

## Determining Rainfall variations and the Effect on Vegetation Coverage in (rain fed / irrigated) areas of Punjab Province, Pakistan

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### Abstract

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The research is directed towards the impact of heavy monsoon rains and floods on the vegetation pattern of Punjab. It was observed that though floods damaged households, environment and the agricultural crops, but they also contributed in an overall increase of vegetation. Moderate Resolution Imaging Spectroradiometer 250m imagery was used to detect change in the vegetation cover. The rainfall data from Pakistan Meteorological Department was correlated with the vegetation of Punjab for the time span 2008-11. The rain fed zone was found at high positive correlation whereas the irrigated zone had unexpected outcome. In addition to rains and floods several other factors also contributed to the changes in vegetation pattern of Punjab. These included: difference of elevation levels of the rain fed and irrigated zones at sea level, crop harvesting seasons etc. Analyzing the vegetation of Punjab during 2008, 2010 and 2011 it was proved that monsoon rains had a linear relation with vegetation. The high vegetation shore in rain fed and irrigated zones showed increase in June and October for 2008-11. Similarly the medium vegetation coverage in rain fed and irrigated zones also increased in April and December during 2008-11.

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**Keywords:** Vegetation, Rainfall, ENVI, NDVI, Punjab

### 1. Introduction

Vegetation growth has been found as the direct outcome of rainfall. Its growth pattern fluctuates with the increase or decrease in rainfall (Spano et al., 1999). Rainy seasons play an important role in regulating the growth pattern and the harvest time of vegetation (Omotosho, 1992).

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The province of Punjab faces heavy monsoon rainfalls during summer season. Since the last few years monsoon rains have occurred at a very high intensity which had resulted in flooding primarily in the regions lying at low elevations. This mainly occurs within the irrigated regions of Punjab. The 2008 monsoon rainfall had damaged various agricultural crops (WHO, 2008). The 2010 rainfall had normal precipitation till the mid of July, but till the end of month there was an intense increase in its intensity, which resulted in peak water flows in different areas of Punjab (WFP, 2010). The maximum rainfall observed in 2010 was 800mm (Kronstadt et al., 2010). Resultantly negative growth factor was observed in the crops of cotton, sugar cane, rice, millet, sorghum, maize and many fodder crops after 2010 floods (Wang et al., 2011), (Ministry of Finance, 2011). Similarly in 2011 maximum rainfall received in Punjab was in Islamabad and Lahore. Major crop damaged due to the resultant flooding included cotton, rice, fodders and Rabi crops. While minor to ignorable damage was caused to the crops of sugar cane and Kharif vegetables due to their height up to 5 to 7 feet and their end of harvest season. The accumulative rainfall varied from 400 to 1300 mm (SUPARCO, 2011).

### **1.1 Remote Sensing Analysis of Vegetation Cover**

To analyze rainfall patterns and monitor the resulting flood impacts, remote sensing tools have been found very useful (Gaurav et al., 2011). They can map the environmental and climatic processes easily (Melesse et al., 2007). The GIS and Remote Sensing based technologies can map the vegetation pattern. They can analyze regional and global vegetation processes and identify plant communities and ecotone dynamics in the form of digital maps and satellite imagery (Feng et al., 2009). Satellite remote sensing can provide information about vegetation changes at different spatial and temporal scales (Xie et al., 2008). It measures the vegetation in terms of indices (Lu et al., 2004). The most common and reliable vegetation index is the normalized difference vegetation index (NDVI) (Ibrahim, 2008).

### **1.2 Moderate Resolution Imaging Spectroradiometer (MODIS)**

Moderate Resolution Imaging Spectroradiometer (MODIS) is a key NASA instrument for monitoring the vegetation dynamics due to its high spatial, radiometric and spectral resolution (Evrendilek and Gulbeyaz, 2008), (Song et al., 2008). It has 36 spectral bands with 12 bit radiometric resolution. Its highest number of spectral bands makes it a global coverage of the Earth (Zhan et al., 2002). Its vegetation indices results are very accurate. The NDVI values lie between -1 and +1. The negative values

are indication of land features other than vegetation. The positive values are the indication of presence of vegetation (Yacouba et al., 2009). NDVI is an indication of the presence of vegetation in the ecosystem. It is an extensively used approach to detect the vegetation dynamics by using multi-temporal data from MODIS sensors (Höpfner and Scherer, 2011).

### 1.3 NDVI and Rainfall Relationship

NDVI values are in coherence with the rain data. Comparison of daily rainfall data with the NDVI percentiles has revealed highest correlation results for various land cover types (Benhadj et al., 2008). NDVI indices are used to study changes in vegetation cover. Remote sensing helps to establish relationship between climate and vegetation i.e. rainfall and NDVI. Variations in rain patterns can increase or decrease vegetation cover. A research conducted to check the change in NDVI index in the North Western Libya to analyze the effect of vegetation concluded that there was a direct trend observed between rainfall and vegetation cover (Ibrahim, 2008).

While analyzing the relationship between climate and NDVI the limiting factor is rainfall that can hinder or promote vegetation. NDVI has also been used to monitor rainfall pattern in the case if accurate rainfall data is unavailable (Foody, 2003). A study focusing on the relationship between rainfall and NDVI in Senegal stated that the areas with high positive correlations between rainfall and NDVI indices highlight dense vegetation (e.g. steppe, savanna, agriculture) whereas the places with low positive (or negative) correlation values show poor vegetation (e.g. areas of land degradation) (Li et al., 2004). Analyzing the correlations between NDVI and the meteorological data i.e. average temperature, average humidity, average precipitation and average sunshine hours; it was revealed that NDVI was highly correlated with the precipitation and temperatures.

It was also found that while moving from North to South the dependency of NDVI upon temperature reduced, but the dependency of NDVI upon rainfall increased (Song et al, 2008).

