^α & Qurat-ul-ain Fatima ^σ

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Keywords : Climate, MODIS, NDVI, remote sensing, time series, vegetation phenology.

1. INTRODUCTION

Long-term observations of remotely sensed vegetation dynamics have held an increasingly prominent role in the study of terrestrial ecology (Budde et al., 2004; Prasad et al., 2007; Ouyang et al., 2012). A major limitation of such studies is the limited availability of sufficiently consistent data derived from long-term remote sensing (Ouyang et al., 2012). 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). One of the key factors in assessing vegetation dynamics and its response to climate change is the ability to make frequent and consistent observations (Thomas and Leason, 2005; Ouyang et al., 2012). Ability to assess how environmental changes affect dynamics of vegetation is increasingly important for better predictions of climate change effects (Aguilar et al., 2012). Popularity of the application of the NDVI (Rouse et al., 1973; Tucker, 1979) in ecological studies has enabled quantification and mapping of green vegetation with the goal of estimating above ground net primary productivity and other landscape-level fluxes (Wang et al., 2003; Pettorelli et al., 2005; Aguilar et al., 2012). 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; Ahmad, 2012a). The NDVI is the most commonly used index (Ahmad, 2012b) and serves as a measure of photosynthetic activity within a certain area (Fontana, 2009).

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).

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) 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). The linear response of vegetation NDVI to rainfall for regions with low vegetation cover and rainfall is well documented (Malo and Nicholson, 1990; Yang et al., 1998; Kawabata et al., 2001; Ji and Peters, 2003; Wang et al., 2003; Groeneveld and Baugh, 2007; Aguilar et al., 2012). The relationship between NDVI and climatic

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factors are location-dependent, more detailed analyses are needed (Wang et al., 2003; Aguilar et al., 2012).

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument onboard the Terra and Aqua satellite platforms (Huete et al., 2006; Carrão et al., 2008; Ahmad, 2012c). Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon (Salomonson and Toll, 1991; GSFC/NASA, 2003; Huete, 2005; Ahmad, 2012c). The MODIS has been applied in diverse applications for two reasons, the advantage of daily data and the possibility for high-quality data covering large land areas (Zhao et al., 2009; Ouyang et al., 2012) and offers a good opportunity to monitor and analyze regional land surface processes. This is especially true for NDVI vegetation analysis, for which MODIS provides a standard product (Piao et al., 2006a; Zhao et al., 2009; Ouyang et al., 2012). 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).

The MODIS, high temporal resolution sensor allow detailed monitoring of the temporal change in vegetation (Weissteiner et al., 2011; Ouyang et al., 2012). Higher resolution sensors provide spatial detail while low resolution satellites offer high temporal repetition at the expense of spatial resolution (Ouyang et al., 2012). Over the last two decades, studies of vegetation dynamics have explored several approaches to improve the spatial-temporal resolution of data from remote sensing sources. Integrating medium to high spatial resolution data with high temporal resolution data can provide a means to detect most of the variation in vegetation (Jin and Steven, 2005; Ouyang et al., 2012).

The MODIS NDVI datasets provides unique opportunities for monitoring terrestrial vegetation conditions at regional and global scales (Yang et al., 1997; Piao et al., 2006), and has widely been used in research areas of net primary production (Potter et al., 1993; Paruelo et al., 1997; Piao et al., 2006), vegetation coverage (Tucker et al., 1991; Myneni et al., 1997; Los et al., 2001; Zhou et al., 2001; Piao et al., 2003; Piao et al., 2006), biomass (Myneni et al., 2001; Dong et al., 2003; Piao et al., 2006), and phenology (Reed et al., 1994; Moulin et al., 1997; Piao et al., 2006).

Multi-year time series of NDVI can reliably measure yearly changes in the timing of the availability of high-quality vegetation. 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

(Hamel et al., 2009; Meneses-Tovar, 2011). The NDVI has the potential ability to signal the vegetation features of different eco-regions and provides valuable information as a remote sensing tool in studying vegetation phenology cycles at a regional scale (Guo, 2003). Phenology has emerged recently as an important focus for ecological research (Menzel et al., 2001; Hashemi, 2010).

II. STUDY AREA

The study area lies in the north-eastern Punjab province of Pakistan from 30° 11' 52" to 32° 27' 19" North latitude and 71° 53' 23" to 75° 56' 24" East longitude. The research area is consists of six districts (Figure 1); Lahore, Sheikhupura, Hafizabad, Nankana Sahib, Kasur and Okara of the province.

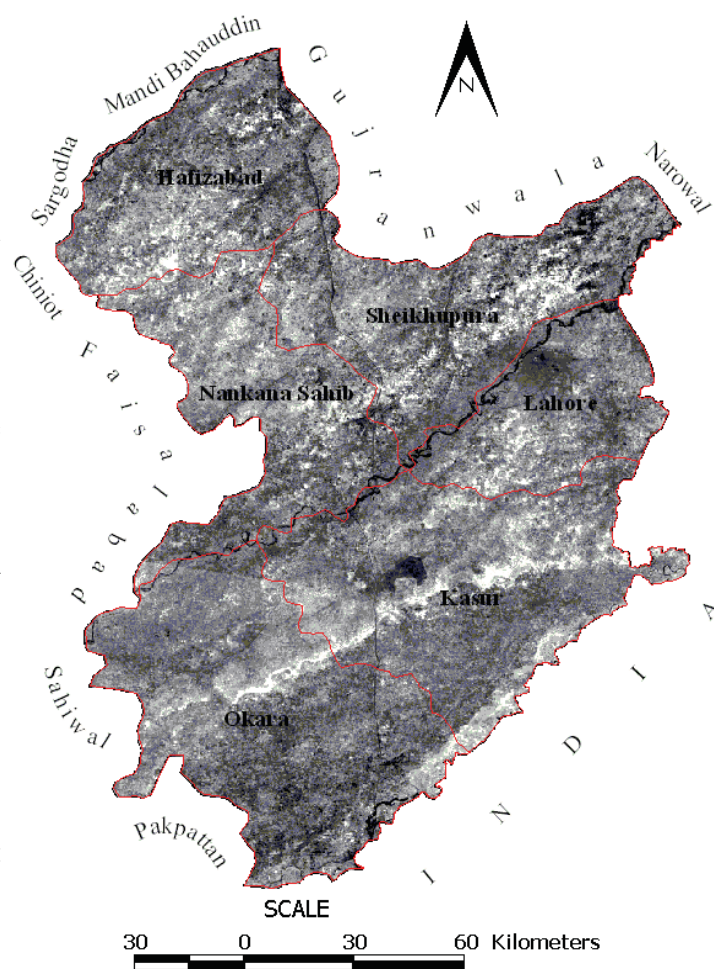


Figure 1 : Study Area - Landsat ETM+ May 31st 2003 mosaic image. Source : <http://glovis.usgs.gov/>

III. RESEARCH DESIGN AND METHODS

The MODIS is a key instrument onboard the Terra satellite and provides images over a given pixel of land specifically designed for measurements of land surface dynamics (Huete, 2005). The MODIS sensors, as a newer generation sensor specifically designed for,

inter alia, terrestrial applications (Fontana, 2009) and a validation with accurately georeferenced composite data from the MODIS sensor revealed the high accuracy of the orthorectified NDVI composites and emphasized the great importance of orthorectification for data quality in rugged terrain (Barnes et al., 1998; Fontana, 2009). The MODIS provides higher radiometric sensitivity (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).

