Spatio-temporal SPOT VGT image analysis for crop mapping in India

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Abstract- India, the seventh largest country in the world situated between latitudes 8° 4' and 37° 6' longitudes 68° 7' and 97° 25'. The present study is based on secondary sources of time series data obtained 15 years 1996-99 to 2010-11. The total, actual & normal rainfall, rice & wheat yield and area were data analysis of continuous 15 years (1996-99 to 2010-11). It was found 15 years R^2 value 0.13 (13%). The mean standard deviation of all the study period was 101.1mm. Moreover, the coefficient of variation CV =0.09 of data. The developed model explained rainfall 13% and rice yield 64% of the variability in rainfall and rice yield. The analysis of rice yield with rainfall CV=0.07 was observed and coefficient of correlation between rainfall and yield was 0.09. The rice yield and rainfall was shown good correlation. Although wheat is grown during non-monsoon months, its production shows a rather weak but significant correlation with monsoon rainfall is 0.09 for rice but negative for wheat is -0.26. The relationship between year wise rainfall and yield of wheat was computed which less than linear function is provided value of R^2 of 0.46, which is reasonably less indicating that 46% variation in wheat yield is explained by the yearly rainfall. But the high value of R^2 of 0.64, which is high indicate that 64% variation.Satellite-derived vegetation indices are the most powerful way to represent the overall plant health, and in turn can be related to plant productivity.The series of SPOT VGT images areas identified the distribution of crop pattern in whole areas based on tonal variation which are assign red, yellow, cyan and blue color are mentioned very low, low medium and high classes based on grouping of slicing of images. In ERDAS IMAGINE, create a pseudo colour table to set the value <100 red color, 101-150 yellow colour, 151-200 cyan colour and >201 blue colour classes were classified. The rice area change was observed 66% to 67.1%. The area increase due to rainfall pattern was good during this period but in wheat area decrease 67% to 65.1%. The statistical analysis and remote sensing data analysis show the good correlation to develop yield as well as areas of rice and wheat crop. The rainfall is good for rice yield as well area. But it is not good to rainfall for wheat crop.

Index Terms- DN Value, GIS, IGP, Imagery &VGT

I. Introduction

The overall growth of the Indian economy has depended much on the performance of agriculture. Agriculture contributes to 29.93% of India's GDP. Rice-wheat production systems occupy 24 million hectares of cultivated land in the Asian subtropics. Rice-wheat systems cover 32% of the total rice area and 42% of the total wheat area and account for about one-third the total rice and wheat production. The states are growing rice and wheat in Haryana, Punjab, West Bengal, Maharashtra, Uttar Pradesh, Kerala, Karnataka, Gujarat, Bihar, Pondicherry and Delhi. Maharashtra has the highest net area sown in the country [1]. In short, the future sustainability of one of India's most productive cropping systems – the rice–wheat system covering around 10 million hectares is threatened by environmental degradation [2]. In some of the states like Haryana and Punjab, which lie in the fertile Indo-Gangetic plains of India,. Indo Gangetic Plain (IGP) in India is the major foodgrain-growing region, which produces about 50% of the total foodgrains to feed 40% of the population of the country [3]. Rice (*Oriza sativa*) –wheat (*Triticum aestivum*) cropping system is the main cropping system of the Indo Gangetic Plains (IGP) in India [4] & [5]. Monitoring of crop conditions is important for the economic development of any nation. The use of remote sensing has proved to be very important in monitoring the growth of agricultural crops and in irrigation scheduling. The time series of satellite images are a cost effective, high quality source of data to assess land cover dynamics and to monitor changes in large areas. Potentially, the quality can be improved by adding into analysis other crop growth indicators (meteorological and statistical).Satellite remote sensing and GIS technology are now widely used for environmental monitoring and mapping the distributions of land surface biophysical parameters that have an important effect on climate [6]. This is because these satellite-derived datasets provide spatially continuous data (not sampled at individual points) and yield time series signatures from which temporal patterns, changes and relationships may be extracted [7]. A wide variety of satellite remote sensing data from LANDSAT – TM, SPOT, IRS 1C & 1D, CARTOSAT & R-SAT are now available to earth resource scientists for generating information on natural resources. Remote sensing provides tools for advanced cropping system management [8]. The use of remotely sensed data facilitates the synoptic analysis of cropping system, and change at local and regional over time. Multi temporal remote sensing data are widely acknowledged as having significant advantages over single date imagery [9] for studying dynamic phenomena. Simple remote sensing indicators derived from SPOT VEGETATION instrument can be successfully used as a source of crop yield predictors for the Mediterranean and Central Asian countries. The VGT imagery has a spatial resolution of 1 km. It is therefore more suitable for national and regional monitoring of major seasonal variations in vegetation patterns. Time series of optical satellite images acquired at high spatial resolution is a potentially useful source of information for monitoring agricultural practices [10]. In this paper the SPOT data Vegetation index is used to monitor the vegetation cover change in India. The aim of this study is to establish the spatial and temporal changes in vegetation cover and their relation to the rainfall pattern.

II. RESEARCH ELLOBORATIONS

Objectives

The time series remote sensing SPOT VGT data is useful to understand changing of rice-wheat system in India.

