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Detection of Vegetation Changes through Implications of Multi-Temporal Remote Sensing Data with Special Reference to Province Punjab, Pakistan

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ABSTRACT

The proposed research studies the seasonal and temporal variations within the floral canopy throughout Punjab Province using Remote Sensing tools and MODIS (Moderate Resolution Imaging Spectroradiometer) Satellite Imagery during 2008-11. Provincially it comprises of 64% distributed farms with a contribution of 55% farm land area within Pakistan. Of the total country's cultivated land area i.e. 42.62 Million Acres, it contributes 27.04 Million Acres. Observing the Vegetation coverage in the Land Use/Land Cover data derived from the MODIS Satellite Imagery showed dependence of seasonal NDVI variations upon the nature of distribution and type of vegetation cover viz., range land, forest cover, grazing land, arable land, barren land etc. As denser the Vegetation coverage, so more positiveNDVI values resulted. While as lower the elevation, so less the NDVI values. Floral canopy comprising of shrubs, trees, agricultural crops and bushes is dominated in spring and Monsoon seasons while canopy cover of herbs, grasses and low shrubs is prominent in Summer and Winter. Most notable temporal increase in vegetation cover included: 709% rise in Rain fed zone in April, 812.5% rise in Irrigated zone and 1455.7% rise in Rain fed zone during October 2010-2011 for high vegetation; while 591.4% rise in Rain fed zone during June 2008-2009 for medium vegetation.
KEYWORDS: Meteorological factors, MODIS, NDVI, Punjab, Vegetation canopy

1. INTRODUCTION

Vegetation growth pattern varies seasonally and temporally depending upon climatic and meteorological parameters viz., rainfall, temperature, humidity, soil moisture, sun shine duration, wind speed etc. as the most prominent ones while soil fertility, topography, geology, geography and human factors like livestock breeding being crucial influential factors[1]. Rainfall increases vegetation cover especially crops growth in agricultural areas. Crops lying at lower elevations as in Irrigated zone are often damaged in Monsoon season due to continuous rain and flood waters. The water coming from unprecedented Monsoon rains flows into rivers thus exacerbating river ecology [2] and reducing its carrying capacity ultimately resulting in disastrous magnitude of floods [3]. High humidity, rise in Mean Temperature values and Sun Shine hours result in higher seed germination and enhanced growth rate. Soil temperature being sensitive climatic element stimulates floral growth and development considerably [4, 5]. The study relies on Satellite Remote sensing technique to estimate extent of vegetation through vegetation index and detect variations in its growth patterns while relating it with the environmental and climatic processes [6, 7, 8]. GIS and Remote Sensing tools have been extensively used for plants identification to the extent of biomes, community level as well as species level. They have been used for mapping vegetation changes of very large areas caused by the natural factors like fire, landslides, flooding, Tsunamis, avalanche or any disease outbreak [9,10]at different spatial, temporal, spectral and radioactive resolutions[11, 12].GIS and Remote Sensing tools have been used for vegetation classification into different types with particular threshold values such that each threshold value is set for a single vegetation type [13].Change detection, one of major applications of GIS and RS integrated system, is used in various perspectives like vegetation dynamics, population dynamics, land cover change etc. Best change detection technique for judging change in vegetation cover is Normalized Differential Vegetation Index (NDVI). This involves application of the remote sensing approaches and then conversion of raster data in to vector format. Different overlay techniques can be used henceforth to undertake change in vegetation cover [14]. The NDVI technique indicated significant rise in vegetation of the study area due to vegetation improvement programs and conservation projects initiated by the government [15]. Studies have revealed that NDVI values are highest in

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the plain region, second highest in the mountainous region and very low values in the city area. Defining NDVI thresholds gave clear estimation of annual changes in vegetation across the Estuary system [16].
The study area covers whole of Punjab Province, which occupies 50.7 Million Acres (20,517,562 ha) geographical area. Its physical location is between latitude 27.42'N and 34.02'N and longitude values of 69.81'E and 75.23'E.

