STUDY OF CLIMATE VARIABILITY AND ITS CORRELATION WITH SUGARCANE YIELD OVER BAGALKOT USING REMOTE SENSING.

[1]Shruti Y, [2]Hattarki Pooja, [3]K C Gouda, [4]P P Nageswara Rao.

[1]*Senior Research Fellow-UAS, GKVK,* [2]*Guest Lecturer-Gulbarga University,* [3]*Senior Scientist-CMMACS,NAL,* [4]*Outstanding Scientist ISRO (Retd) & Faculty Member-VTU-EC,KSRSAC.*

A World bank funded project - KWDP-II Sujala-III under Watershed Dept GoK, University of Agricultural Sciences, GKVK, Bangalore, India.

Abstract The study investigates the climate change over Bagalkot region and determine the factor that greatly influence the growth and yield of sugarcane crop. Multi-source observations like remote sensing reanalysis, Indian Meteorological Department etc. are used to analyze variations in the multi-temporal climate data i.e temperature, rainfall, soil moisture, solar radiation, humidity over the study region in terms of the climatology, inter annual variability and trend analysis of the climate parameters at long term scale. The satellite derived Normalized Difference Vegetation Index is used to determine the crop profile and Statistical methods are used to compute ∑NDVI(GGP) and correlation with the sugarcane crop Yield is carried out to determine the influence of climate parameters on the sugarcane yield over Bagalkot.

Keywords— ***multi-source, reanalysis, multi-temporal climate data, variability, trend analysis.***

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1. INTRODUCTION

Climate is the average weather in a given location, averaged over a fairly long time period, at least 10 years. When we talk about climate, we often talk about average values of meteorological variables, such as temperature, rainfall, humidity, solar radiation, soil moisture at a given location at a given time of year. If the climate changes over time, it can directly affect human activities by altering the crops that can be grown, the supply of fresh water etc., also affects natural ecosystems.

Over the past two decades, there has been growing concern about the effects of human-produced greenhouse gases and other environmental pollutants on Earth's climate. Satellite data records are beginning to be long enough to evaluate multi-temporal changes. These changes can be examined for evidence of climate change. In order to produce a data record that extends long enough for climate change studies, measurements from different satellites must be intercalibrated with each other and then combined together into a single record.

The potential of remote sensing to provide independent, timely and reliable data on land use and cropping at a high level of spatial disaggregation has been recognized for over two decades. Satellite based crop estimations have been carried out for major food grains. Sugarcane is one of the important commercial crops in the tropics and sub-tropics and is the main source of sugar in world. India is one of the leading countries in sugarcane cultivation and Indian sugar industry, second largest after the textiles industry, has been playing a vital role in the socio-economic transformation of the country. About 50 million sugarcane farmers and their dependants have been involved in sugarcane cultivation. There is an urgent need to develop techniques, which are sustainable from environmental, production and socio-economic points of view. In this study, we discuss some basic climate results obtained using Remote Sensing data, and discuss some climate related research we have performed and assess the impact of climate variability on the sugarcane crop production.

2. MATERIALS AND METHODOLOGY

2.1 DATA COLLECTION

Various climatic parameters have been considered like rainfall, temperature, solar radiation, humidity, soil moisture. The data is been collected from multiple sources like TRMM and NCEP Reanalysis. Data for the sugarcane yield have been manually collected from Dept of Economics and Statistics, Krushi ilakhe Bangalore. Also ground truth is been collected from areas surrounding Mudhol Taluk, Bagalkot shown in Figure 1.

Data sets used for analysis were from the following
*TRMM (Tropical Rainfall Measuring Mission) from National Aeronautics and Space Administration (NASA)
*NCEP/NCAR Reanalysis (National Centers for Environmental Prediction and National Centre for Atmospheric Research)
*Earth System Research Laboratory (ESRL) *National Oceanic & Atmospheric Administration (NOAA)

Data is in netCDF format is extracted and Processed using GrADS. Data extracted to regional scale for the different time scales. This data is summarized and stored for analyzing the changes
and calculate the trends and anomaly for the different climate parameters.

MOD13C2.005 MODIS/Terra Vegetation Indices Monthly L3 Global 0.05Deg CMG is been used to get the NDVI data for the specific region and to analyze the sugarcane growth profile and relate with the drought years.