Study area

India, the seventh largest country in the world situated between latitudes 8° 4’ and 37° 6’ longitudes 68° 7’ and 97° 25’ (Figure 1) and occupies a geographical area of 32,87, 263 sq.km. [11]. The country exhibits great diversity in climate, topography, flora- fauna and land use patterns. The climate may be broadly described as tropical monsoon type. The south-west or the summer monsoon is the main source of rainfall in the country providing 80% of the precipitation. Study area is represented by two distinct seasons: a *Rabi* season (dry season) from November to April and a *Kharif* season (rainy season) from May to October (Figure 2).

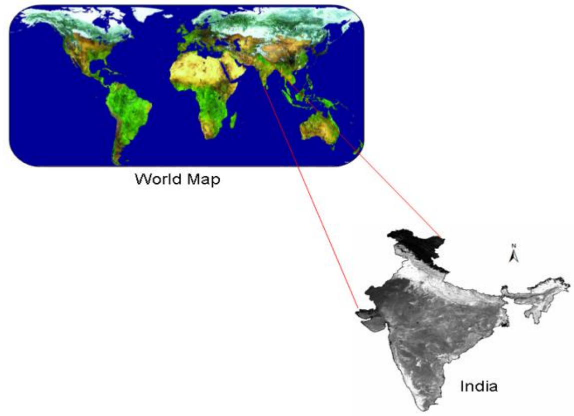

Figure 1: Study area

The data and method

The present study is based on secondary sources of time series data obtained 15 years 1996-99 to 2010-11. The data were collected from the published records, bulletin of the Directorate of Agricultural Statistics and the Institute of State Planning, U.P., ICAR, DRR and other national level institute. The climatic data (rainfall etc.) of India were obtained from IMD, Pune. The total, actual and normal rainfall of continuous 15 years 1996-99 to 2010-11 data were collected.

The remote sensing data used for this study included ten-day composite NDVI products of SPOT- VEGETATION (VGT) sensor for the period. The data S10 was downloaded from the VGT free data product Internet site (http://free.vgt.vito.be). SPOT- VEGETATION [12] has been found very useful to study the dynamics of agricultural system at regional level. The digital map of India with different states was used and states information was taken from planning commission report. The time series images (map) were prepared in ERDAS IMAGINE 8.2 and geo referencing/rectified and masking the area (India) in ARC GIS 10 software.

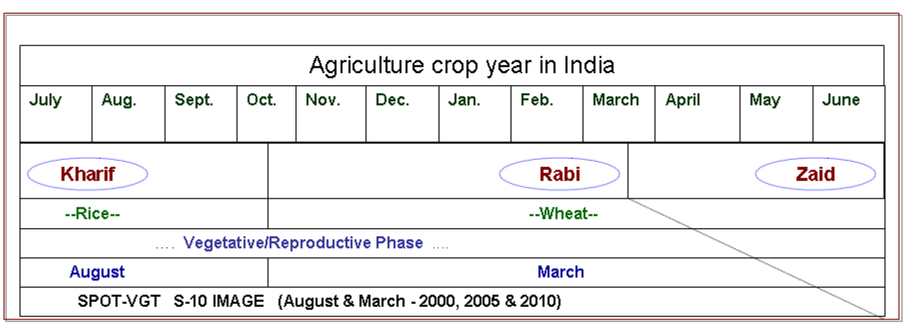

Figure 2: Crop calendar of India during Kharif & Rabi season

Methodology

The study established the methodology for spatial analyst of crop mapping. The utilized data for research included temporal remotely sensed data (SPOT VGT), climatic data (rainfall data), agricultural data (crop area and yield) and digital maps (country map). The satellite images were download from website and pre-processed. This included the importing of .hdf to .img format images into a standard format of the ERDAS IMAGINE 8.2 Then the dataset were geometrically corrected into the WGS84 Geographic lat/ long projection system. The study area subset with a vector polygon file (.shp file) representing the area boundary (AOI). The single band was stacked to create temporal series data (year: 2000, 2005 & 2010) of initial March (Rabi) and initial August (Kharif) month (Figure 3). The images were convert in digital numbers (DN Values) based in to series of classes, so there corresponding all the dates were generated from DN values. The numbers of gray levels classes were identified based on colour range.