2. METHODOLOGY

The study relies on Vegetation data viz., NDVI derived from MODIS Satellite Imagery which is a ratio of 2 different spectral bands i.e. dividing the difference by the sum of near IR band and Red band. The formula employed is: NDVI = NIR –R/ NIR + R

Where,

NIR: spectral reflectance in Infrared band

R: spectral reflectance in Red band [12].

High photosynthetic activity shows more reflectance in the NIR band while less reflectance in the red band. NDVI gives best vegetation analysis results in continuous temporal data. As more growth in the vegetation so will be the higher values of NDVI [17].

The proposed study consists of climatic data obtained from the Pakistan Meteorological Department (PMD) for the study area. MODIS imageries for 4 different months representing 4 seasons viz., April (early-Summer), June (Summer), October (post-Monsoon) and December (early-Winter) are collected [18, 19, 20] and NDVI data is derived such that dense vegetation cover comprising of shrubs, trees and fully grown agricultural crops with NDVI values $0.26 < NDVI < 1$ is categorized as high vegetation; bushes, herbs and developing crops with NDVI values $0.15 < NDVI < 0.25$ are categorized as medium vegetation; while low shrubs and grasses with NDVI values $0 < NDVI < 0.15$ are categorized as low vegetation. The land area (in km2) within Punjab province covered by the aforementioned 3 vegetation classes is compared seasonally as well as temporally for 4 years i.e. 2008, 2009, 2010 and 2011.Subsequentlya field survey for ground truthing of the vegetation data is also conducted. Graphs are prepared to monitor trend of seasonal and temporal variation in vegetation cover while undertaking climatic factors [21].

3. RESULTS AND DISCUSSION

a. Trend of High Vegetation Cover

Primary Data analyses reveal that the high vegetation cover varies in an irregular manner. It shows 133.8% and 97.7% temporal rise in April within Irrigated zone during 2008 to 2009 and 2010 to 2011 respectively (as shown in Figure 1) while 709% rise in Rainfed zone during 2010 to 2011 (as shown in Figures 2 and 3) due to higher % Humidity (8 am), Mean Minimum and Maximum Temperatures in 2009 than 2008 as well as higher Rainfall during April 2011as shown in Figure 1 adding to the soil moisture and hence expediting growth of vegetable plants. In October 288.2% and 812.5% rise is observed in Irrigated zone during 2008-2009 and 2010-2011 (see Figures 1, 4 and 5) respectively while 52.3% and 1455.7% rise in Rain fed zone during 2008-2009 and 2010-2011 (see Figures 5 and 6). This is due to adequate and precedent rainfall in 2009 and 2011 than the unprecedented precipitation in earlier years. Trees and shrubs are at optimum growth due to comparatively higher Mean Minimum and Maximum Temperature values in 2009 than 2008 as well as higher % Humidity (8 am and 5 pm) and Mean Temperature (minimum and maximum) values in 2011 than the earlier year [22]. The spss p-values of correlation between high vegetation and Rainfall with +0.770 and +0.762 results for Irrigated and Rain fed zones respectively during the study duration verify the dependence of NDVI increase on precipitation. Moreover owing to lower elevation in Irrigated zone i.e. approximately 200-600 feet altitude range (as compared to Rain fed zone which lies at higher elevation i.e. 350-1200 feet range), more rain water accumulates within the soils of the area particularly after Monsoon season adding to the soil moisture and humidity than Rain fed zone; hence a more favorable Vegetation growth is observed as in 2011 [23].

In December Vegetation decreases in Irrigated zone (-97.7%) and Rain fed zone (-100%) for the year 2009-2010 while showing -100% decrease in Irrigated zone for the year 2010-2011. It is attributable to the damaged crops of rice, cotton, sugarcane and many others due to 2010 floods [23]inundation caused in agricultural regions of Pakistan by 2011 rains as well as the downfall trend in the % Humidity (8 am) in 2011 than 2010[24].