Figure 1. GPS Locations of the fields in study area.

2.2 STUDY AREA

The district of Bagalkot is situated entirely on the North Karnataka Plateau which is part of the larger Deccan Plateau shown in Figure 2. Located in north central Karnataka, it is positioned at 16°12′N 75°45′E and covers an area of 6593 km². Bagalkot district has six taluks — Bagalkot, Badami, Hungund, Mudhol, Jamkhandi and Bilgi.

The average elevation in this area reaches approx 610 m. The climate is warm and dry throughout the year and rainfall is scarce. Bagalkot is devoid of large canopy tree vegetation , the region is semi arid. The Rivers Krishna, Ghataprabha and Malaprabha flow through the region but are non perennial.

Soil in the area can be categorized as either the majority black or minority red. Black soil retains moisture and is often used for the cultivation of cotton. Rabi and jowar are primarily cultivated in Bagalkot, as are groundnut, cotton, maize, bajra, wheat, sugarcane and tobacco. Common rock type in the region include greenstone, quartzite, sandstone and limestone.

The dry climate makes the region susceptible to drought and crop failure. Bagalkot district has an area of 6593 sq.km. and a total Population of 1.65 million. The average rainfall in the district is 562 mm, receives 40% of the total rainfall in the south west monsoon period from June to September.

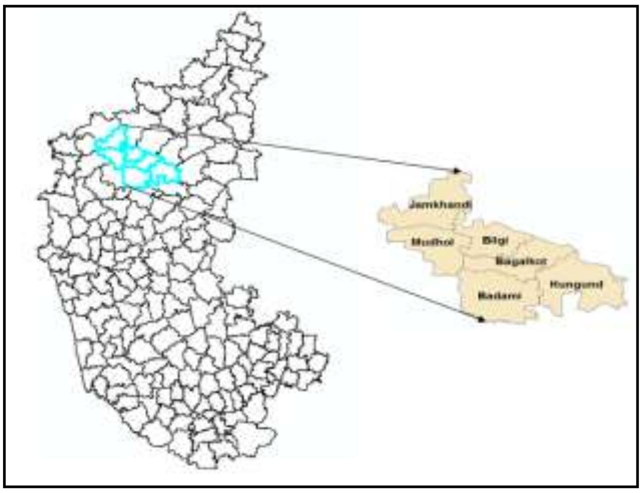

Figure 2. Location of the study area State of Karnataka, India.

3. METHODOLOGY

Collected data is categorized and prepared according to the goal of the study. Climatic data – Rainfall, Temperature, Solar-Radiation, Soil-moisture, Humidity data is collected from the satellite images. Using GrADS the data specific to the study area i.e., Bagalkot is extracted specifically to the time period required for the study. Finally data extracted is processed to calculate the trends and anomaly for the various parameters and individually correlated with sugarcane yield.

3.1 EXTRACTION OF REGIONAL DATA FROM GLOBAL DATA.

The extracted data from the various Big data files are stored in files for analysis as shown in the Figure 3.