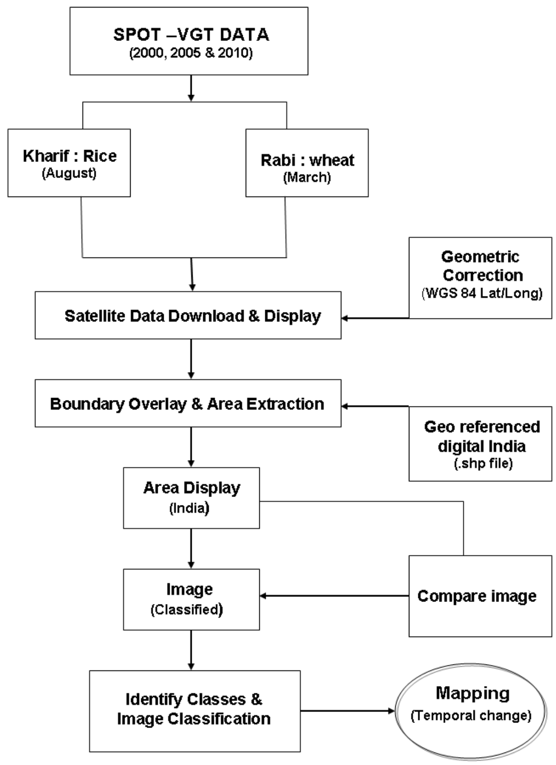

Figure 3: Flow chart of Methodology used in the study

III. RESULTS OR FINDINGS

(A) Statistical method

The different type of statistical data analysis *viz.* Coefficient of Variation (CV), Correlation of Coefficient (R^2) and Trend Analysis to given important scenario of change pattern of time series data. The inter relationship between yield and rainfall over the fifteen years. Based on the correlation regression analysis, the yield estimation model was generated. The findings are discussed in sequence as under. That is also employed to study the trends in area and production of rice and wheat crops and cropping system.

(i) Annual temporal variation of rainfall

Figure 4 shows a general decline in the mean annual rainfall in the study area especially in recent years. It was found those 15 years R^2 value 0.13 (13%). The mean standard deviation of all the study period was 101.1mm. Moreover, the coefficient of variation CV =0.09 of data. More than 60% of the cropped area in India still depends solely on monsoon rainfall [13]. The average rainfall of fifteen years was observed 1147.5mm. The normal rainfall R^2 =0.02 value with linear trend was observed (Figure 4). The actual rainfall showed in decreasing trend in year 2009-10 (Table 1) observed (972.8 mm) and also observed 981.4 mm in year 2002-03. In India, the onset of the southwest monsoon is expected in June or July, depending on location.

Table 1: Overall Rainfall of India during 1996-97 to 2010-11 (June –May)

Year	Over all rainfall (June -May)	
	Actual Rainfall (mm)	Normal Rainfall (mm)
1996-97	1195.5	1190.3
1997-98	1291.5	1198.3
1998-99	1275.5	1198.8
1999-00	1183.5	1197.0
2000-01	1043.7	1195.5
2001-02	1120.2	1196.0
2002-03	981.4	1205.4
2003-04	1278.0	1196.5
2004-05	1085.9	1197.3
2005-06	1185.4	1196.8
2006-07	1133.0	1195.5
2007-08	1180.2	1194.8
2008-09	1075.0	1196.4
2009-10	972.8	1195.6
2010-11	1212.3	1191.7
SD	**101.19**	**3.34**
Mean	**1147.59**	**1196.39**
CV	**0.09**	**0.00**

The actual rainfall data were used for both rice and wheat yield inter-relationship during fifteen years (1996-2010). Data collected for rainfall, yield of rice and wheat for fifteen years (1996-2010) were analyzed using concept of rainfall productivity relationship. Descriptive statistical analysis was made especially for the correlation, coefficient of variation and trend R^2 and various parameters. The statistical information on crop area, production and productivity form the backbone of agricultural statistical system. Regional data analysis is extremely vital since it forms the basis for economic and policy planning by the state and central governments. It is easily to formulate and initiate appropriate policy measures if the data with regard to the trend of production in obtained and analyzed in advance [14].