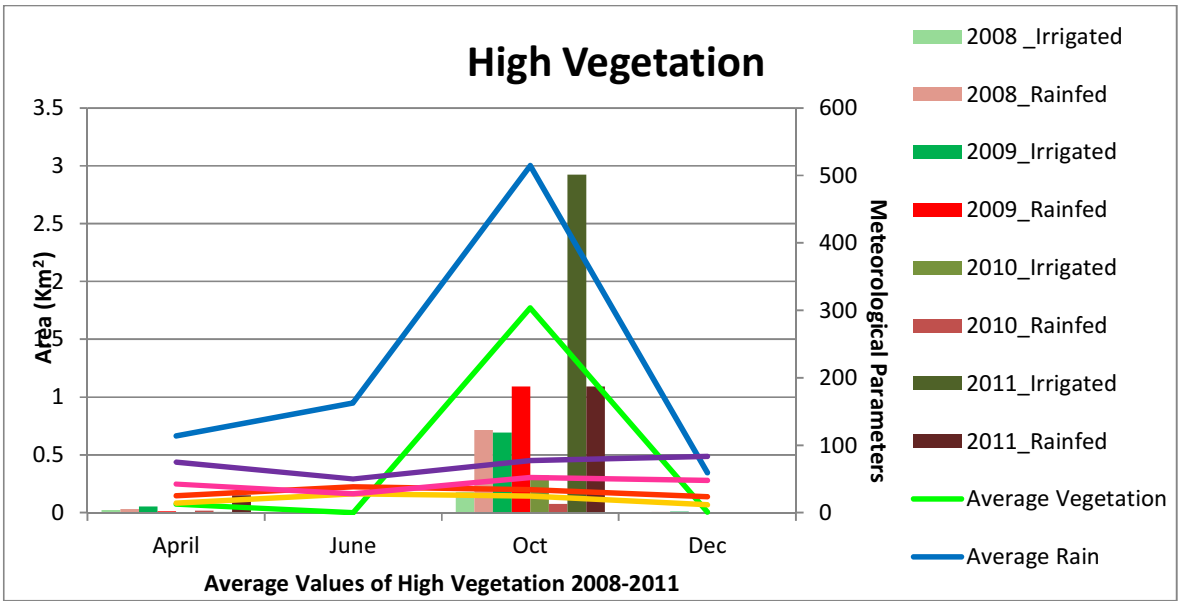

Figure 1: Trend of high vegetation and meteorological data

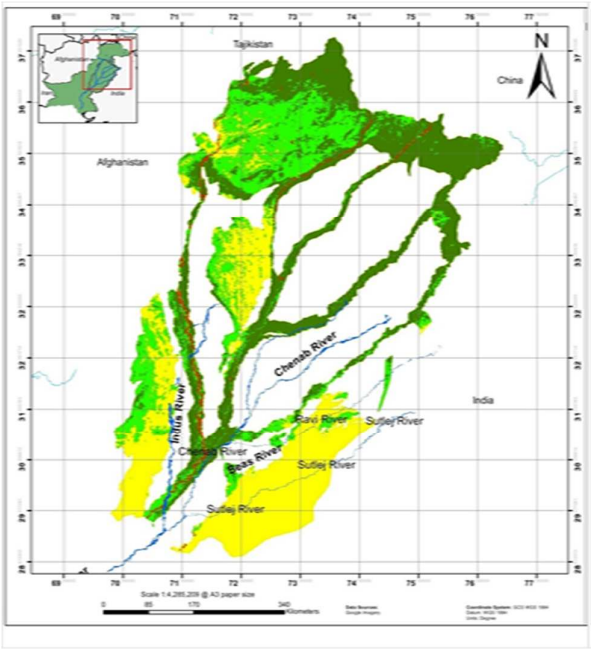

Figure 2: Vegetation cover of Rain fed zone in April 2010 April

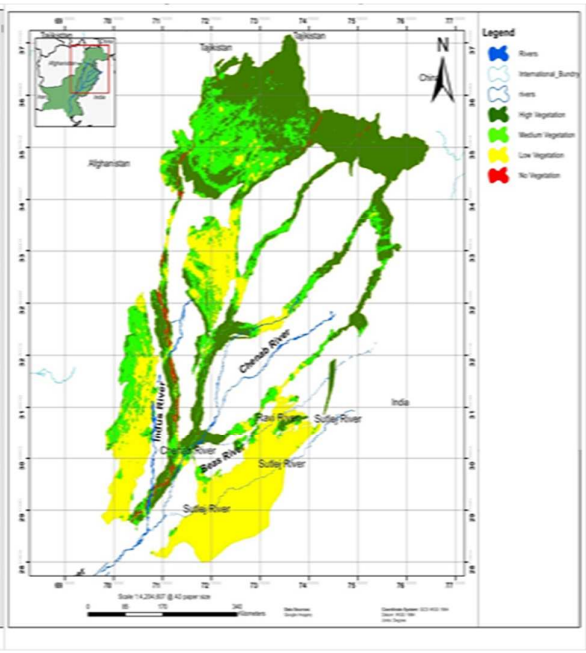

Figure 3: Vegetation cover of Rain fed zone in 2011

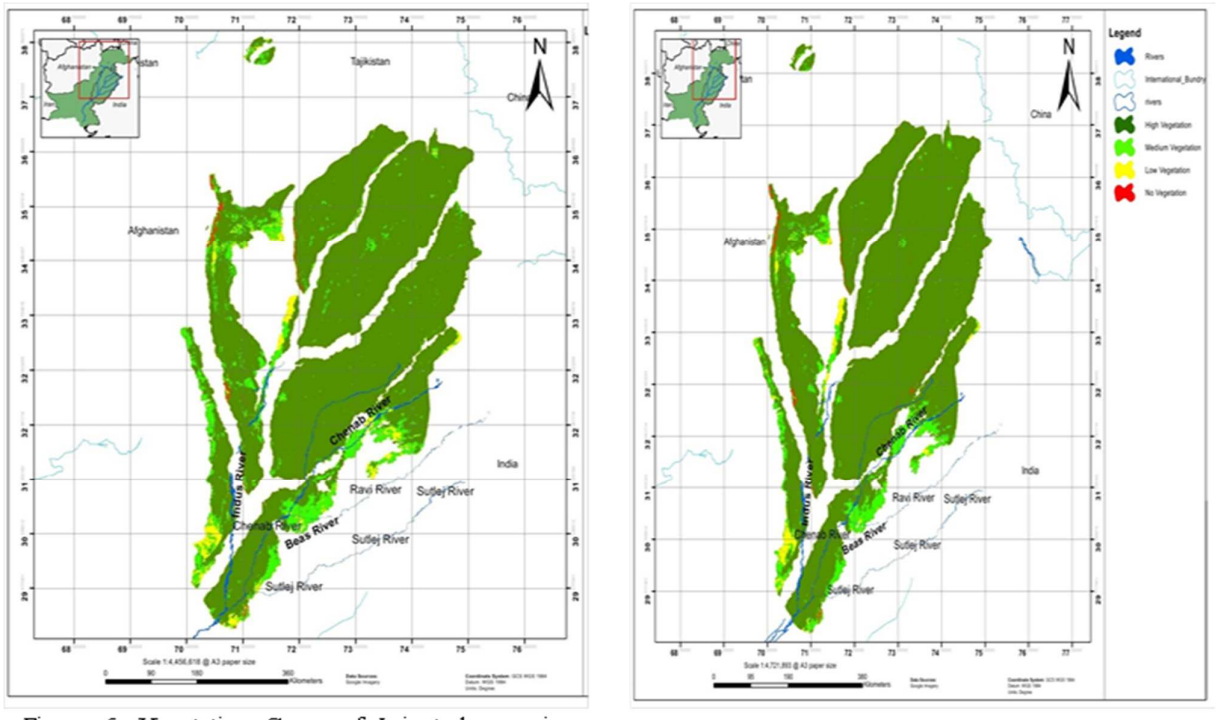

Figure 4: Vegetation cover of irrigated zone October 2010 and 2011

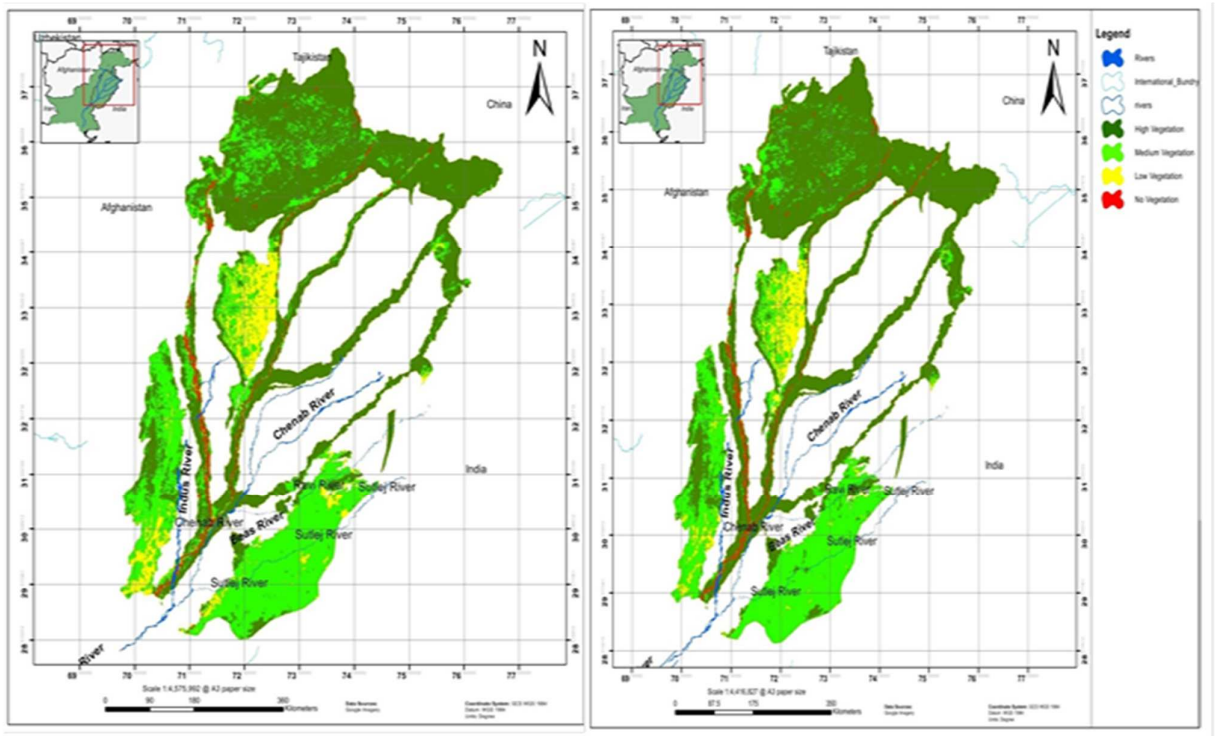

Figure 4: Vegetation cover of Rain fed October 2010 and 2011

b. **Trend of Medium Vegetation Cover**

In April the medium vegetation cover increases by 55.2% in Rain fed zone for the year 2010-2011 due to enhanced Mean maximum Temperature, % Humidity (8 am and 5 pm) and Rainfall in 2011 than the earlier year (see Figure 7).