### 1.4 Study Area

Punjab lies in the Eastern side of Pakistan. The area of Punjab province lies in the latitude values between 27°42' to 34°02' north and longitude values between 69°18'

to 75°23' east (Figure 1.2) (Rahim and Hasnain, 2010). The climate of the province varies from cold and humid to very hot and dry (Muhammed et al., 2004). 70% of the rainfall occurs during the monsoon season. Rainfall extent generally reduces from North to South due to difference in the gradients (Mahmood, 1995) (Framji et al., 1982). The topographical gradient of the province increases while moving from West to East (Warwick, 2007). About three quarters of the province land lies under irrigation system for crop cultivation.

### **1.5 Types of Land in Punjab**

The land of Punjab is divided into two types based upon the type of agriculture i.e. rain fed zone (Figure 1.1) and the irrigated zone (Figure 1.2). The level of vegetation in rain fed is usually less prominent except during the monsoon season, when rainfall increases (Gosal, 2004). Generally cities in the rain fed zone are located at higher altitudes than the irrigated zone (Chandy, 1999). During Kharif crop seasons, agriculture is carried out in both these zones but during Rabi crop season major influence is towards the irrigated zone (Bhutta et al., 1992). Moreover in the rain fed zone irrigation depends upon precipitation while in the irrigated zone it is carried out by river channels (Mahmood, 1995).



Figure 1.1: MODIS image of Rain fed zone in Punjab



Figure 1.2:MODIS image of Irrigated zone in Punjab

## 1.6 Aims and Objectives of the Study

The objectives of the study include:

1. Calculate vegetation cover (NDVI)of irrigated and rain fed areas in Punjab for the years: 2008, 2009, 2010 and 2011.
2. To determine rainfall extent data on seasonal basis for all the four years.
3. Compare the NDVI values of rain fed zone with the rainfall data to check the effect of intense rainfall upon vegetation.
4. Compare the NDVI values of irrigated zone with the flooding data to check the effect of flooding upon vegetation.

## 2. Methodology

The methodology followed different steps. Firstly the Satellite data was analyzed using the remote sensing tools. The vegetation cover was calculated based upon the Normalized Differential Vegetation Index (NDVI) and divided in to relevant classes via different threshold values. These classes when converted in to spatial data indicated the spatial and temporal changes in vegetation.

### 2.1 Data Collection

The satellite data consisting of MODIS images was downloaded from the website [www.ladsweb.nascom.nasa.gov](http://www.ladsweb.nascom.nasa.gov). The level 1B product images were preferred for calculating vegetation cover as they have been adequately processed (YCEO, 2010). The MODIS 250m resolution data consisted of bands 1 and 2 with 645nm and 858nm wavelengths respectively (Zhan et al., 2002).

Methodology used for the research was based upon the following steps as described in Figure 2.1.

- Preprocessing of satellite data
- Calculate Vegetation Cover via NDVI
- Classify the Vegetation cover into 3 classes
- Convert the vegetation classes in to Spatial Data
- Spatial and graphical Analysis of Vegetation cover change

The satellite images downloaded were projected and geo-referenced. Then vegetation cover was calculated by applying Normalized Differential vegetation index equation (1) for each MODIS image (Akiyama et al., 2008).i.e.

$$NDVI = (b1-b2) / (b1+b2) \dots\dots\dots (1)$$

Where,

b1= red band

b2= near Infrared band(Hangbin et al., 2011).

After this step vegetation cover was divided in to three classes by defining different threshold values. i.e. High vegetation, Medium vegetation, and Low vegetation (Vierrick et al., 1992). The data was downloaded for four months throughout 2008 to 2011 to represent the four major seasons i.e. Spring season, Summer season, Autumn season, Winter season. The software used during the study included ArcGIS 9.3, ENVI 4.7 and MS Excel 2010.