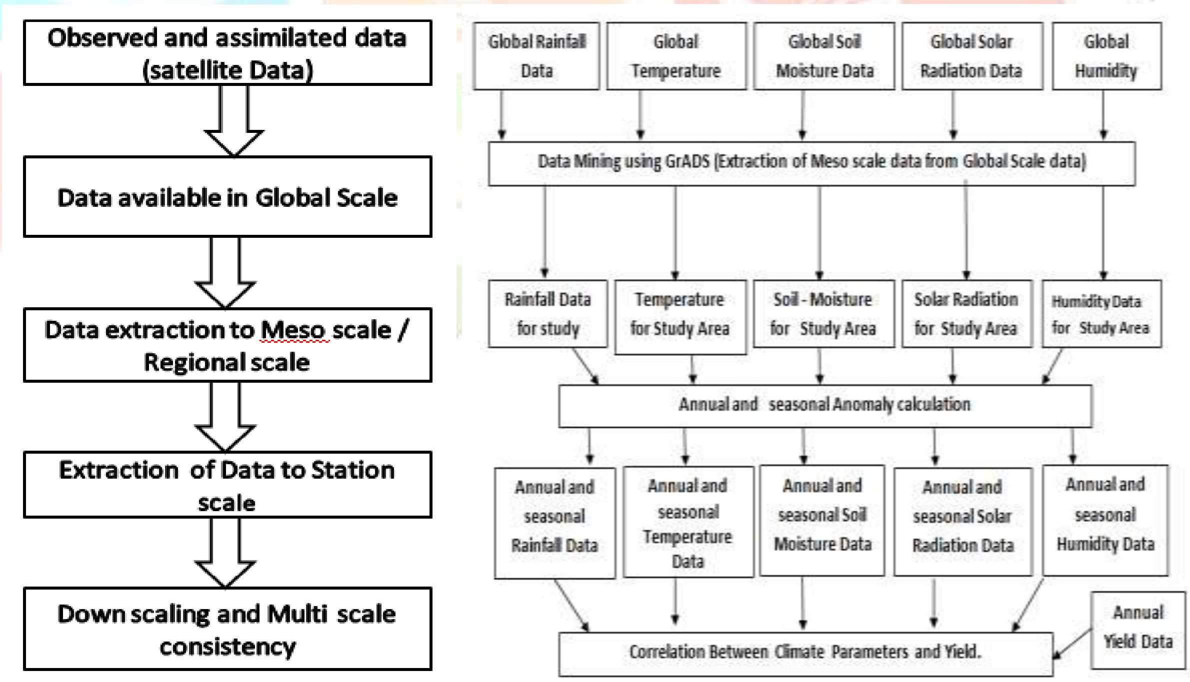

Figure 3. Extraction of Station Data from Global Data and Data Flow Diagram showing the Correlation analysis of climate and sugarcane crop parameters.

Extraction of the station-scale data from the global-scale (netCDF files) is done using GrADS. Then the monthly and yearly average values is calculated. The data can be understood through the trends and the equations obtained.

3.2 ALGORITHMS OF CLIMATOLOGY

As the study involves multi-source data and they have inherent bias against the real observation, it is often useful to consider the parameter anomaly (from model mean) rather than parameter itself, to mitigate the bias.

The anomaly is generally computed as shown below.

$$R_a(i, j, n) = \frac{R(i, j, n) - \overline{R}(i, j)}{R(i, j)} \times 100$$

Where n = time period in years mean at location (i, j) at given time scale. Similarly the above procedure is repeated for all the climatic parameters. The above process is repeated for the 5 climatic parameters for climatology analysis (obtain yearly trends) to view the change and the trend pattern.

3.3 Correlation Study of Climatic Parameter and Sugarcane Yield

To quantify the impact of weather and climate parameters on the sugarcane crop yield over Bagalkot, the correlation analysis is done and presented in this section. The process of the extraction, analysis and comparison of various climatic parameters from multiple sources and their correlation with the yield is presented. Data Flow Diagram showing the Climatology analysis is illustrated here in the Figure 3.

4. RESULTS AND DISCUSSIONS

The climate variability over Bagalkot has been studied by considering multi-source data. Here we considered mainly rainfall, temperature, solar radiation, humidity and soil moisture as these parameters mainly affects the sugarcane growth and total yield. For the climate analysis over Bagalkot very high resolution data are being used. This section presents the trend and climate analysis of weather parameters

1. Analysis of Temperature.

The Annual Temperature analysis for the last 14 years (2000-2013) over the Bagalkot is presented in following Figure 5.

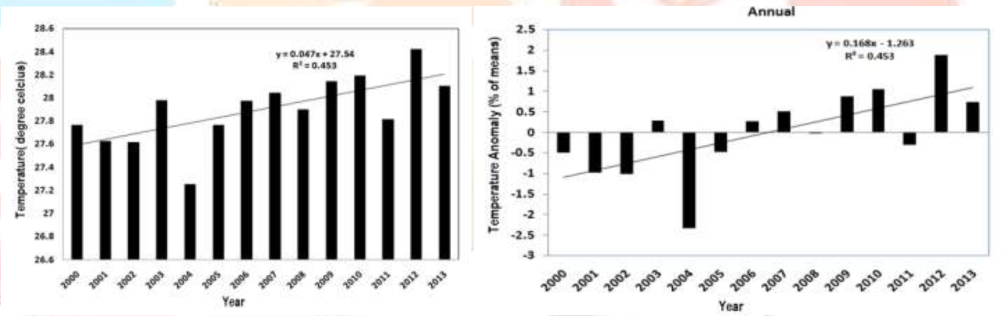

Figure 5. Temperature Trend patterns and Anomaly Analysis

It is found the overall average trend is about (0.047 degree/yr). The Annual Temperature anomaly is computed and presented above.