Earth location data is available at sub-pixel accuracy. This extraordinary geolocation accuracy is achieved due to several reasons (Wolfe et al., 1995; 2002; Fontana, 2009): First, the spacecrafts carrying MODIS are very stable and provide highly precise external orientation knowledge. Second, the MODIS instrument was designed to give precise interior orientation knowledge (Khlopenkov and Trishchenko, 2008; Fontana, 2009). Third, an accurate global DEM (Logan, 1999; Fontana, 2009) is used to model and remove relief-induced distortions. Fourth, a global set of GCPs based on Landsat imagery served to determine biases in the sensor orientation, which were finally used to improve geolocation processing (Ackerman et al., 1998; 2006; Fontana, 2009).

The MODIS NDVI data products for research area were acquired, in this case MOD13A1 (MODIS TERRA_500 m) data were downloaded from the Land Processes Distributed Active Archive Center (LPDAAC). Tile number covering this area is h24v05, reprojected from the Integerized Sinusoidal projection to a Geographic Lat/Lon projection, and Datum WGS84 (GSFC/NASA, 2003; Ahmad, 2012a). A gapless time series of MODIS NDVI composite raster data from 18th February, 2000 to 16th November, 2012 with a spatial resolution of 500 m was utilized (Figure 2) for phenologically-tuned MODIS NDVI-based time series development. The datasets provides frequent information at the spatial scale at which the majority of human-driven land cover changes occur (Townshend and Justice, 1988; Verbesselt et al., 2010).

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). The NDVI is related to the absorption of photosynthetically active radiation and basically measures the photosynthetic capability of leaves, which is related to vegetative canopy resistance and water vapour transfer (Wan, 2003; Rahman et al., 2004; Ahmad, 2012a).

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; Nicandrou, 2010; Ahmad, 2012a; 2012b). 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; Nicandrou, 2010; Ahmad, 2012a).

ERDAS imagine 2011 software was used for extraction of NDVI layer from MODIS data product and development of gapless composite image from 18th February, 2000 to 16th November, 2012. In this study, eighteen villages out of six districts of north-eastern Punjab province were selected randomly. The data products were used to generate phenological time-series variation profile for Kot Jan Muhammad, Amarkot, Jodhwala, Sukka Chak, Adilgarh, Jagganwala, Qila Deva Singh, Ali Raza Abad, Shakranj Pur, Titranwali, Ajanwala, Makki Unchi, Bodal Khaneke, Asrur, Katlohi Kallan villages and phenological temporal comparison at 16-days interval for Thatha Khudayar and Haveli villages, year 2007 to 2011. Further, biomass versus NDVI and mean maximum; January 2011 to December 2011 was generated for Bahak Maqaiyaddin village of the research area.



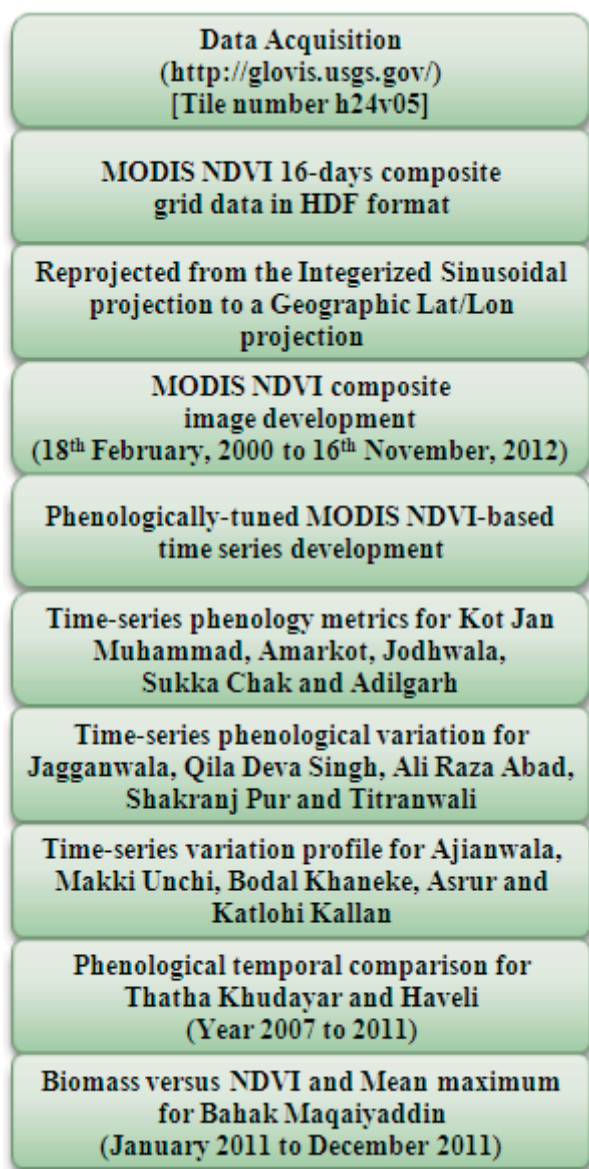


Figure 2 : Scheme for research design and methods.

Remote sensing is often used for detecting seasonal vegetation changes (Sakamoto et al., 2005). 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). 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). 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).

IV. RESULTS

Figure 3 shows time-series phenology metrics for Kot Jan Muhammad district Hafizabad. The profile showed that climate was more or less stable. The trend analysis showed slight positive tendency due to increase in precipitation in winter season or western disturbances especially during 2009 to 2012, but severe dryness was observed in January 2003 (NDVI value 0.85) and June 2010 (NDVI value -0.01). Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.72 while the NDVI value on 16th November, 2012 was 0.28 (Figure 3).

The phenological studies can be used to evaluate the effects of climate change (Chandola et al., 2010). The vegetation phenology is important for predicting ecosystem carbon, nitrogen, and water fluxes (Baldocchi et al., 2005; Richardson et al., 2009; Chandola et al., 2010), as the seasonal and interannual variation of phenology have been linked to net primary production estimation, crop yields, and water supply (Aber et al., 1995; Jenkins et al., 2002; Chandola et al., 2010).