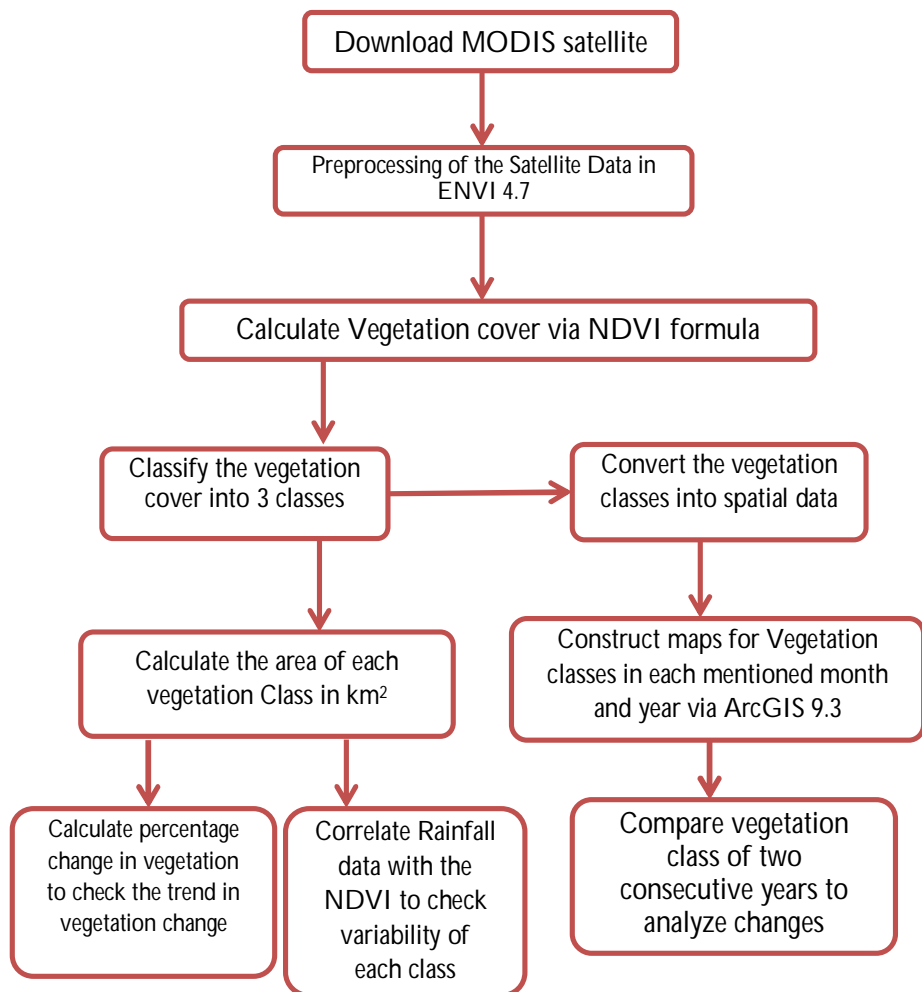


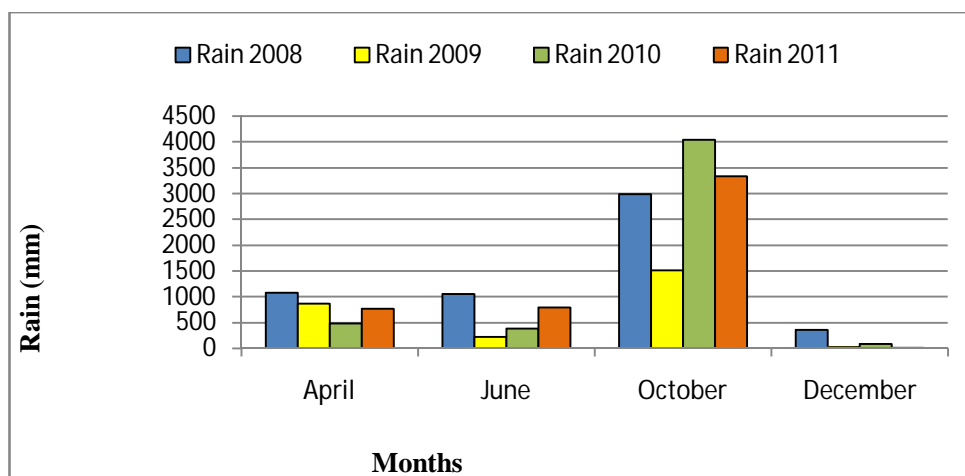
Figure 2.1: Flowchart of Methodology

### 3. Results

#### 3.1 Correlation of Meteorological Variables with the Vegetation Classes

The Rainfall trend followed a diverse pattern for the years 2008-11 as shown in Graph 3.1. In the spring season the rain pattern had been good to average for all the four years. For the summer season it decreased through all the years from 2009-11 but remained constant for 2008. In the monsoon season it increased at an exceptional level for the years 2008, 2010 and 2011. But it remained good for 2009. In winter season the level of rainfall fell down at very low to negligible level.

Graph 3.1: Rainfall Data in Punjab for 2008-11



Source: Pakistan Meteorological Department Karachi

### 3.2 Analyzing Change Detection in Vegetation

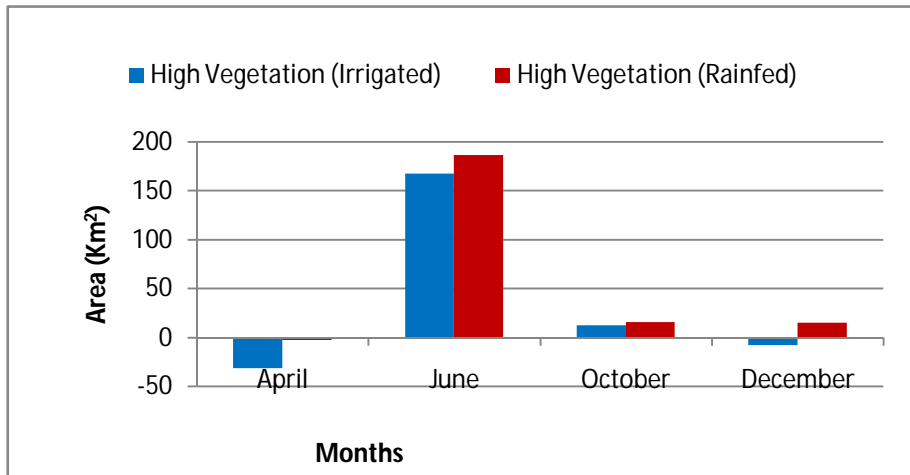
The graphs showing percentage change data in the vegetation for years 2008-11 have different results. This is explained as follows.

#### 3.2.1 Overall Vegetation Change in 2008-11

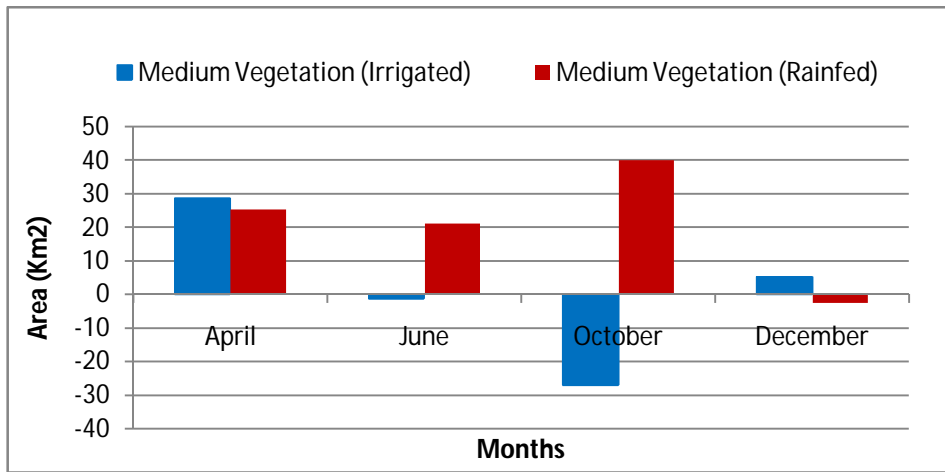
The high vegetation increased in October and December (Graph 3.2). In June it showed an exceptionally increasing trend, while in December it increased only in the rain fed region. The medium vegetation increased in April, June and October (Graph 3.3).