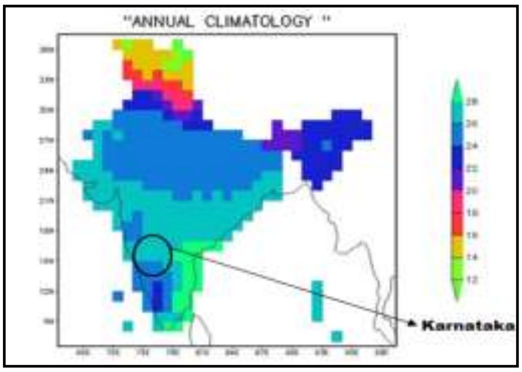

Figure 6. The Annual Temperature climatology (0C) over Karnataka and Bagalkot.

The annual Temperature anomaly trend shows an overall increasing trend (0.168 degree/yr) indicating there is a overall increase in the annual temperature. Figure 6 shows the Annual Temperature climatology (0C) over Karnataka and Bagalkot.

2. Analysis of Rainfall.

The annual rainfall analysis for the last 14 years (2000-2013) over the Bagalkot using TRMM data is carried out. The rainfall anomaly and trend is computed and shown in the Figure 7.

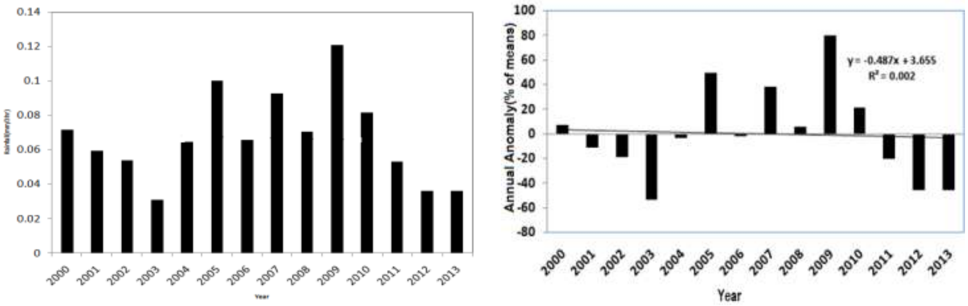

Figure 7. Rainfall Trend patterns and Anomaly Analysis

The annual rainfall anomaly trend shows an overall decrease in annual rainfall. It shows the recent years i.e. 2011, 2012 and 2013 continuously shows negative anomaly (deficit) which is a bad signal for the agriculture as well as other sectors. Figure 8 shows the annual rainfall climatology over Karnataka.

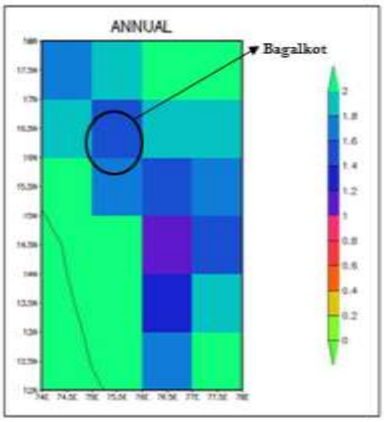

Figure 8. The Annual rainfall climatology (mm/day) over Karnataka and Bagalkot

3. Analysis of Solar Radiation.

The Annual solar radiation analysis for the last 14 years (2000-2013) over the Bagalkot is presented in the Figure 9.
The annual Solar radiation trend shows an overall increase in trend (0.604 W/m^2). The annual solar radiation anomaly trend is (0. 502 W/m^2) indicating there is an overall increase in the annual solar radiation. The Figure 10 shows the solar radiation over the globe and Bagalkot respectively. This dataset is extracted using netCDF files which is reanalysis data (satellite data) that is later processed using GrADS.