Figure 4 shows time-series phenology metrics for Amarkot district Lahore. The profile showed that climate was not stable and the trend analysis showed negative tendency. The fluctuations in the phenological profile were due to variation in the temperature-precipitation at Amarkot. Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.60 while the NDVI value on 16th November, 2012 was 0.28 (Figure 4). The soil productivity in winter season was higher as compared to summer season. In summer season the temperature raises upto 51°C or more and in winter the temperature falls below 0°C. The monsoon occurs in summer season from June till September. Monsoon rains bring much awaited relief from scorching heat. These monsoon rains are quite heavy by nature. The western disturbances generally occur during the winter months and causes moderate rainfall (Khan, 1993; Ahmad, 2012).

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, 2012).

Figure 5 shows time-series phenology metrics for Jodhwala district Kasur. The profile showed that climate was stable and the trend analysis showed slight positive tendency. The NDVI value on 18th February, 2000 was 0.52 while the NDVI value on 16th November, 2012 was 0.49 (Figure 5). The variation in the vegetation phenological temporal metrics was due to changes in the temperature-precipitation. The green cover fraction

and soil productivity in winter season was much higher as compared to summer season. The NDVI has been used for several decades, which is advantageous for studying historical changes (Trishchenko et al., 2002; Ahmad, 2012).

Figure 6 shows time-series phenology metrics for Sukka Chak district Okara. The profile showed that climate was stable and the trend analysis showed positive tendency. The NDVI value on 18th February, 2000 was 0.68 while the NDVI value on 16th November, 2012 was 0.23 (Figure 6). The fluctuations in the phenological profile were due to variation in the temperature-precipitation. The winter disturbances were stronger as compared to summer monsoon and land degradation or desertification can't be seen at Sukka Chak. The soil productivity in winter season was much higher as compared to summer season. The phenology metrics showed a clear relationship with the seasonality of rainfall, winter and summer growing seasons (Wessels et al., 2011; Ahmad, 2012).

Figure 7 shows time-series phenology metrics for Adilgarh district Nankana Sahib. The profile showed that climate was stable and the trend analysis showed gradually positive tendency. The NDVI value on 18th February, 2000 was 0.64 while the NDVI value on 16th November, 2012 was 0.36 (Figure 7). The green cover fraction and soil productivity in winter season was much higher as compared to summer season.

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).

Figure 8 shows time-series phenological variation for Jagganwala district Hafizabad. The profile showed that climate was stable and the trend analysis showed no change during the entire period, but severe dryness was observed in December 2002 and January 2003. Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.69 while the NDVI value on 16th November, 2012 was 0.35 (Figure 8). The fluctuations in the phenological profile were due to variation in the temperature-precipitation. The winter disturbances were much stronger as compared to summer monsoon and land degradation or desertification can't be seen at Jagganwala. The green cover fraction and soil productivity in winter season was much higher as compared to summer season.

Variations in vegetation activity have been linked with changes in climates (Los et al., 2001; Tucker et al., 2001; Zhou et al., 2001; 2003; Lucht et al., 2002; Piao et al., 2003). Besides climate alterations leading to changes in the productivity and phenology of natural vegetation (Villalba et al., 1998; Villalba et al., 2003; Baldi et al., 2008), direct human drivers such as land use and land cover changes (Grau et al., 2005; Fearnside, 2005; Huang et al., 2007; Baldi and Paruelo,

2008; Baldi et al., 2008), infrastructure enterprises (Canziani et al., 2006; Baldi et al., 2008), and urban expansion (Romero and Ordenes, 2004; Pauchard et al., 2006; Baldi et al., 2008; Ahmad, 2012) took place.

Figure 9 shows time-series phenological variation for Qila Deva Singh district Nankana Sahib. The profile showed that climate was stable and the trend analysis showed gradual positive tendency during the entire period, but little dryness was observed in January 2003 (NDVI value 0.13) and July, 2010 (NDVI value 0.09). Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.73 while the NDVI value on 16th November, 2012 was 0.25 (Figure 9). The NDVI exhibits a strong correlation with the typical green vegetation growth stages (Zhao et al., 2005; Gao and Mas, 2008; Ahmad, 2012; 2012a).

Figure 10 shows time-series phenological variation for Ali Raza Abad district Lahore. The profile showed that climate was more or less stable during the entire period. The fluctuations in the phenological profile were due to variation in the temperature-precipitation at Ali Raza Abad. The NDVI value on 18th February, 2000 was 0.61 while the NDVI value on 16th November, 2012 was 0.32 (Figure 10).

To enhance the vegetation signal in remotely sensed data and provide an approximate measure of live green vegetation, a number of spectral vegetation indices have been developed by combining data from multiple spectral bands into single values because they correlate the biophysical characteristics of the vegetation of the land-cover (Campbell, 1987) from the satellite spectral signals (Yang et al., 2008).

Figure 11 shows time-series phenological variation for Shakranj Pur district Okara. The profile showed that climate was not stable, severe interannual variation in temperature-precipitation was observed at Shakranj Pur and the trend analysis showed gradual positive tendency during the entire period. Severe dryness was observed in August 2008 (NDVI value 0.004). Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.51 while the NDVI value on 16th November, 2012 was 0.25 (Figure 11).

Figure 12 shows time-series phenological variation for Titranwali district Nankana Sahib. The profile showed that climate was stable and the trend analysis showed no change. The fluctuations in the phenological profile were due to variation in the temperature-precipitation during the entire period. The winter disturbances were much stronger as compared to summer monsoon and land degradation or desertification can't be seen at Titranwali. The green cover fraction and soil productivity in winter season was much higher as compared to summer season. Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.67 while



the NDVI value on 16th November, 2012 was 0.27 (Figure 12).

Figure 13 shows time-series variation profile for Ajianwala district Sheikhpura. The profile showed that climate was stable and the trend analysis showed slight positive change, but little dryness was observed in January 2003 (NDVI value 0.05). The fluctuations in the phenological profile were due to variation in the temperature-precipitation during the entire period. The winter disturbances were much stronger as compared to summer monsoon at Ajianwala. Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.72 while the NDVI value on 16th November, 2012 was 0.35 (Figure 13).

Time series of acquired multi-spectral image represent characteristics of a landscape and each element represented has a particular spectral response. The time series of such vegetation indices observed over a period can help in further classification of the vegetation as crop and other type of vegetation (Musande et al., 2012).

Figure 14 shows time-series variation profile for Makki Unchi district Sheikhpura. The profile showed that climate was stable and the trend analysis showed no change. The green cover fraction and soil productivity in winter season was much higher as compared to summer season. The NDVI value on 18th February, 2000 was 0.78 while the NDVI value on 16th November, 2012 was 0.26 (Figure 14). 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, 2012).