In June and October this trend was found only for the rain fed region while in December it only increased for the irrigated region. The low vegetation trend increased only in the irrigated zone of April (Graph 3.4).

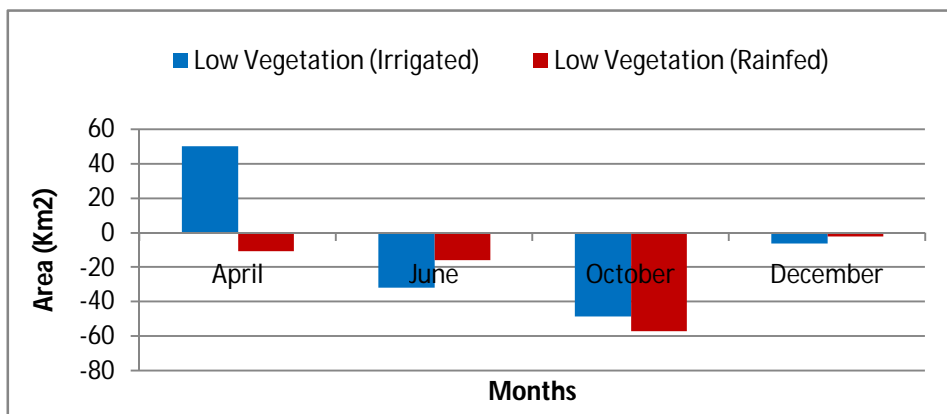




Graph 3.2: Percentage Change of High Vegetation in 2008-11



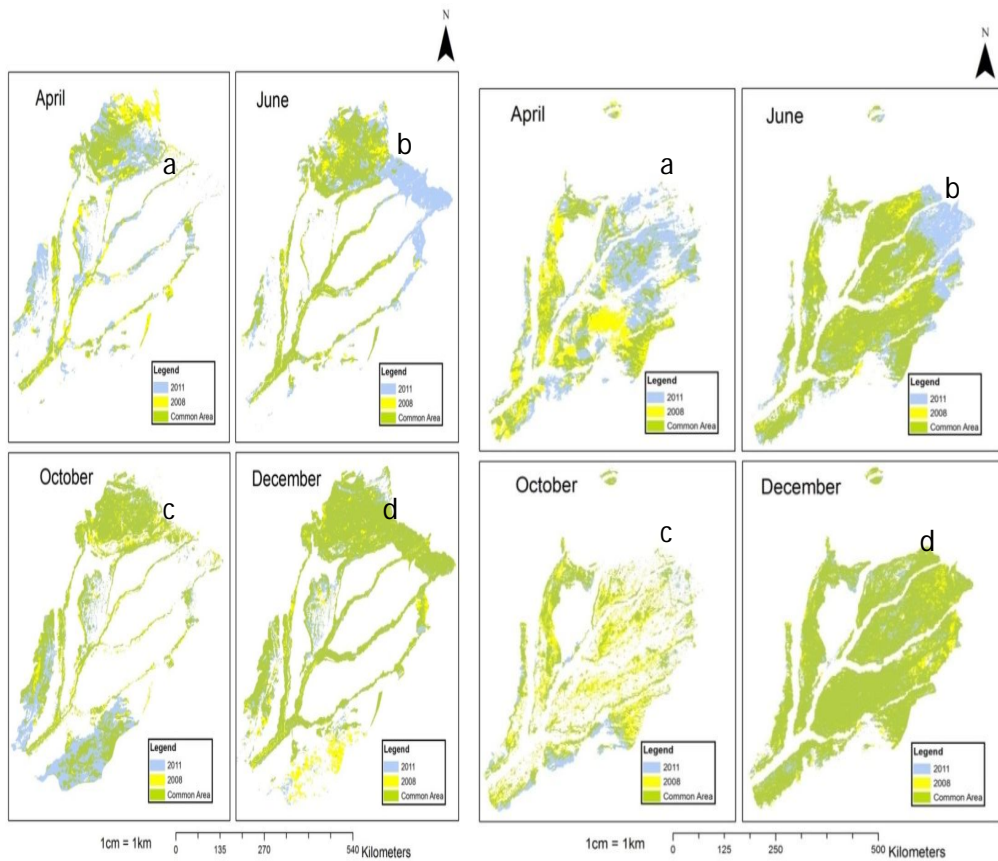
Graph 3.3: Percentage Change of Medium Vegetation in 2008-11



Graph 3.4: Percentage Change of Low Vegetation in 2008-11

During 2008-11 the rain fed zone showed increased high vegetation cover in June, October and December while decreased cover during April (Figure 3.1). In the irrigated zone during 2008-11 the high vegetation cover enhanced in June and October but decreased in April and December as shown in Figure 3.2

In the rain fed zone during 2008-11 duration, medium vegetation showed increased coverage in April, June and October but decreased coverage in December as shown in Figure 3.3. The medium vegetation cover in the irrigated zone showed increase in April and December during 2008-11 but decrease in June and October as shown in Figure 3.4.



In the rain fed zone during 2008-11 duration, medium vegetation showed increased coverage in April, June and October but decreased coverage in December as shown in Figure 3.3. The medium vegetation cover in the irrigated zone showed increase in April and December during 2008-11 but decrease in June and October as shown in Figure 3.4.