It increases considerably in June within the Irrigated zone for the time span of 2008-2009 (251.4%) and 2009-2010 (142.2%) while in Rain fed zone it shows 591.4% increase in 2008-2009due to rise in Mean maximum and minimum Temperatures in 2009 than in 2008 as well as higher % Humidity (8 am and 5 pm) and Rainfall in 2010 than the former year. In December it increases till 146.8% within Irrigated zone for the year 2008-2009 while showing 102.7% increase in Rain fed zone for the year 2010-2011. This is because the years 2009 and 2011 received controlled Rainfall than 2008 and 2010, hence no trees or crops were inundated by flash floods during these years [25]. Furthermore the year 2011 showed higher Mean maximum and minimum Temperature values with higher % Humidity (5 pm) than previous year which flourished floral growth considerably. In October the trend is on continuous rise because of increasing Humidity, Mean Temperatures and Monsoon Precipitation in the subsequent years [23, 26]. The vegetation cover shows a significant downfall in December for the year 2009-2010 in Irrigated zone (-79.9%) and Rain fed zone (-60.3%). It is due to the decreased Mean minimum Temperature and % Humidity (5 pm) values in 2010 than 2009 as well as the inundation caused by 2010 Rainfall and floods within Punjab in post October period, which reduced medium vegetation coverage in 2010 than 2009.