Figure 15 shows time-series variation profile for Bodal Khaneke district Kasur. The profile showed that climate was not stable; the trend analysis showed negative tendency and severe dryness was observed in August-September 2011 (NDVI value -0.02). The fluctuations in the phenological profile were due to variation in the temperature-precipitation at Bodal Khaneke. Fluctuations were observed at start/end pixel values. The NDVI value on 18th February, 2000 was 0.23 while the NDVI value on 16th November, 2012 was 0.17 (Figure 15).

The ecology of the north-eastern Punjab province is mainly arid to semi arid. Abundant evidence verifies that the natural resources were unwisely over-exploited to achieve higher growth rates in agriculture. The country is now suffering from problems like water scarcity for crop cultivation with salinity and sodicity problems, more erratic and low rainfalls for rain-fed agriculture and low carrying capacity of rangelands representing more three-fifth of total geographic area. Agriculture is the only sector which is entirely dependent on the quality of natural resources for sustaining higher productivity (Farooq et al., 2007; Ahmad, 2012).

Figure 16 shows time-series variation profile for Asrur district Sheikhpura. The profile showed that climate was not stable and the trend analysis showed gradual positive tendency during the entire period, but little dryness was observed in January 2003 (NDVI value 0.05). The profile also showed gradual increase in precipitation from December 2004 to November 2012. The winter disturbances were much stronger, and the duration also increased from December 2009 to present at Asrur. The NDVI value on 18th February, 2000 was 0.43 while the NDVI value on 16th November, 2012 was 0.23 (Figure 16). The healthy and dense vegetation show a large NDVI (Fuller, 1998; Ahmad, 2012).

Figure 17 shows time-series variation profile for Katlohi Kallan district Kasur. The profile showed that climate was more or less stable. The trend analysis showed no change, but little dryness was observed in January 2003 (NDVI value 0.12). The NDVI value on 18th February, 2000 was 0.68 while the NDVI value on 16th November, 2012 was 0.32 (Figure 17).

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; Ahmad, 2012) 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, 2012).

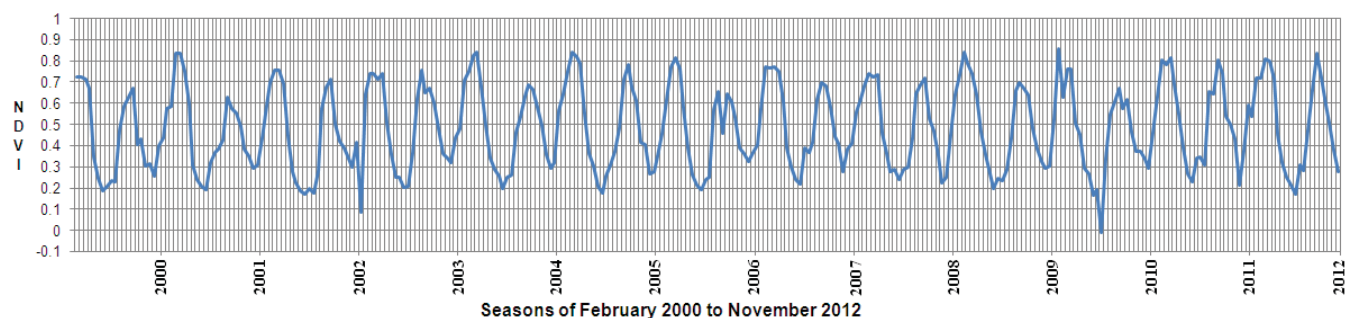
Figure 18 shows phenological temporal comparison for Thatha Khudayar district Sheikhpura. In this profile MODIS NDVI 500 m data products for the period 2007 to 2011 at 16-days interval was evaluated. The findings showed that the impact of summer monsoon was stronger as compared to winter disturbances. The precipitation was received in both the summer and winter season. The climate was stable during the entire period at Thatha Khudayar.

Figure 19 shows phenological temporal comparison for Haveli district Okara using MODIS NDVI 500 m data products at 16-days interval for the period 2007 to 2011. The temporal curves indicate that climate was stable, green cover fraction, and biomass productively increased due to precipitation in summer and winter season. The profile showed maximum soil and biomass productivity in 2009 and minimum in 2010 and land degradation can't be seen at Haveli.

Figure 20 shows biomass versus NDVI and mean maximum from January 2011 to December 2011 for Bahak Maqaiyaddin district Hafizabad. The biomass and NDVI demonstrated clear inter-seasonal consistency indicated by the larger amount of biomass and the corresponding higher NDVI values in January, February, March, July, August, September and October

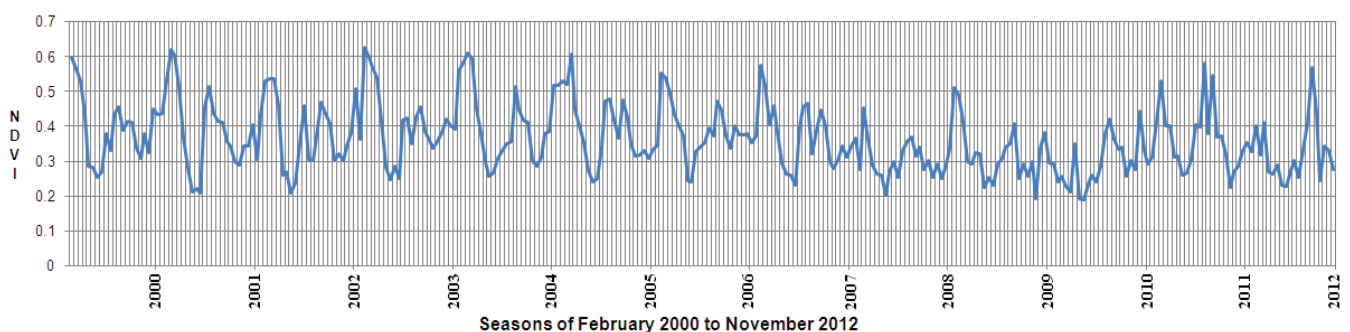
2011 and the smaller amount of biomass in April, May, June, November and December 2011 at Bahak Maqaiyaddin. The variations in biomass are fairly well represented by the changes of NDVI. The inter-seasonal

consistency of NDVI and biomass support the common use of NDVI to study vegetation response to climate variation (Anyamba and Eastman, 1996; Kogan, 1997; Li and Guo, 2012).