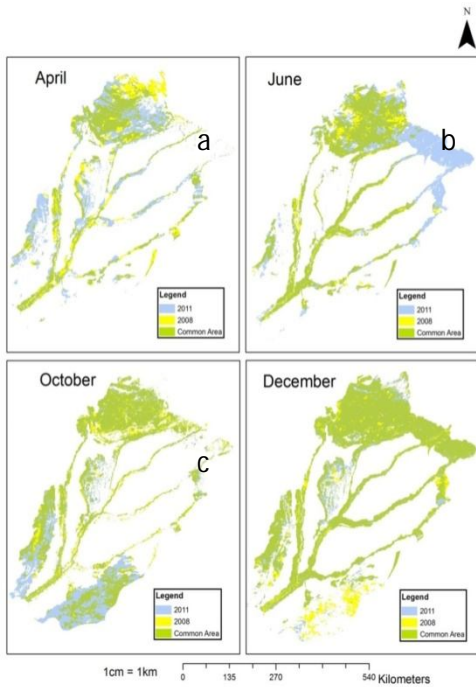


Figure 3.3: Percentage Change in Medium Vegetation of 2008-11 in Rain fed zone (a. April, b. June, c. October, d. December)

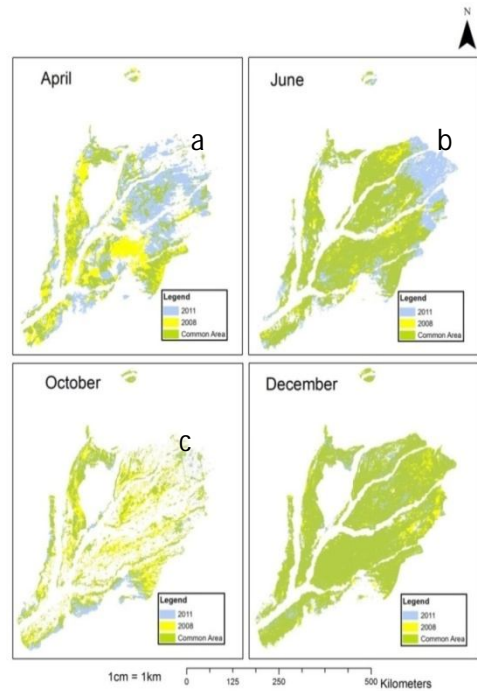


Figure 3.4: Percentage Change in Medium Vegetation of 2008-11 in Irrigated zone (a. April, b. June, c. October, d. December)

## 4. Discussions

### 4.1 Change Detection Analysis in Vegetation

The percentage change analysis has been found effective in predicting the trend of change in the vegetation of both the irrigated regions (flood hit areas) and the rain fed regions during the mentioned time span for this study (Shank, 2008). Initially for the year 2008-09 the high and medium vegetation showed marked increase for the month of June especially in the rain fed zone. This would have been due to heavy monsoon rains and hence the flooding effect of the previous year (Vehmeyer and Hendrickson, 1950). The rain fed zone showed increased vegetation as the levels of precipitation was high in the zone. Moreover the marked increase in vegetation as compared to that of 2008 had been the result of early harvest and damage to the crops of 2008 (FAO, 2010).

The high vegetation increased in December 2009 as the intense monsoon rains of 2008 had bad impact upon the Rabi crops of the year (Förster et al., 2008). Thus the 2009 Rabi crops showed improved growth. Secondly in December 2009 the vegetation had been grown well as the images were acquired from the last week of the month, while 2008 data belonged to the first week of the month. The increase in June was more than that of December as summer season received higher rainfall than winter season. Furthermore Kharif crops are grown in both the irrigated and rain fed zones while Rabi crops are merely grown in the irrigated zones. Hence rain fed zone showed greater degree of increase in vegetation during summer season (Fang et al., 2005). The high and medium vegetation decreased at negligible level in October and April while low vegetation increased during this period (Graph 3.3). This had been the result of the early crop harvest as compared to the previous year (FAO, 2010).

In the 2009-10 era trend shifted towards high vegetation in June (Figure 3.1) as 2010 data showed the vegetation of later days of June while 2009 showed the data of earlier days of June. Hence the newly sown crops had been grown well till the end of June. The rain fed zone showed less degree of increase as there had been less monsoon rainfall in 2009 (Zhang et al., 2005). The medium vegetation enhanced during the months of April and October due to earlier harvesting of crops (high vegetation). The rain fed zone showed an increase in the high and medium vegetation during October indicating that the heavy monsoon rainfall of 2010 was fruitful for the overall increase in vegetation (Chima et al., 2011).

But the high vegetation decreased in December while medium and low showed increase (Figure 3.2, 3.3) as the 2010 images had been of early December, so the newly sown Rabi crop seeds exhibited comparatively less vegetation. This means that the soil's water holding capacity in both the rain fed and irrigated zones was highly affected by the intense 2010 rains and floods (Meng et al., 2004).

During the 2010-11 era high vegetation trend increased in April only for the rain fed zone, which showed that the 2010 monsoon rainfall was useful for its vegetation. The flood mainly inundated the irrigated zone crops as it was found at lower elevation. In the month of June the high vegetation decreased and medium and low vegetation increased, as the crops had been newly sown thus showing lesser vegetation in the early June (Ali et al., 2009). But in the month of October and December the high vegetation increased showing that the 2011 rainfall and flooding were useful for the vegetation of the rain fed and irrigated zones subsequently (Fraiture et al., 2007). The increase in the month of October was less than December as crop harvesting had been done during October. Secondly December 2011 data showed the vegetation of later dates hence the Rabi crops had been grown well than that of 2010 (PCP, 2011).