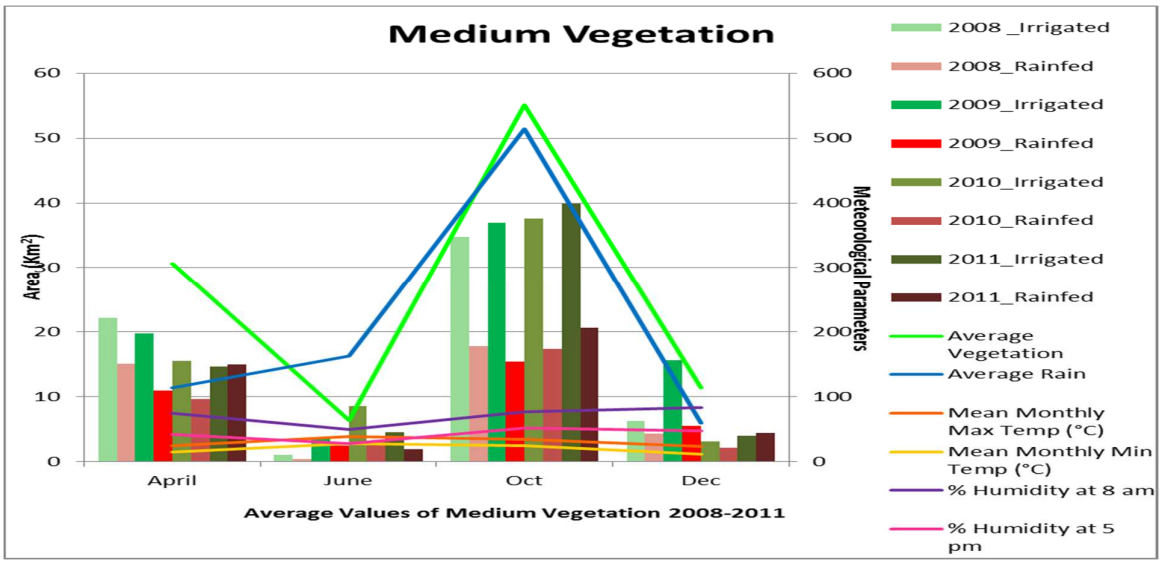

Figure 5: Trend of medium vegetation and meteorological data

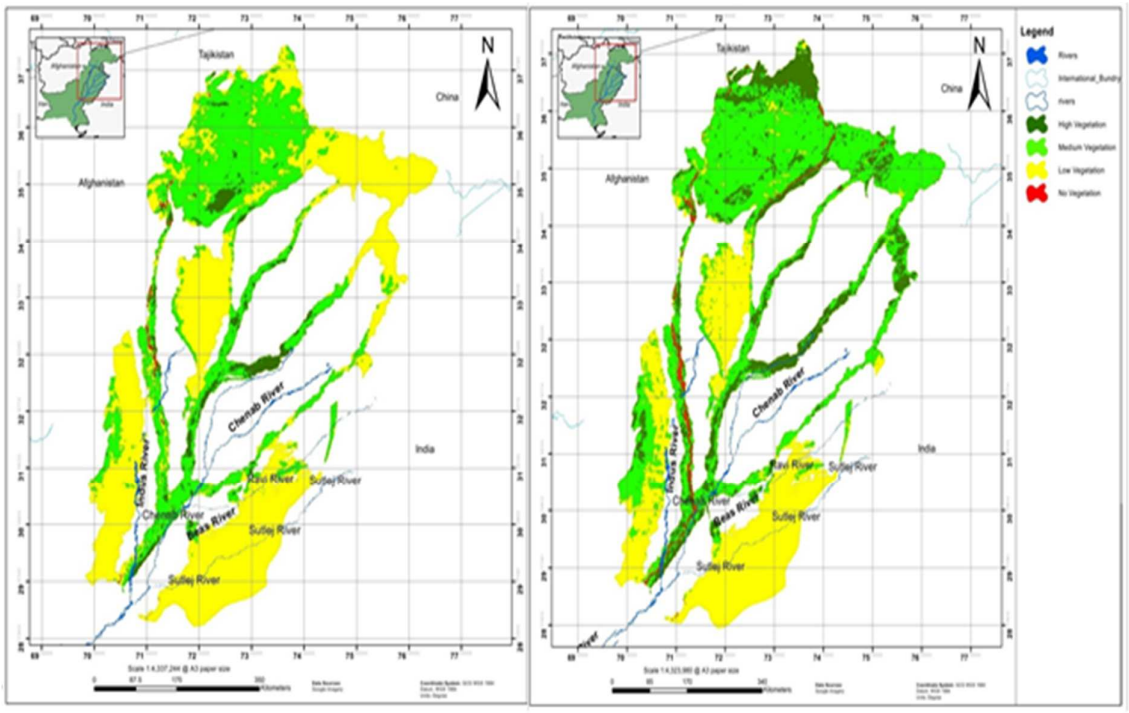

Figure 6: Vegetation cover of Rain fed during 2008 and 2009 respectively

c. Trend of Low Vegetation Cover

The low vegetation shows variable trend with 23.4% rise in April within Rainfed zone for the year 2009-2010; while in June 34.8% and 121% rise in Irrigated and Rain fed zones subsequently for the year 2008-2009due to low Rainfall, reduced high and medium vegetation thus giving more space availability for growth of low vegetation canopy comprising herbs and grasses. The low vegetation decreases in April (-36.8%) within Irrigated zone for the year 2010-2011 as in 2011 medium and high vegetation comprising of shrubs, trees and crops expanded. Moreover the low vegetation shows-29.3% reduction in June within Rain fed zone for the year 2009-2010 because in June 2009 due to drought conditions; less growth of shrubs, crops and trees was observed thus expanding growth of grasses. Similarly the -32.4% decrease in low vegetation of Punjab within Irrigated zone in October for the year 2010-2011 is due to the expansion and prominence of medium and high vegetation in 2011 as compared to 2010; due to moderate rainfall in 2011 