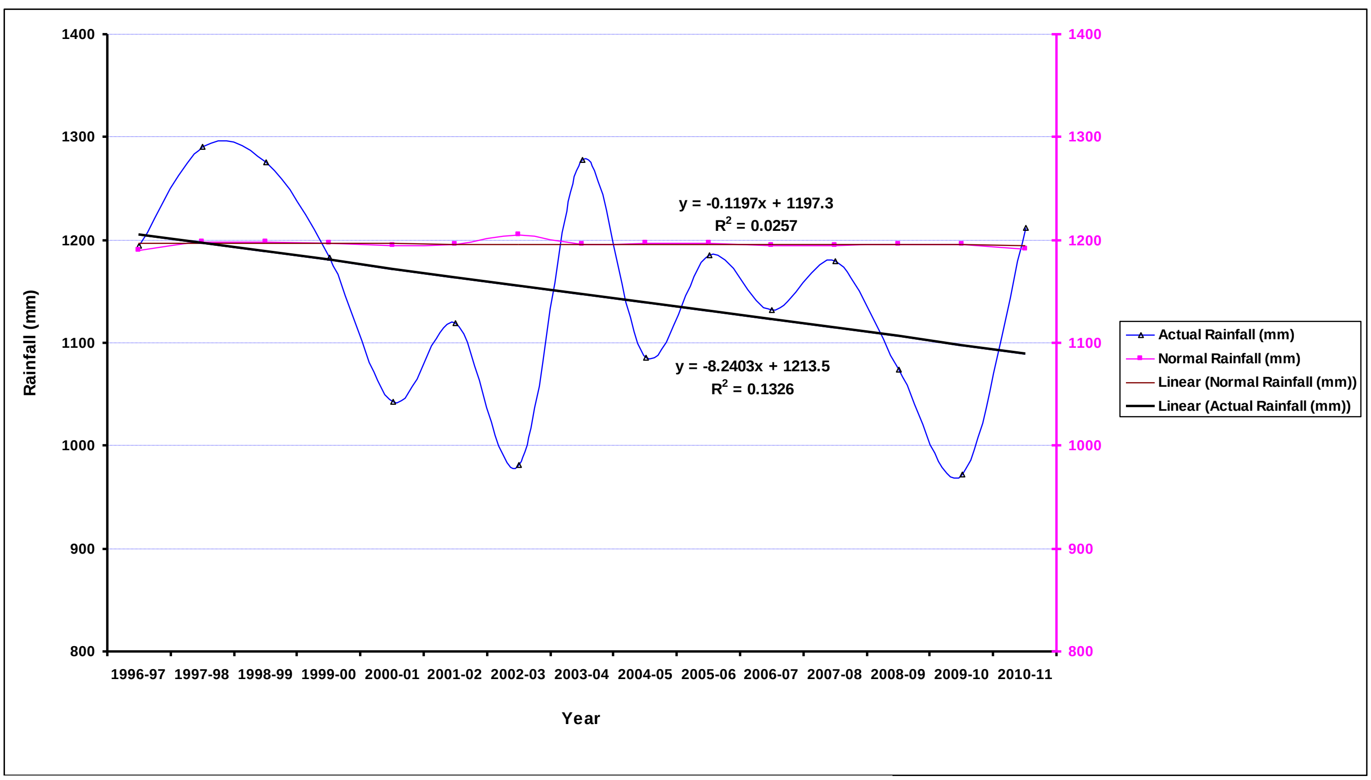

Figure 4: Time series Rainfall data of India (1996-2010)

(ii) Relationship between Rainfall and Yield of Rice crop

The yearly and seasonal rainfall data for the fifteen years were computed considering the crop growing season length based on planting and harvest dates. The coefficient of determination (R^2) was determined. The developed model explained rainfall 13% and rice yield 64% of the variability in rainfall and rice yield (Figure 5). The analysis of rice yield with rainfall CV=0.07 was observed and coefficient of correlation between rainfall and yield was 0.09. The rice yield and rainfall was shown good correlation (Table 2). The trend of rice yield (64%) was observed with increasing trend of rainfall (13%).

Table 2: Statistical relationship between Fifteen Years Rainfall: Actual & Normal Rainfall (mm),Rice & wheat yield(Kg/ha) of India.

Year	Over all rainfall (June -May)	Rice	Wheat
	Actual Rainfall (mm)	Yield (Kg/ha)	Yield (Kg/ha)
1996-97	1195.5	1842	2679
1997-98	1291.5	1900	2485
1998-99	1275.5	1921	2590
1999-00	1183.5	1986	2778
2000-01	1043.7	1901	2708
2001-02	1120.2	2079	2762
2002-03	981.4	1744	2610
2003-04	1278.0	2078	2713
2004-05	1085.9	1984	2602
2005-06	1185.4	2102	2619
2006-07	1133.0	2127	2708
2007-08	1180.2	2202	2802
2008-09	1075.0	2178	2907
2009-10	972.8	2125	2839
2010-11	1212.3	2239	2938
COFF. CORR.		**0.09**	**-0.26**
CV		**0.07**	**0.05**