Furthermore the results of the study highlighted the cities that are either in the irrigated zone or lie in both zones due to their geographic location, had their vegetation badly damaged by floods. These include Bahawalpur, Bhakkar, D. G. Khan, Khushab, Layyah, Mianwali, Muzaffargarh, Rahim Yar Khan and Rajanpur (Save the Children, 2010). Their lower elevations are the most common cause of damage to vegetation due to stagnant water of flood (Pakistan Agriculture Cluster, 2010). On the other hand the areas where high vegetation reached at its peak due to positive impacts of rains and floods included cities like Attock, Chakwal, Islamabad, Kasur, Lahore, Mianwali, Rawalpindi and Sialkot in the rain fed zone while Faisalabad, Khanewal, Multan, Pakpattan, Sahiwal, Sargodha and Toba Tek Singh in the irrigated zone (Government of the Punjab, 2010).

Generally the month of June showed lesser degree of high vegetation as the Kharif crops have been recently sown (Kaleemullah et al., 2001). Therefore the low and medium vegetation dominated during this period but moving through the years 2008-11 it showed marked increase in high vegetation especially in the rain fed zone showing that the high precipitation had good impact upon its vegetation.

The rain water occurring at higher elevations (rain fed zone) usually overflows and reaches at lower elevations (irrigated zone (Soomro et al., 2010). It either fills up the rivers or remains stagnant in the cropping regions. Thus the increase of high vegetation in irrigated zone was less than the rain fed zone. This proved that the rain fall and flooding had been favorable for increasing the trend of vegetation towards high vegetation (Aziz and Tanaka, 2011). The medium vegetation showed increase in April during the 2008-11 eras (Figure 3.1) while in the rain fed zone the low vegetation decreased (Figure 3.3) which clearly depicted that the low vegetation had been replaced by the medium vegetation due to rain but in irrigated zone low vegetation trend increased due to flooding from the Indus River (Kamal, 2008).

Secondly the medium vegetation in October decreased in the irrigated zone (Figure 3.2) indicating that the floods had bad impact upon the vegetation of irrigated zone as the water overflow exceeded the limit of soil's water holding capacity (Khaliq, 1980). But the rainfall had good impact upon the vegetation of rain fed zone as it naturally irrigated its vegetation. It enhanced the output of rain fed agriculture (Wani et al., 2009). On the other hand during December the high vegetation increased in the rain fed zone only while medium vegetation increased in the irrigated zone only. This again proved that the high monsoon precipitation had positive impact upon the vegetation of rain fed zone (Ibrahim, 2008) while in the irrigated zone trend shifted towards medium vegetation due to the stagnant water (PRCS, 2008). On the whole there existed a high positive correlation between rainfall and the vegetation cover.

As the rainfall increased the vegetation in the rain fed zones of the province shifted towards high vegetation trend (Asayehegn, 2012). But in case of the irrigated zone the result was different. The vegetation of irrigated zone showed decrease in the high vegetation cover in the days recently following intense flooding. This is because the irrigated zones being at lower elevations carried most of the stagnant water after flooding. This filled up the spaces in the soil of irrigated area. The soil's water holding capacity overcame and hence it lost the capacity to hold high vegetation. Thus mostly the high vegetation (or crops) was damaged in the irrigated zones. But later on the irrigated zone showed improved vegetation for the next sown crops. Moreover the increase in vegetation due to rains/floods could be attributed to the vegetation other than agriculture (Chaudhry, 2010).

## **5. Conclusion**

The graphical and the pictorial representation of the vegetation cover data showed that there was an overall increase in the high vegetation cover during the time span 2008-11. The high vegetation cover in the irrigated zone increased 167% and 12.5% while in rain fed zone it increased 186% and 15% in the months of June and October respectively. Similarly the medium vegetation cover in the irrigated zone increased 29% and 5% while in the rain fed zone it increased 25% and 40% in April and December respectively. This has been mainly due to the rainfall and flooding in the years 2008, 2010 and 2011. Moreover the factors like crop harvesting seasons, different elevation levels of the rain fed and irrigated zones in Punjab also played a major role in exhibiting variations in the vegetation pattern of Punjab. Hence there had been multiple reasons for the increase in vegetation of Punjab amongst which precipitation and floods played the major role. Therefore this study can play a key role to study vegetation pattern changes in the flood sensitive regions and analyze its multiple impacts. It can also be used to study the disease outbreak after flash floods. Moreover it can also help in designing a flood forecasting model for the province of Punjab in future.

### **5.1 Recommendations**

- The high vegetation and medium vegetation classes should have been classified via supervised classification approach to keenly analyze the change in the vegetation cover of forest, agricultural crops and grasses separately.
- Researches should be undertaken in future to verify the results by applying the same methodology to the MODIS images downloaded for slightly different dates than the ones used for this research.
- The study should be extended in future by including the year 2012 as well in the time span so as to check the 2011 flooding effect in the Rabi crops of 2012. This would help in authenticating the results.
- Further study should be done in future comprising of NDVI data of all the twelve months to check the monthly variations in the vegetation of Punjab within the time span of 2008-11.