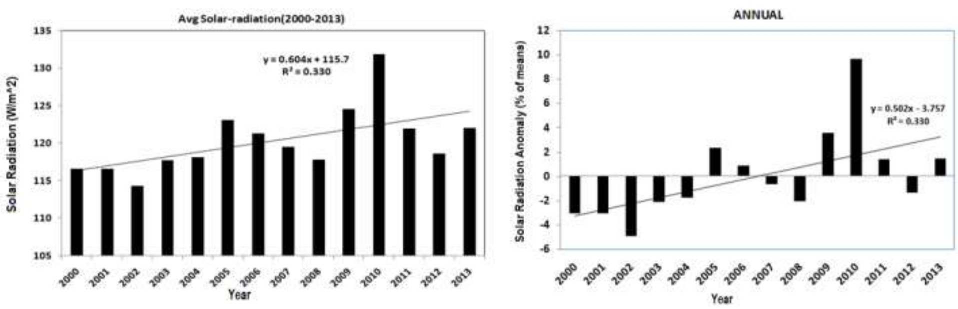

Figure 9. Solar radiation Trend patterns and Anomaly Analysis

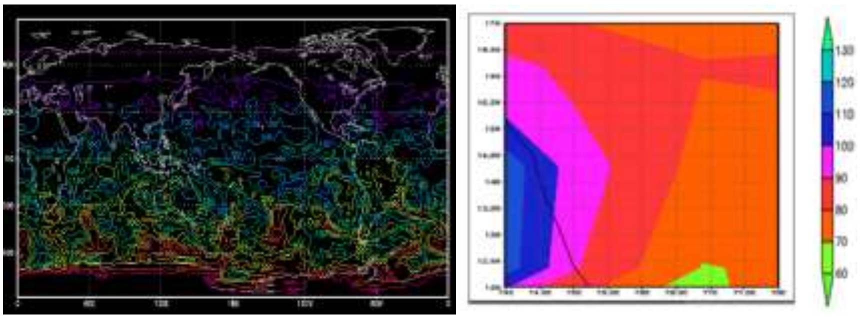

Figure 10. Daily Solar Radiation.

4. Analysis of Soil Moisture.

The Annual Soil Moisture analysis for the last 14 years (2000-2013) over the Bagalkot is presented in following Figure 11.

The annual soil moisture anomaly trend as indicated shows decreasing trend. Figure 12 shows the Annual Soil Moisture over the globe and Bagalkot respectively. This dataset is extracted using netCDF files which is reanalysis data (satellite data) that is later processed using GrADS environment.