and consequently less damages to shrubs and trees as compared to floods and inundation caused in 2010 which intensely damaged shrubs and trees hence low vegetation constituting grasses with NDVI values lying between 0 and 0.15 appeared dominant [23, 26]. Moreover the results are strengthened by the SPSS p-values of correlation between low vegetation and Rainfall i.e. -0.572 and +0.673 for Irrigated and Rain fed zones respectively, indicate higher positive correlation within Rain fed zone.

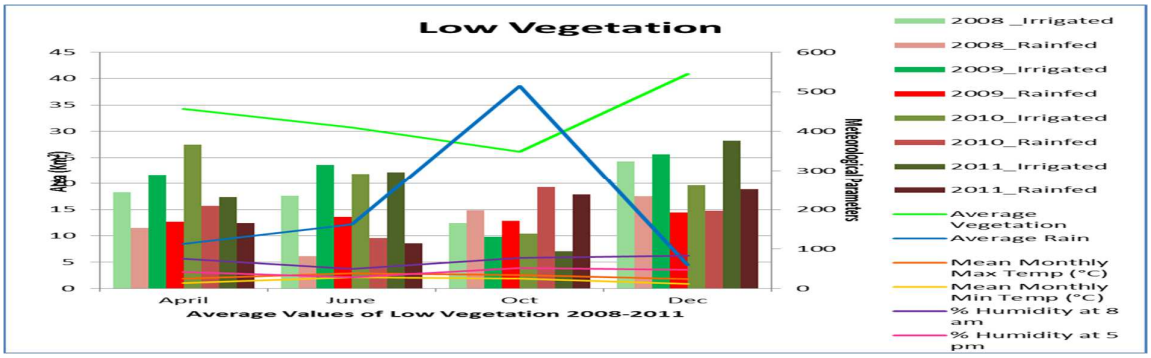

Figure 7: Trend of low vegetation and meteorological data

4. Conclusions

Punjab is the province with diverse climate. Its northern side faces more rainfall than southern side. Its major landscape comprises of agricultural lands. The graphical representation of the meteorological data along with the vegetation as depicted pictorially and graphically, indicate that meteorological parameters highly influence vegetation growth with marked impacts upon grasslands and cultivated lands in comparison to forests. The research has proposed an approach for modeling temporal NDVI data from MODIS Satellite Imagery in the study area and relating it with the seasonal vegetation variations.

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