## References

- Akiyama, T., Ishihara, M., Wahid, D. A. (2008). Seasonal Patterns of MODIS/NDVI at Different Altitude Zones in Takayama Forest. 29th ACRS, Proceedings in CD-ROM, PS-2-14. Colombo, Sri Lanka.
- Ali, H., Afzal, M.N., Muhammad, D. (2009). Effect of sowing dates and plant spacing on growth and dry matter partitioning in cotton (*Gossypiumhirsutum* L.). *Pakistan Journal of Botany*, 41(5), 2145-2155
- Asayehegn, K. (2012). Irrigation versus Rain-fed Agriculture: Driving for Households' Income Disparity, A Study from Central Tigray, Ethiopia. *Agricultural Science Research Journal*, vol. 2(1), 20-29
- Aziz, A., Tanaka, S. (2011). Regional Parameterization and Applicability of Integrated Flood Analysis System (IFAS) for Flood Forecasting of Upper-Middle Indus River. *Pakistan Journal of Meteorology*, 8(15), 21-38
- Benhadj, I., Duchemin, B., Er-Raki, S., R. Hadria, R., Maisongrande, P., Simonneaux, V., Mougnot, B., Khabba, S., Kharrou, M.H., Chehbouni, A., (2008). Land Use and Crop Evapotranspiration in Tensift/Marrakech Plain: Inter-Annual Analysis Based on MODIS Satellite Data. 13<sup>th</sup> IWRA World Water Congress. France, 1-15
- Bhutta, M.N., Vlotman, W.F., Khan, M.A., Roos, P., (1992). Seepage losses from irrigation canals of Punjab, Pakistan," *Advances in planning, design and management of irrigation systems as related to sustainable land use: Proceedings of an international conference 535-43*, Leuven, Belgium, Center for Irrigation Engineering, Katholieke University, 2
- Chandy, K.T., (1999). *Soils of Punjab-Soil Science*. Agricultural and Environmental Education Series, 365 (13)
- Chaudhry, S.A., (2010). Pakistan: Indus Basin Water Strategy – Past, Present and Future. *The Lahore Journal of Economics*, 15, 187-211
- Chima, G.N., Ijioma, M. A., Nwagbara, M.O., Nwaugo, V.O., (2011). Sensitivity of vegetation to decadal variations in temperature and rainfall over Northern Nigeria. *Journal of Soil Science and Environmental Management*, 2(8), 228-236
- Evrendilek, F., Gulbeyaz, O., (2008). Deriving Vegetation Dynamics of Natural Terrestrial Ecosystems from MODIS NDVI/EVI Data over Turkey. *Sensors*, vol. 8, pp. 5270-5302,
- Fang, J., Piao, S., Zhou, L., He, J., Wei, F., Mynemi, R., Tucker, C.J., Tan, K., (2005). Precipitation patterns alter growth of temperate vegetation," *Geophysical Research Letters*, 32, 1-6
- Feng, M., Wensheng, Z., Qiang, L., (2009). Research the dynamics of landscape spatial pattern of urban-rural ecotone using multi-temporal remote sensing image. *Institute of Electrical and Electronics Engineers International*, 5, 264-267
- Food and Agriculture Organization (FAO), (2010). *Crop Prospects and Food Situation*. Global Information and Early Warning System on Food and Agriculture, 2, 1-30
- Footy, G.M., (2003). Geographical weighing as a further refinement to regression modeling: An example focused on the NDVI-rainfall relationship. *Remote Sensing of Environment*, 88(3), 283-293

- Förster, S., Kuhlmann, B., Lindenschmidt, K.E., Bronstert, A., (2008). Assessing flood risk for a rural detention area. *Natural Hazards and Earth System Sciences*, 8, 311–322
- Fraiture, C., Smakhtin, V., Bossio, D., McCornick, P., Hoanh, C., Noble, A., Molden, D., Gichuki, F., Giordano, M., Finlayson, M., Turrall, H., (2007). Facing Climate Change by Securing Water for Food, Livelihoods and Ecosystems. *International Crops Research Institute for the Semi-Arid Tropics*, 4(1),1-21
- Framji, K.K., Garg, B.C., Luthra, S.D.L. (1982). *Pakistan. Irrigation and Drainage in the World – A Global Review*, 2,1-16
- Gaurav, K., Sinha, R.,Panda, P.K., (2011). The Indus flood of 2010 in Pakistan: a perspective analysis using remote sensing data. *Natural Hazards*, 59, 1815 – 1826
- Gosal, G.S., (2004). Physical Geography of Pakistan, *Journal of Punjab Studies*, 11(1),19-37
- Government of the Punjab, (2010). *Floods 2010 Flood & Damages*. Government of the Punjab, Pakistan.
- Hangbin, Z., Xiaoping, Y., Jialin, L. (2011). MODIS data based NDVI Seasonal dynamics in agroecosystems of south bank Hangzhouwan bay. *African Journal of Agricultural Research*,6(17), 4025-4033
- Höpfner, C., Scherer, D. (2011). Analysis of vegetation and land cover dynamics in north-western Morocco during the last decade using MODIS NDVI time series data. *Copernicus Publications*, 8, 3953-3998
- Ibrahim, A.A., (2008). Using Remote Sensing Technique (NDVI) for Monitoring Vegetation Degradation in semi-arid lands and its relationship to precipitation: Case study from Libya. *The 3rd International Conference on Water Resources and Arid Environments and the 1st Arab Water Forum*. Tarhuna, Libya
- Kaleemullah, M., Habib, Z., Muhammad, S., (2001). Spatial distribution of reference and potential evapotranspiration across the Indus Basin Irrigation Systems Lahore. *Pakistan: International Water Management Institute*, 24, 1-55
- Kamal, A., (2008). Environmental flows Indus river system in Pakistan. *Proceedings of 3rd international conference on water resources and arid environments and the 1st Arab Water Forum*. Riyadh, Saudi Arabia
- Khaliq, I.A., (1980). Irrigation System in Pakistan: Measures to Improve Irrigation Efficiency at the Farm Level," *Pakistan Engineering Congress, 70th Annual Session Proceedings*, 57 (445)
- Kronstadt, K.A. Sheikh, P.A., and B. Vaughn, B., (2010). Flooding in Pakistan: Overview and Issues for Congress," *Congressional Research Service*, 1-28
- Li, J., Lewis, J., Rowland, J., Tappan, G., Tieszen, L.L. (2004). Evaluation of land performance in Senegal using multi-temporal NDVI and rainfall series. *Journal of Arid Environments*,59 (3),463–480
- Lu, D., Mausel, P., Brondízio, E., Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, 25(12), 2365–2407
- M. Shank, (2008). Using Remote Sensing to Map Vegetation Density on a Reclaimed Surface Mine. *Incorporating Geospatial Technologies into SMCRA Business Processes*, Atlanta, GA, 25.
- Mahmood, A., (1995). Economics of Barani (Rainfed) Farming and Farm Household Production Behaviour in Pakistan. *The Pakistan Development Review*, 34(4), 901-912