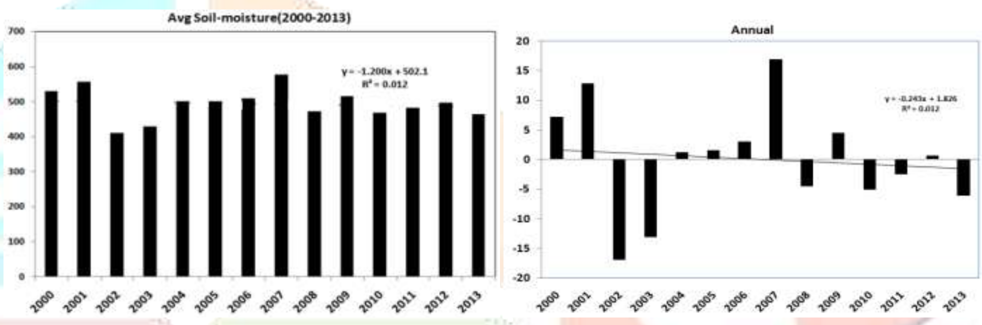

Figure 11. Soil Moisture Trend patterns and Anomaly Analysis

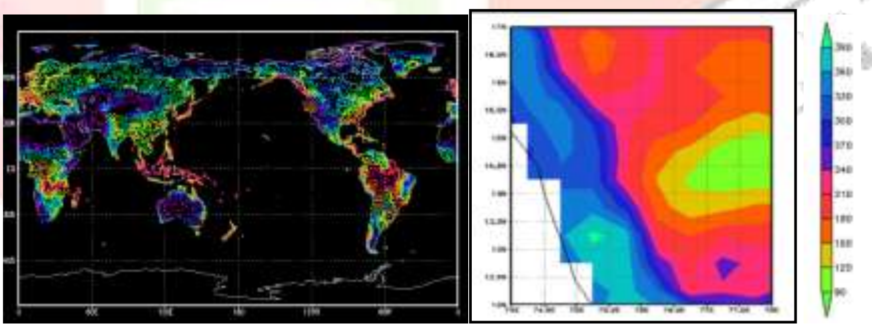

Figure 12. Annual Soil Moisture

5. Analysis of Humidity.

The graph for the Annual Trend and Annual Anomaly is shown in the Figure 13 indicating the overall increase in the humidity over the years. Among the 14 years 2010, 2011 and 2013 humidity was more than 70% that is clearly shown in the Anomaly.

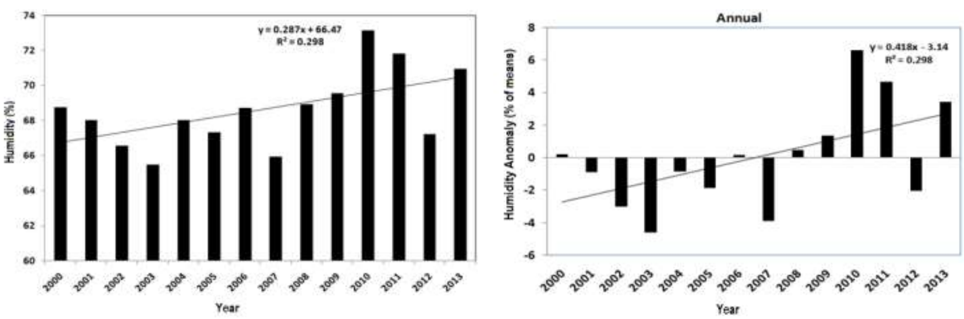

Figure 13. Humidity Trend patterns and Anomaly Analysis

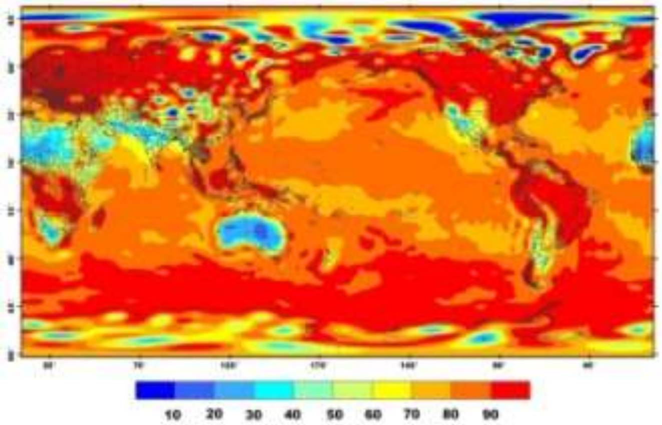

Figure 14. Daily Humidity Using ArcGIS

Figure 14 shows the Daily Humidity over the globe using ArcGIS software. This dataset is extracted using netCDF files which is reanalysis data (satellite data) that is later processed using GrADS environment.

6. Correlation between the climatic parameters and sugarcane crop yield.

Climatic analysis in the above section helps to relate the parameters with the yield. The Climatic factors that are temperature, rainfall, solar radiation, soil moisture, humidity when correlated with the yield as shown in the Figure 15 using the following relation.

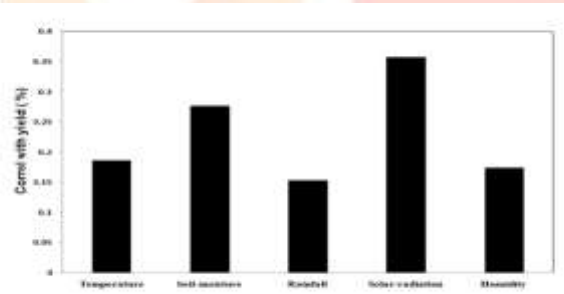

Figure 15. Graph showing correlation of Climatic factors with yield in percentage (%).

This analysis is used to form the following Relation expression Where Y=Sugarcane Yield (T/Ha), T = Temperature (0C), Sm = Soil Moisture (fraction),
R = Rainfall (mm) and H = Humidity (%).