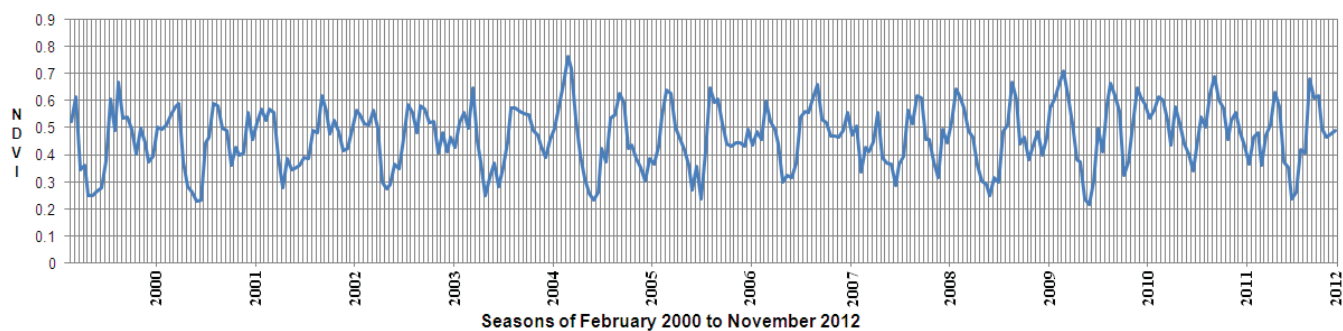
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Figure 3 : Time-series phenology metrics for Kot Jan Muhammad, District Hafizabad.



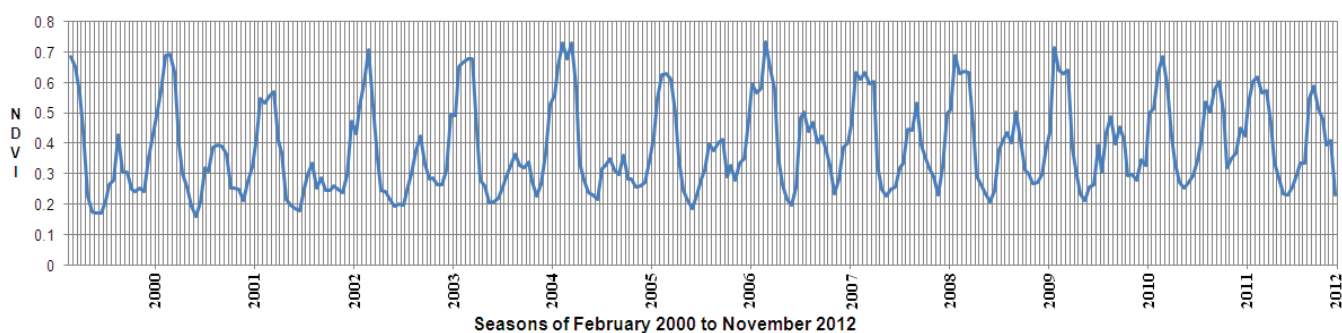
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Figure 4 : Time-series phenology metrics for Amarkot, District Lahore.



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Figure 5 : Time-series phenology metrics for Jodhwala, District Kasur.



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Figure 6 : Time-series phenology metrics for Sukka Chak, District Okara.

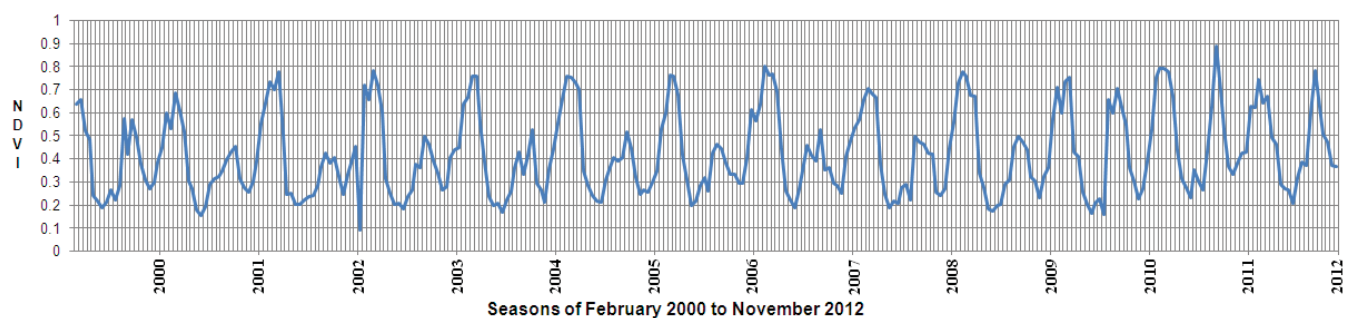


Figure 7 : Time-series phenology metrics for Adilgarh, District Nankana Sahib.

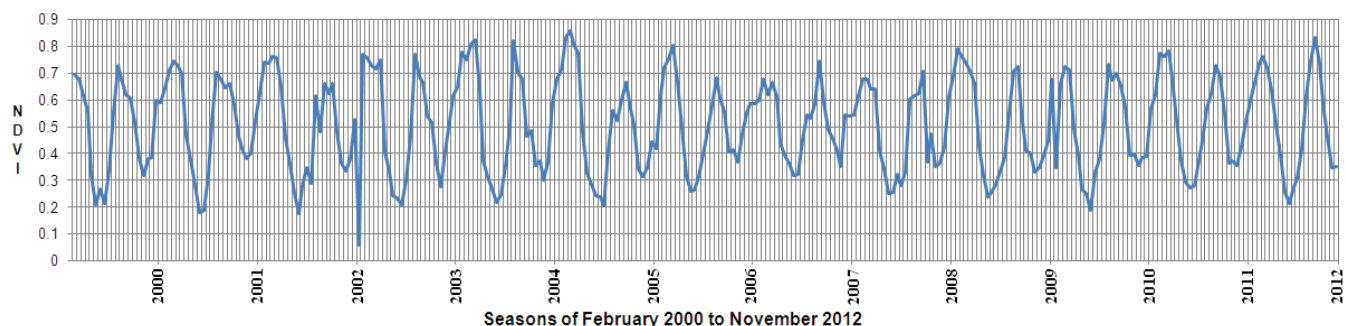


Figure 8 : Time-series phenological variation for Jagganwala, District Hafizabad.

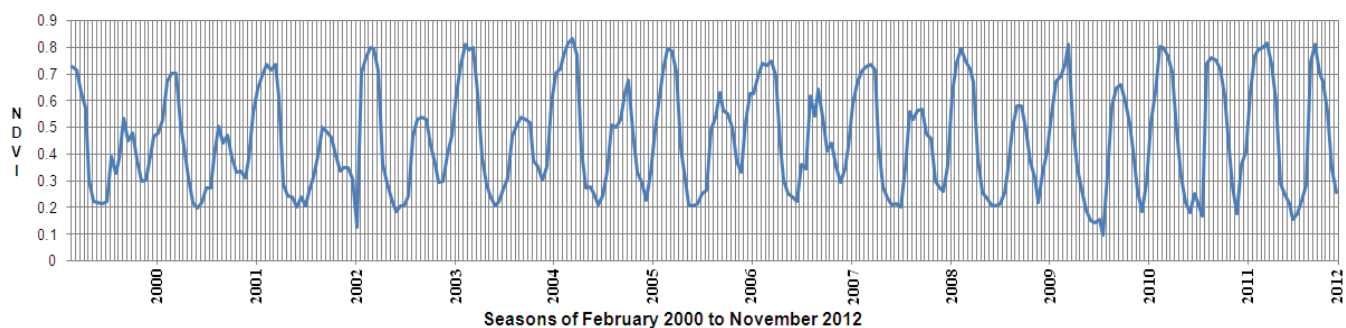


Figure 9 : Time-series phenological variation for Qila Deva Singh, District Nankana Sahib.