- Melesse, M.A., Weng, Q., Thenkabail, P.S., Senay, G.B., (2007). Remote Sensing Sensors and Applications in Environmental Resources Mapping and Modelling. *Sensors*, 7, 3209-3247
- Meng, K., Zhang, X., Sui, Y., Zhao, J., (2004). Analysis of Water Characteristics of Black Soil Cover Long-term experimental Researches in Northeast China. *Bulgarian Journal of Plant Physiology*, 30(3-4), 111-120
- Ministry of Finance, (2011). Pakistan: Flood Impact Assessment. *Pakistan Economic Survey 2010-11* Ministry of Finance, Government of Pakistan, 221-222
- Muhammed, A., Stewart, B.A., Mitra, P., Shrestha, K.L., Ahmed, A.U., Chawdhury, A.M. (2004). *Water Resources in South Asia: An Assessment of Climate Change - associated Vulnerabilities and Coping Mechanisms*. Asia-Pacific Network for Global Change Research, 1-63
- Omotosho, J.B. (1992). Long-range prediction of the onset and end of the rainy season in the west African Sahel," *International Journal of Climatology*, 12(4), 369–382
- Pakistan Agriculture Cluster, (2010). Preliminary damage assessment in the agriculture sector for flood-affected areas of Pakistan. Conducted by the agriculture cluster.
- Pakistan Red Crescent Society (2008). Pakistan: Floods," *International Federation of Red Cross and Red Crescent Societies, Pakistan*, 1-4
- Pakistan Space and Upper Atmosphere Research Commission (2011). *Pakistan Rain/Flood 2011 Report on Flash floods, breaches in canals and damage to infrastructure and agriculture sectors in Sind Province*, Karachi, 1 – 26
- Planning Commission of Pakistan, (2011). *Agriculture, Annual Plan 2011-12*, 8, 71-85
- Rahim, S.M.A., Hasnain, S., (2010). Agroforestry trends in Punjab Pakistan. *African Journal of Environmental Science and Technology*, 4(10), 639-650
- Save the Children, (2010). *Rapid Assessment Report of Flood-Affected Communities in D.G. Khan District, Punjab, Pakistan*. Save the Children Monitoring, Evaluation and Accountability Unit. Pakistan, pp. 1-15
- Song, D., Guo, P., Sheng, H., (2008). Spatial Distribution Pattern of MODIS-NDVI and Correlation between NDVI and Meteorology Factors in Shandong Province in China. *PIERS Online*, 4(2), 191 – 196
- Soomro, A.G., Memon, A. H., Gadehi, M.A., (2010). Use of Groundwater for Agricultural Production in DehDesvi of ThanoBoola Khan, Jamshoro Sindh. *Pakistan Agricultural Research Council*, 26(2), 60-69
- Spano, D., Cesaraccio, C., Duce, P., Snyder, R.L. (1999). Phenological stages of natural species and their use as climate indicators," *International Journal of Biometeorology*, 42(3), 124 - 133
- Veihmeyer, F.J., Hendrickson, J.H. (1985). Soil Moisture in Relation to Plant Growth. *Annual Review of Plant Physiology*, 1, 285-304
- Viereck, L.A., Dyrness, C.T., Batten, A.R., Wenzlick, K.J. (1992). *The Alaska Vegetation Classification*. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1-138
- Wang, S.Y., Davies, R.E., Huang, W.R., Gillies, R.R. (2011). Pakistan's two-stage monsoon and links with the recent climate change," *Journal of Geophysical Research*, 116, 1-15
- Wani, S.P., Sreedevi, T.K., Rockström, J., Ramakrishna, Y. S. (2009). *Rain fed Agriculture: Unlocking the Potential*. CAB International, 7, 1-310

- Warwick, P.D. (2007). Overview of the Geography, Geology, and Structure of the Potwar Regional Framework Assessment Project Study Area, Northern Pakistan. Regional Studies of the Potwar Plateau Area, Northern Pakistan, 1-9
- World Food Programme (2010). Pakistan Flood Impact Assessment. Pakistan, 1-28.
- World Health Organization (2008). Pakistan Floods Situation Report# F-1-2008. Pakistan, 1-9
- Xie, Y., Sha, Z., Yu, M., (2008). Remote sensing imagery in vegetation mapping: a review," *Journal of Plant Ecology*, 1(1), 9-23
- Yacouba, D., Guangdao, H., Xingping, W. (2009). Assessment of Land Use Cover Changes Using NDVI and Dem in Puer and Simao Counties, Yunnan Province, China. *World Rural Observations*, vol. 1(2), 1-11
- Yale Center for Earth Observation (2010). Obtaining and Processing MODIS Data. The Center for Earth Observation, Yale University, 1-9
- Zhan, X., Sohlberg, R.A., Townshend, J.R.G., DiMiceli, C., Carroll, M.L., Eastman, J.C., Hansen, M.C., DeFries, R.C., (2002). Detection of land cover changes using MODIS 250m data" *Remote Sensing of Environment*, 83, 336-350
- Zhang, X., Friedl, M.A., Schaaf, C.B., Strahler, A.H., (2005). Monitoring the response of vegetation phenology to precipitation in Africa by coupling MODIS and TRMM instruments," *Journal of Geophysical Research*, 110, 1-14