Correl(Y, T) = 0.18,
Correl(Y, Sm) = 0.27,
Correl(Y, R) = 0.15,
Correl(Y, Sr) = 0.35,
Correl(Y, H) = 0.17

The analysis results convey that the Sugarcane yield is very much influenced by the solar radiation as it is the major factor for the generation of carbohydrates. Then the soil moisture that is very much needed for the cane growth. Rain and temperature are also factors influencing the growth of cane.

7. Normalized Difference Vegetation Index.

The Normalized Difference Vegetation Index (NDVI) is a simple transformation of the difference in reflectance in the Near-Infrared (NIR) and Red(R) normalized over the Sum of Reflectance in the NIR plus Red. It has good relationship with many biometric parameters of plants (crops, forest etc).

The NDVI is calculated from these individual measurements as follows:

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$

Where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively

7.1 NDVI Analysis for the sugarcane crop over the period of 14 years.

NDVI Values for the years have been extracted from the MODIS data. The plot has been done for all the 14 years to observe the growth profile of sugarcane crop over the crop growing season (May of previous year to April of the succeeding year). The growth profile of sugarcane crop over the crop growing season is shown below in Figure 16

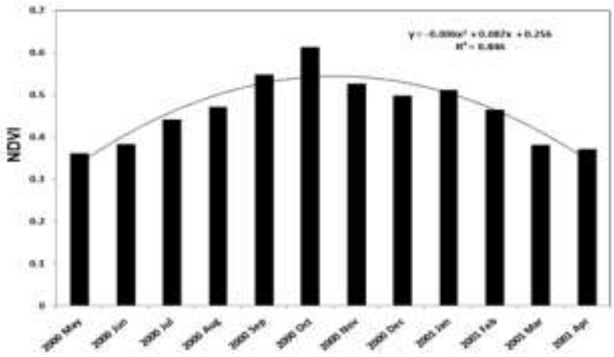

Figure 16. Growth profile of sugarcane crop.

Assuming that the growth cycle of sugarcane crop takes about 365 days, the Grand Growth Phase (GGP) of the sugarcane crop starts 120 days after planting and ends 270 days after planting, the NDVI for the GGP was generated from MODIS data for the period September to February (150 days). This NDVI integrated over the GGP was correlated with the sugarcane yield.
Table 1 shows the NDVI values and the sugarcane yield over the years using the Equation

$$\sum NDVI\ GGP = \sum NDVI\ (Sep, Oct, Nov, Dec, Jan, Feb)$$

YEAR	∑NDVI GGP	Yield (T/Ha)
2000	3.161	120
2001	3.154	119
2002	3.075	97
2003	2.916	94
2004	3.09	77
2005	3.225	103
2006	3.476	96
2007	3.302	92
2008	3.29	93
2009	3.489	109
2010	3.434	108
2011	3.334	104
2012	3.359	96

Table 1. Yield and NDVI Statistics over the Years

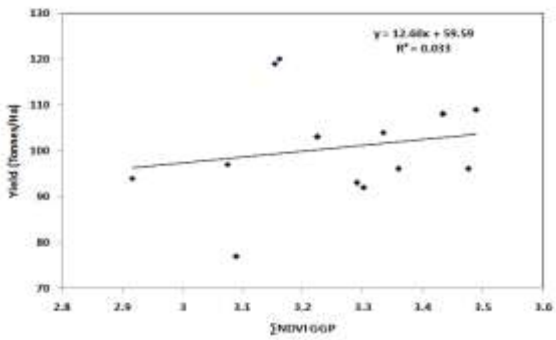

Figure 17. Plot showing the trend for ∑NDVI GGP and Yield.

The equation Y = a + bX can be used for Sugarcane Yield prediction.
Where Y is the Predicted Yield, a is the Y intercept, and b is the slope and X= ∑NDVI GGP. This equation can be used in prediction of yield if X can be determined. The Figure 17 shows a sample plot for the year 2000.

7.2 Impact of Climate Variability on Sugarcane NDVI Profile.

In continuation of rainfall variability analysis done using data from IMD and TRMM further analysis of yearly variability of the NDVI profiles was also carried out. And the results are presented in the Figure 18.
It may be seen that the impact of deficient rainfall in the year 2002-2003 is clearly reflected in the temporal profile of NDVI.