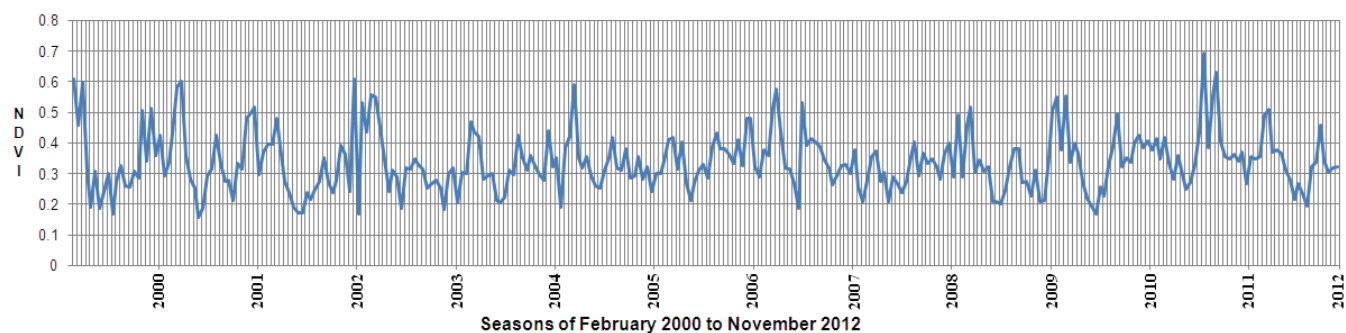


Figure 10 : Time-series phenological variation for Ali Raza Abad, District Lahore.

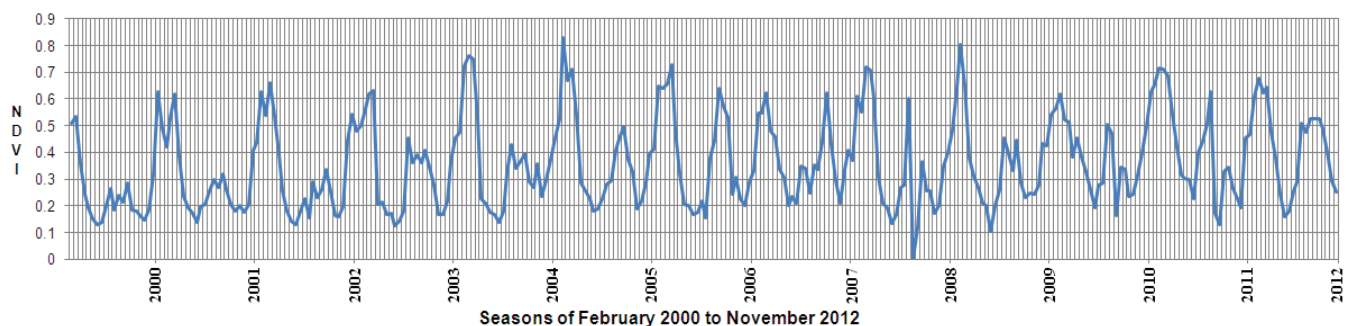


Figure 11 : Time-series phenological variation for Shakranj Pur, District Okara.

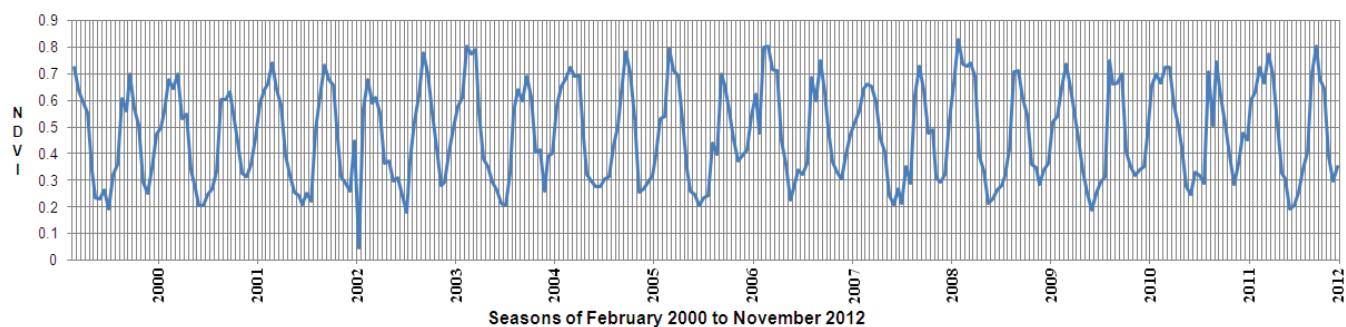


Figure 12 : Time-series phenological variation for Titranwali, District Nankana Sahib.

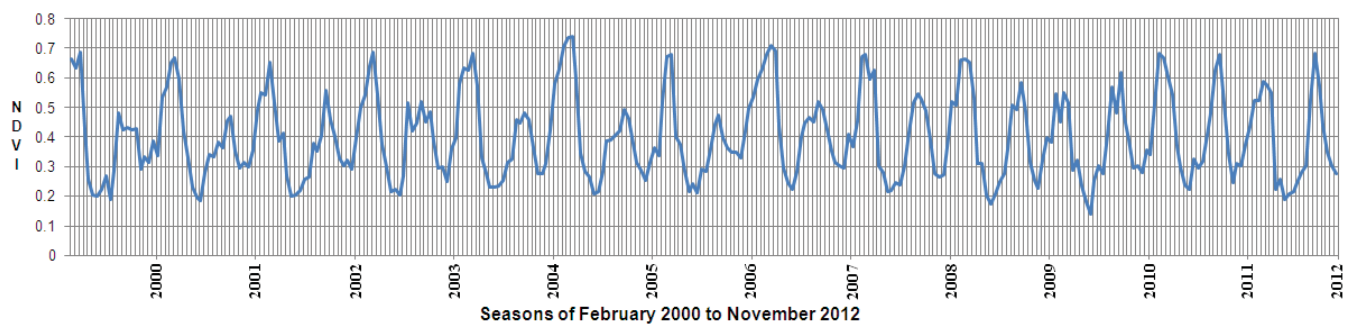


Figure 13 : Time-series variation profile for Ajjanwala, District Sheikhupura.