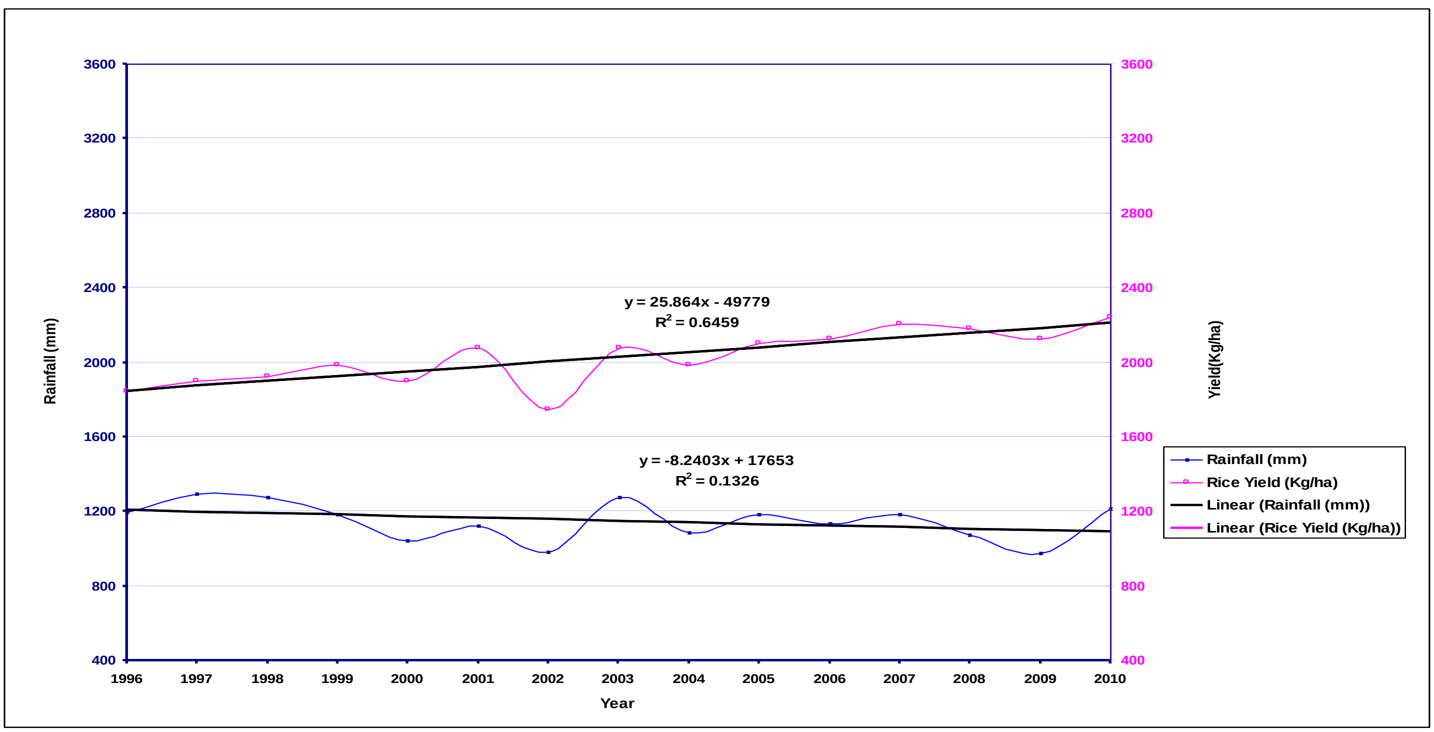

Figure 5: Relationship between Rainfall and rice yield

(iii) Relationship between Rainfall and Yield of Wheat crop

The study of trends in area, production and productivity of tobacco crop grown in over India based on parametric models [15]. The area for second degree (Quadratic) polynomial model; for production and productivity the first degree polynomial models were found suitable to fit the trend of tobacco crop grown in Gujarat state for the period 1951-52 to 1990-91 [16]. The used of first degree polynomial model of the form Log Y = a+b*t to study the trend in area, production and productivity of tobacco crop grown in Assam state for the period 1972-73 to 1999-2000 [17].

The time series of all-India wheat and rice yield data shows a sudden increase after the mid-1960s that can be attributed to the Green Revolution. The year-to-year variability of wheat production is weaker than that of rice, and lacks a strong association with monsoon rainfall in both seasons [18]. It may be due to climate change and urbanization of agricultural land. Although wheat is grown during non-monsoon months, its production shows a rather weak but significant correlation with monsoon rainfall is negative (-0.26) for wheat (Table 2).

The relationship between year wise rainfall and yield of wheat was computed which less than linear function is provided value of R^2 of 0.46, which is reasonably less indicating that 46% variation in wheat yield is explained by the yearly rainfall (Figure 6). The wheat crop yield CV=0.05 was observed. Rice crop is dependent on rainfall but wheat crop is not dependent on rainfall the wheat data show negative relation ship with rainfall. The crop area of wheat and rice is not very much increases because of farmers have not changing the cropping pattern. It is major cereal crops of Indian states.