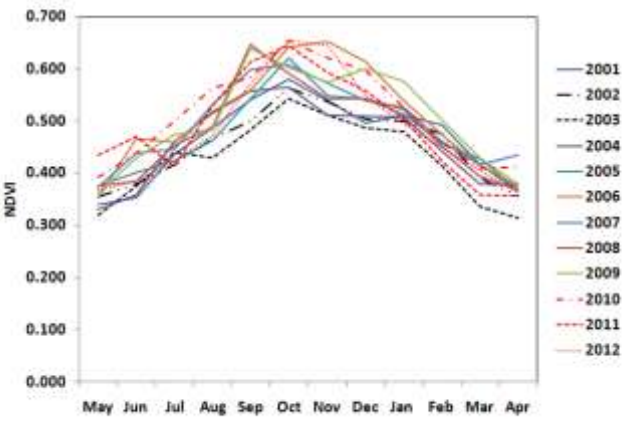

Figure 18. Sugarcane NDVI Growth profile (2001-2012)

4. CONCLUSION

The climate and land cover characteristics of Bagalkot have been studied using multi-source and multi-temporal data. Available global datasets on parameters such as Temperature, rainfall, soil moisture, Solar Radiation, Humidity and land cover have been used in the study and processed using ArcGIS and GrADS. The results obtained were compared to ground truth for validation.

The climatology of rainfall from 53 year IMD gridded data shows the annual rainfall is about 2mm/day and the monsoon average rainfall goes up to 4 mm/day over Bagalkot. The rainfall trend for annual as well as monsoon season are computed annual rainf all trend shows an overall decreasing trend (-0.097mm/yr) and in monsoon the trend is increasing (0.515mm/yr), indicating there is a overall decrease in the annual and increase in monsoon rainfall.

The study of temperature variation shows the annual temperature anomaly trend is (0.033 degree/yr), in monsoon the trend is increasing (0.031 degree/yr), and in summer the trend is (0.006 degree/yr), indicating there is a overall increase in the Temperature.
The annual and seasonal Humidity analysis for the last 14 years (2000-2013) over the Bagalkot and annual Humidity trend shows an overall increasing trend (0.298%) indicating there is an overall increase in the annual humidity. The soil moisture annual anomaly trend is (-0.243 fraction) indicating there is an overall decrease in the annual soil moisture. The solar radiation annual anomaly trend is (0. 502 W/m^2) indicating there is an overall increase in the annual solar radiation.

Climatic analysis in the above section helps to relate the parameters with the yield. The Climatic factors that is temperature, rainfall, solar radiation, soil moisture, humidity when correlated with the yield the following relation was obtained. The analysis results convey that the Sugarcane yield is very much influenced by the solar radiation as it is the major factor for the generation of carbohydrates. Then the soil moisture that is very much needed for the cane growth. Rain and temperature are also factors influencing the growth of cane.

NDVI Analysis for the sugarcane crop over the period of 14 years was carried out. NDVI Values for the years have been extracted from the MODIS data. The plot has been done for all the 14 years to observe the growth profile of sugarcane crop over the crop growing season (May of previous year to April of the succeeding year). This NDVI integrated over the GGP was correlated with the sugarcane yield (∑NDVI GGP = ∑ NDVI (Sep, Oct, Nov, Dec, Jan, Feb). The equation $Y = a + bX$ can be used for Sugarcane Yield prediction provided X is determined. And the study gives a strong relationship between NDVI and Yield over Bagalkot.

In continuation of rainfall variability analysis done using data from IMD and TRMM further analysis of yearly variability of the NDVI profiles was also carried out. It may be seen that the impact of deficient rainfall in the year 2002-2003 is clearly reflected in the temporal profile of NDVI. Although the rainfall was deficient in the years 2012 and 2013, the NDVI profiles appeared normal, may be the farmers were able to manage the deficient rainfall through improved irrigation water management.

This study shows that it is possible to study climate and land cover characteristics and changes using multi source and multi-temporal data acquired by remote sensing and other means and processing them through GIS software for the better understanding of the multi-scale processes associated with weather and climate.

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