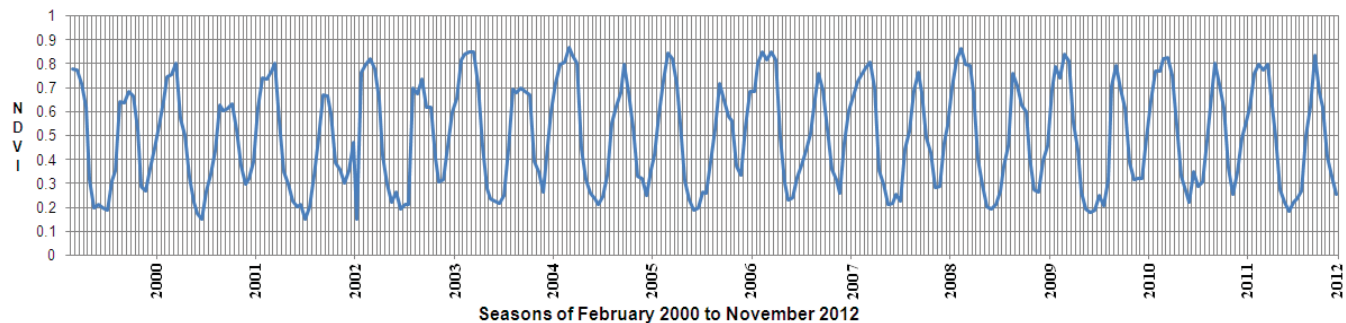


Figure 14 : Time-series variation profile for Makki Unchi, District Sheikhupura.

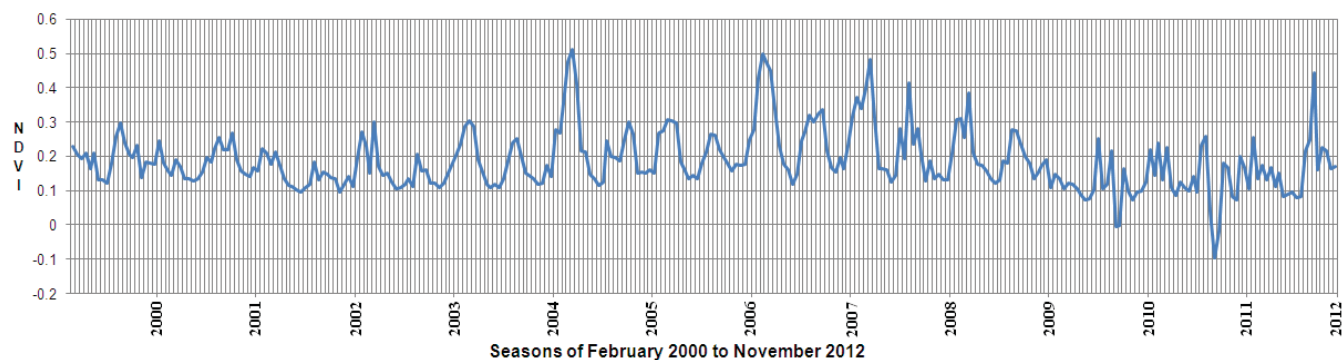


Figure 15 : Time-series variation profile for Bodal Khaneke, District Kasur.

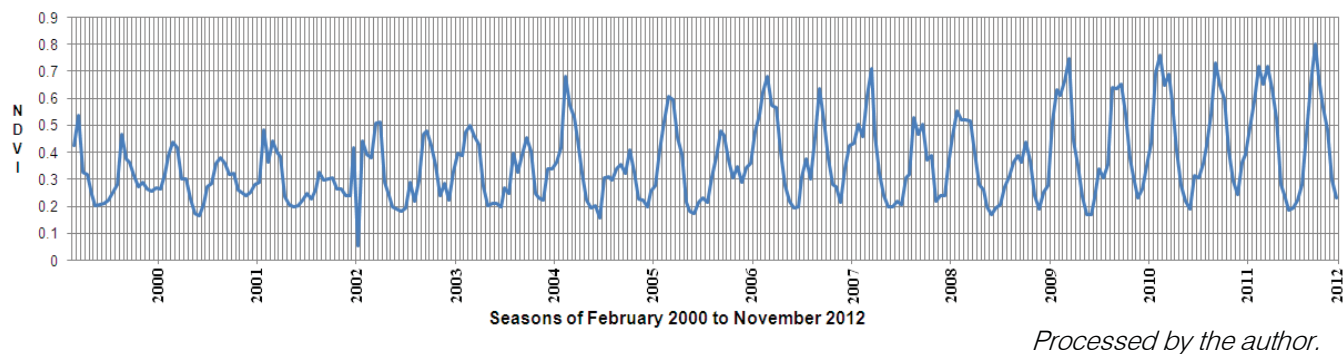


Figure 16 : Time-series variation profile for Asrur, District Sheikhupura.

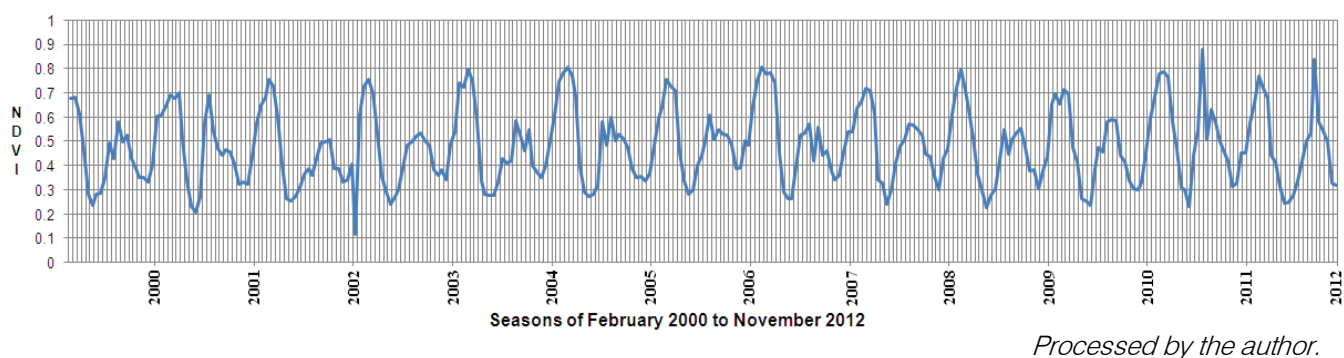


Figure 17 : Time-series variation profile for Katlohi Kallan, District Kasur.