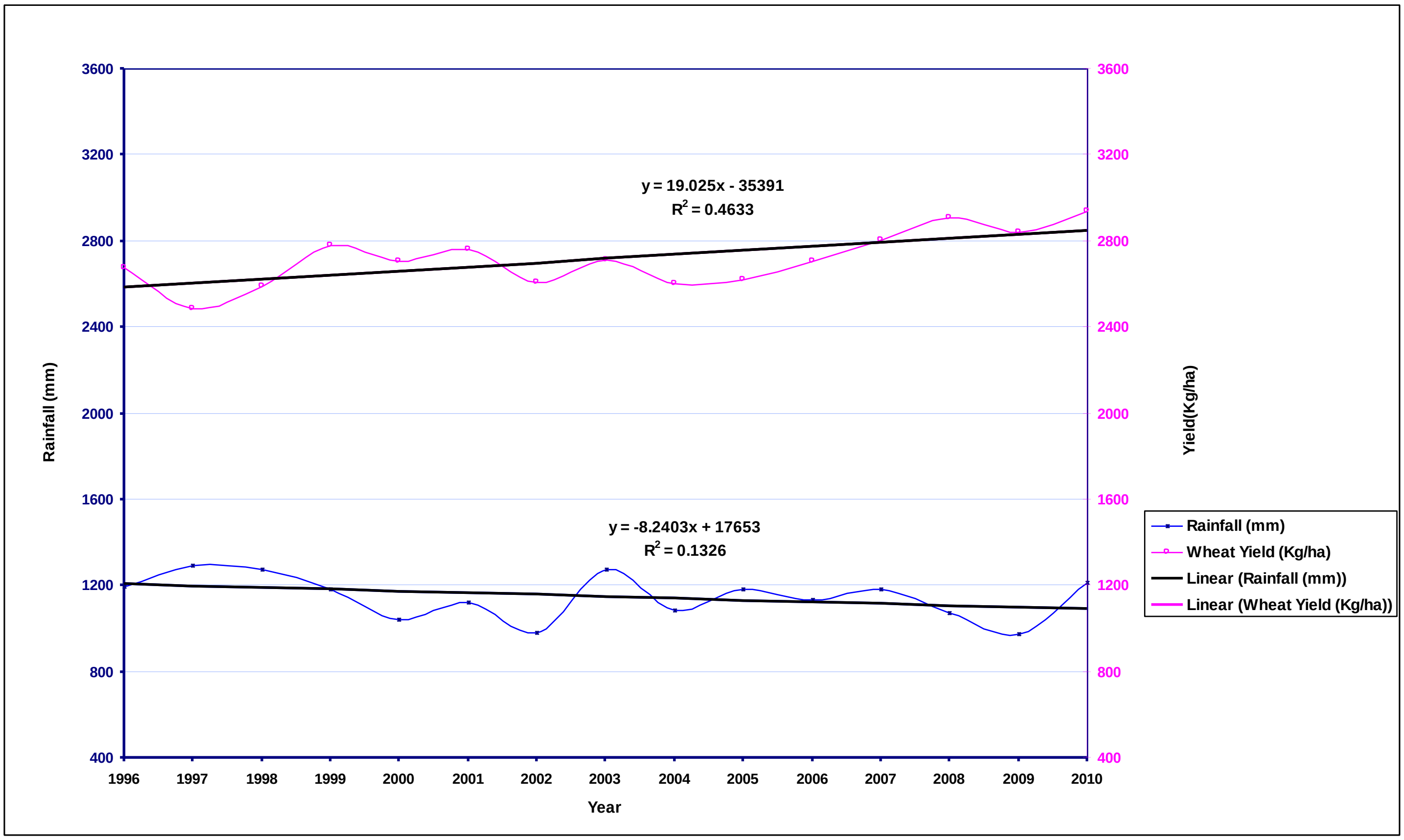

Figure 6: Relationship between Rainfall and wheat yield

(B) Remote sensing method

The area estimation of rice and wheat through SPOT VGT data are shown result that IGP region Punjab, Haryana, U.P., West Bengal , Bihar . Satellite-derived vegetation indices are the most powerful way to represent the overall plant health, and in turn can be related to plant productivity. NDVI represents the leaf vigor of a plant, as demonstrated in the amount of greenness. In the current study for yield estimation, correlation analysis on satellite-derived indices such as weighted mean NDVI was studied. It was found that weighted mean NDVI resulted in good correlation, with yield. The spectral growth profile of rice crop modeled [19] using temporal SPOT VGT data. The color band shows/ highlight the cropped and uncropped area these are mention as low, medium and high classes. The NDVI generated at multiple times in a day from geostationary satellite sensors provide opportunity to get more cloud free NDVI as compared to once or twice overpasses in a day by polar orbiting large view sensor [20]. Multi-date SPOT NDVI data was used to prepare NDVI profiles of various land cover classes [21]. For the major agricultural areas identified the rice-wheat crop calendars were identified using the SPOT VGT IMAGES. The images were classified in ERDAS using Density slicing classification (Un-supervised) algorithm. The class signatures were visually compared and generalized. The availability of the time series VGT images (2000-05-2010) also enabled the area of the range values and cropping pattern of the study area showing the development of vegetation over the year.

Density slicing based classification of SPOT VGT Image:

The SPOT VGT images were downloading in grayscale image /single band converted into colour image due to in colour image easily identify the different crop areas. The pseudocolour tables in gray scale values are mapped to particular colour. Single colour assign single crop and different range divided in different color in to different crop. Slicing based analysis give the very clear view to dividing the image with arrange of values in to unique classes. Those classes are divided in four classes to identify the crop growth pattern in whole areas. In ERDAS IMAGINE, create a pseudo colour table to set the value <100 red color, 101-150 yellow colour, 151-200 cyan colour and >201 blue colour (Table 3). The colour ranges are directly based on DN value and grouped in together and dived in to ranges. This method is good for identification of distribution pattern of particular crop in overall area. In Kharif season images shown in blue colour is good rice crop area but yellow and cyan shown low and middle growth area but red color is very low rice area.

Table 3: Overall tonal classification of SPOT VGT images (Rabi &Kharif) of India

Classes	**Ranges**	**Tone**
Very Low	<100	Red
Low	101-150	Yellow
Middle	151-200	Cyan
High	>201	Red

Kharif

The major IGP areas Punjab, Haryana, Kerala and North east part of India shown good rice coverage area. The yellow and cyan colour tonal variation is too much indicating distribution of cropped area (Figure 7). The image of year 2005, shown good rice covered area in comparison to 2010 image.

Rabi

The analysis of rabi season March is good for wheat crop growth and mainly grown in all over the parts of India. The easily identified in images were particular IGP region Punjab, Haryana, U.P., Bihar, West Bengal, Kerala and parts of North East states of India. In the image analysis based on range of classification blue colour and cyan colour cover the all IGP region. It is also called Wheat belt of India. After image analysis of range of classes year 2010 is good wheat cropped area in comparison to year 2005 image. In year 2005 image wheat cover area low in comparison to year 2010 (Figure 8).The time series image analysis based on colour coding (DN values).

The fifteen years data analyzed in 5years interval as three sets of data series. The data set of rice and wheat (1996-2010) analysis observed rice and wheat areas change due to irregular rainfall in rabi and Kharif season. The rice area change was observed 66% to 67.1%. The area increase due to rainfall pattern was good during this period but in wheat area decrease 67% to 65.1%. The rainfall not much affected the area as shown in Table 4.