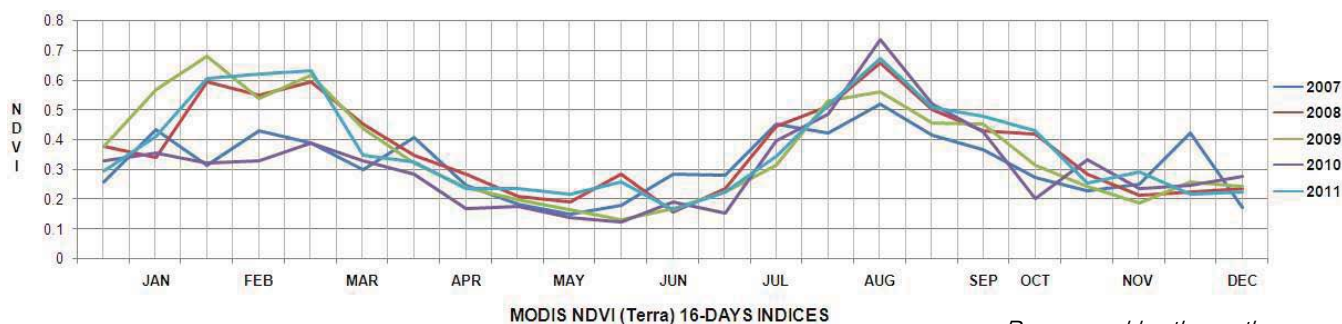


Figure 18 : Phenological temporal comparison for Thatha Khudayar, District Sheikhupura, Year 2007 to 2011.

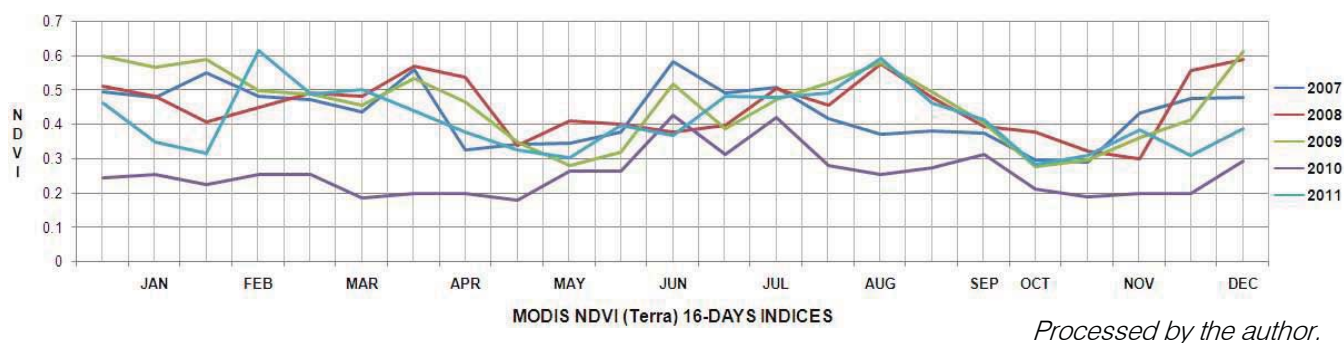


Figure 19 : Phenological temporal comparison for Haveli, District Okara, Year 2007 to 2011.

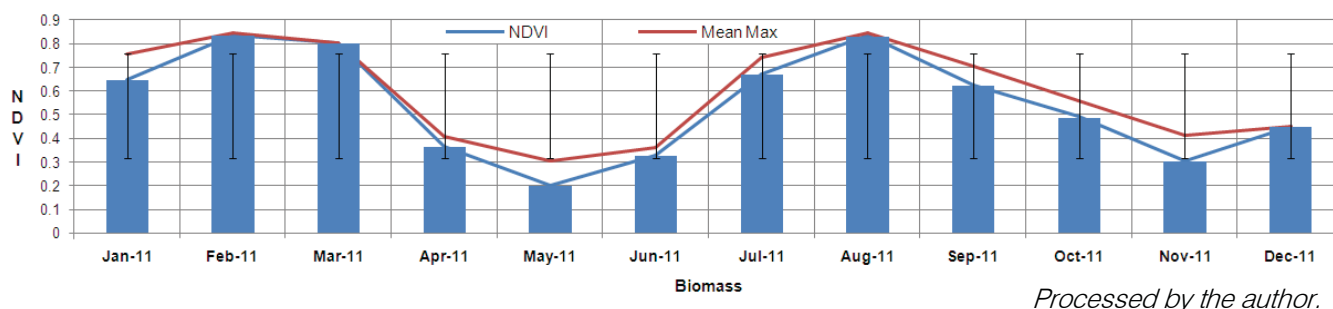


Figure 20 : Biomass versus NDVI and Mean maximum from January 2011 to December 2011 for Bahak Maqaiyaddin, District Hafizabad. (The error bars of biomass are shown with 1 standard deviation).

V. DISCUSSION AND CONCLUSIONS

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, 2012b). Ground cover as estimated did not take into account the physiological status of the vegetation in the sense that we did consider as cover all vegetation whatever its status. The use of NDVI, in general, takes into account mostly the green living vegetation (Cyr et al., 1995; Ahmad, 2012b).

The comparison between the NDVI and biomass indicates that MODIS NDVI data products are suitable for monitoring vegetation condition in the Punjab province. The climatic variation is the major contributor to inter-annual NDVI variation. Precipitation has stronger effects on NDVI than temperature (Li and Guo, 2012). Vegetation phenology derived from remote sensing is important for a variety of scientific applications (Hufkens et al., 2010), and can provide a useful signal for classifying vegetated land cover (Dennison and Roberts, 2003).

This communication presents a new methodology for studying vegetation phenology using remote sensing (Charbonneau and Kondolf, 1993). The methodology provides a flexible means to monitor

vegetation dynamics over large area using remote sensing. Initial results using MODIS NDVI data products for the north-eastern Punjab province of Pakistan demonstrate that the method provides realistic results that are geographically and ecologically consistent with the known behaviour of vegetation. In particular, the MODIS NDVI based estimates of green up onset, maturity onset, and dormancy onset show strong spatio-temporal patterns that also depend on land cover type (Baret and Guyot, 1991; Charbonneau and Kondolf, 1993; Justice et al., 1998).

The results of this research are encouraging and the techniques described provide an improved method for estimating the quantity of vegetative cover across large and complex environment of the north-eastern Punjab province of Pakistan with MODIS NDVI data products. This study also identified several data acquisition and processing issues that warrant further investigation. Studies are under way to assess the importance of coordinating and timing field data collection and image acquisition dates as a means of improving the strength of the relationships between MODIS NDVI data products and land condition trend analysis (Senseman et al., 1996; Ahmad, 2012b) ground-truth data. Due to the continuous provision of information to present days, the MODIS data has been used for many other purposes in geophysical, environmental or agricultural sciences and vegetation change (Chuvieco et al., 2003; Stöckli and Vidale, 2004; Baldi et al., 2008; Ahmad, 2012).

The study demonstrates the successful application of MODIS NDVI products on climatic variation. 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 interannual variation of vegetation dynamics in the north-eastern Punjab province of Pakistan (Ahmad, 2012). The approaches used in this study can be applied to other areas to investigate vegetation response to climate variation.

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