Table 4. Change percentage of rice and wheat area (1996-2010)

Years	**Area Change Percentage (1996-2010) (5Years interval)**	
	Rice	**Wheat**
1996-97 to 2000-01	66.0	67.15
2001-02 to 2005-06	67.1	67.12
2006-07 to 2010-11	66.8	65.14

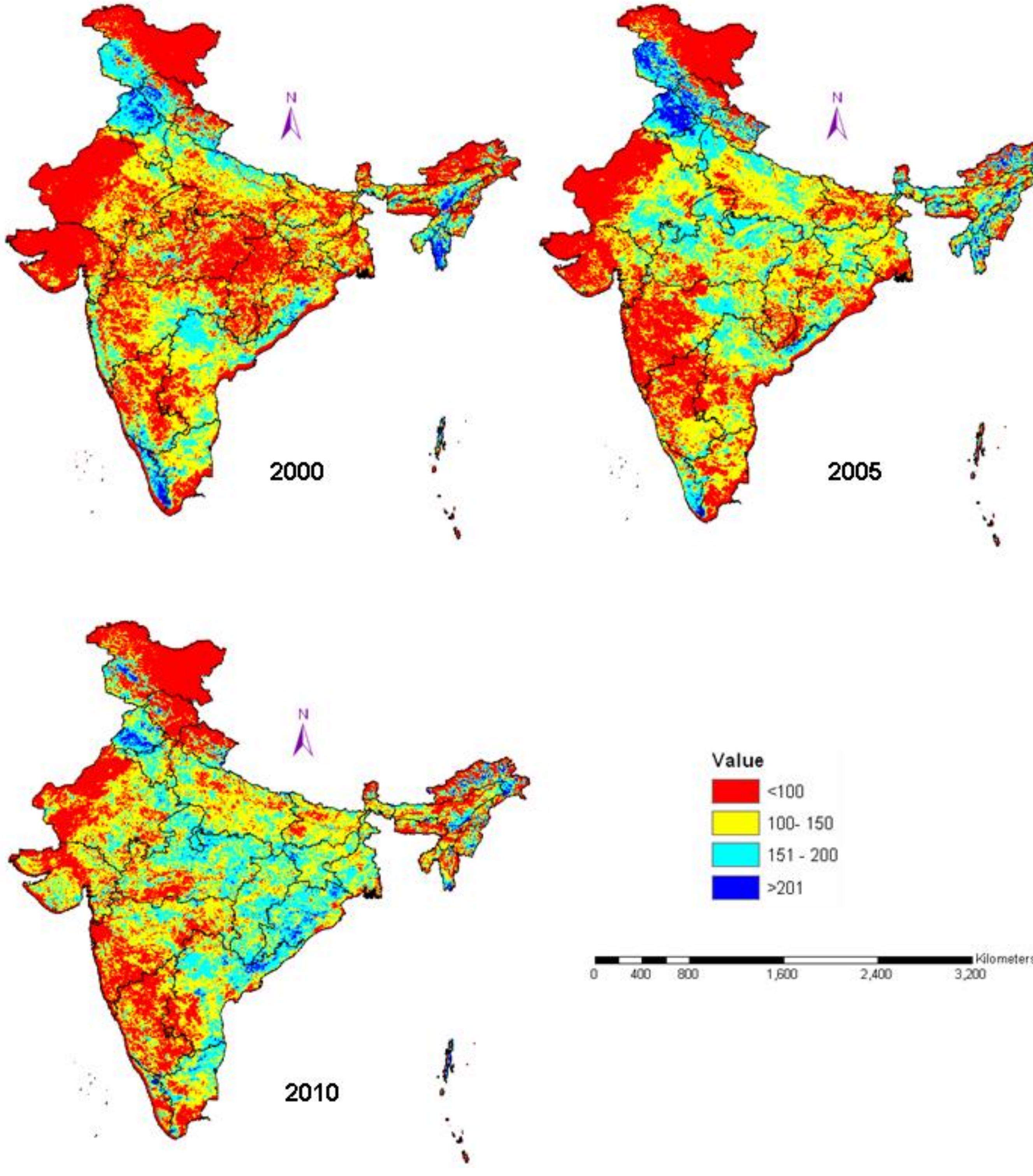

Figure 7: Kharif season map of India derived from multidate SPOT VGT data (March- 2000-05-2010)

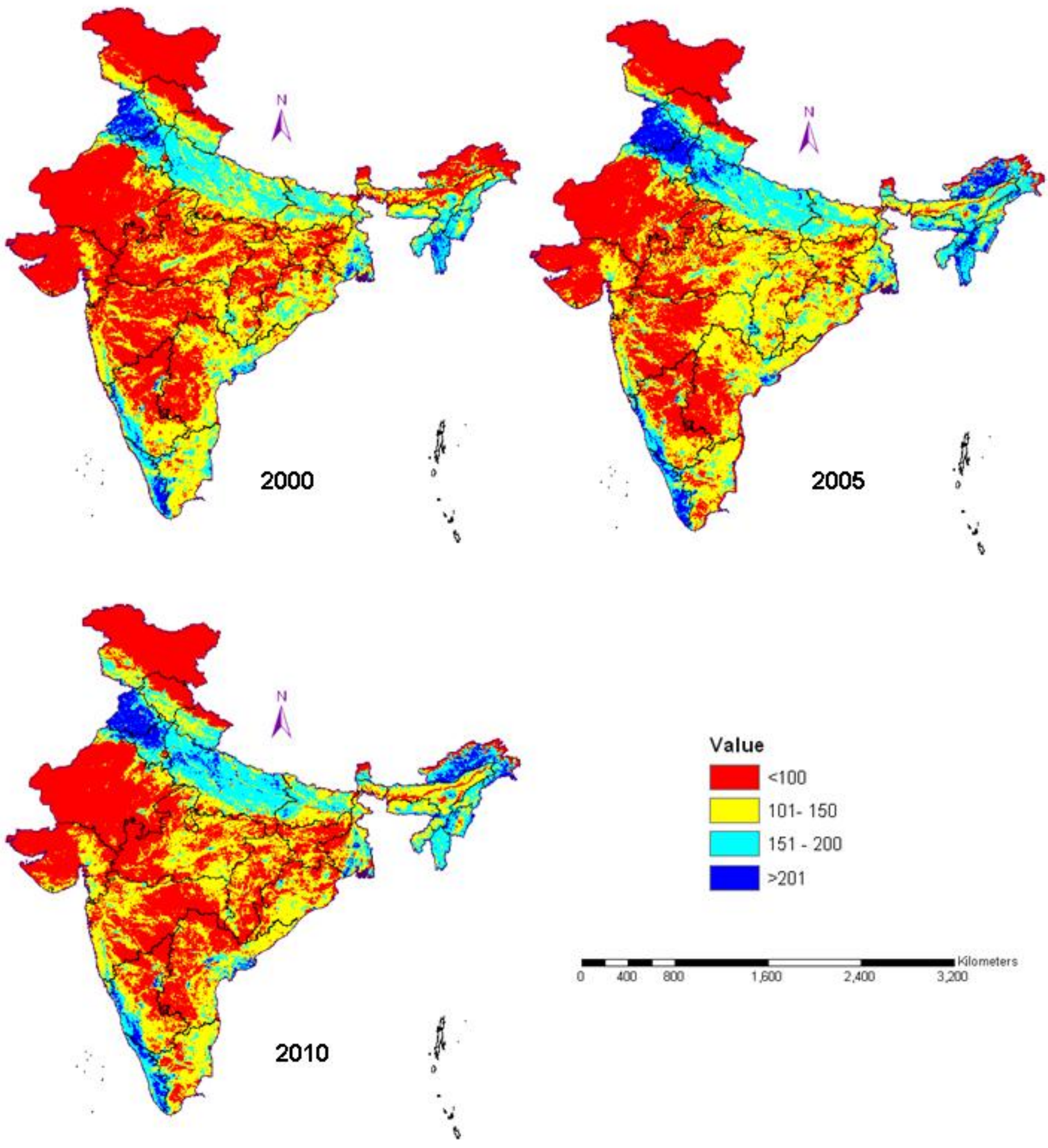

Figure 8: Rabi season map of India derived from multidate SPOT VGT data (March- 2000-05-2010)

IV. CONCLUSION

The rice-system is vulnerable in the context of climate change and urbanization of fertile agricultural land. The current remote sensing study has resulted in generation of time series maps of seasonal wheat and rice crop dynamics. The initial results using the 10-day composite of SPOT VGT data has given promising results. Rice crop depend on rainfall and availability of irrigation source. In India most of the areas covered in Kharif season rice crop and in rabi season wheat crop is major crop. The series of SPOT VGT images areas identified the distribution of crop pattern in whole areas based on tonal variation which are assign red, yellow, cyan and blue color are mentioned very low, low medium and high classes based on grouping of slicing of images. The high temporal SPOT VGT data was able to capture the dynamics of rice planting that varied widely both in the wet and dry season. The spatial data base of rice cropping pattern and crop calendar of India has been generated, which will serve as baseline data for relevant simulation studies on climate change and green house gas emission. Due to rainfall (monsoon) and changing of climatic pattern in coming years but farmers doesn't want to change scenario to grow other crop in large level in rabi and Kharif season. The remote sensing data showed based on density slicing classified rabi and Kharif season: 2000-05-2010 data. Rice and wheat have vegetative growth in March and August season. The area of rice increase 66% to 66.8% but wheat crop areas decrease 67.1% to 65.1% due to distribution of rainfall pattern. The SPOT VGT image analysis red color (<100) shown very low rice and wheat area and blue color (>201) shown both have good crop areas. The annual rainfall data analysis of fifteen years observed R^2=0.13 or 13% and average rainfall was observed 1147.5 mm. The rice and wheat crop yield data coefficient of correlation were observed 0.09 for rice and wheat -0.26 and CV for rice 0.07 and 0.05 for wheat observed after data analysis. The relationship between rainfall and wheat were shown negative relationship. The R^2=0.64 observed for rice and R^2=0.46 for wheat crop observed in time series data of rice and wheat.

The statistical analysis and remote sensing data analysis show the good correlation to develop yield as well as areas of rice and wheat crop. The rainfall is good for rice yield as well area. But it is not good for rainfall for wheat crop. The rice and wheat crops are food basket of India

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