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Research Paper

Prediction of Sugarcane Crop Yield Using Spectral Yield Model of Lau and Donga Fadama Areas of Taraba State, North East Nigeria

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ABSTRACT
This study focuses on Sugarcane Yield Estimation for Taraba state. Yield estimation was done Making use of empirical model which directly relates the crop yield to the derived vegetation indices of NDVI from the Landsat multi-spectral satellite data used in this study. Field data for sugarcane was gathered at the sixth month of growth. This sixth month of growth is the stage of maturity and senescence. For each plot, the whole sugarcane was harvested both the dry and fresh weight of the sugarcane was weighted and recorded in Kg. It is worthwhile to know that generally, the relationship between the NDVI values and yield is that an increase in NDVI values indicates higher yield. Therefore, there was a strong relationship between yield and NDVI for both plantations after successfully performing regression analysis of yield on NDVI values for both plantations. The correlation was a strong (r^2 = 0.779 and 0.724) for Lau plantation and Donga Plantation respectively as shown in the Regression Model Summary Table. Therefore considering that mean r^2 of both models being 0.757, NDVI shows a strong positive relation to Yield. This study indicates that use of geospatial techniques can actually be a vital tool in yield estimations of vegetations.
KEYWORDS: *NDVI, LANDSAT, MULTI-SPECTRAL, EMPRICAL MODEL*

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I. INTRODUCTION

Earlier estimation of sugar cane yield is a vital element for sugar industry. Many operations of sugar production are based on yield estimation, such as planning for the season management including manpower, transportation, storage, marketing ...etc. The direct ground field estimation has low precision and feasibility due to the wide areas of the sugarcane fields (50-100 hectares), difficult accessibility especially during the rainy season, the height of the plants (1.5-2.00 m), high cost of transportation together with the limitations of human`s eyes. Baghdadi, et al 2018

Jeferson et al 2011 evaluated the feasibility to estimate the yield at municipality level in São Paulo State, Brazil, using 10-day periods of SPOT Vegetation NDVI images and ECMWF meteorological data. Twenty municipalities and seven cropping seasons were selected between 1999 and 2006. The plant development cycle was divided into four phases, according to the sugarcane physiology, obtaining spectral and meteorological attributes for each phase. The most important attributes were selected and the average yield was classified according to a decision tree.

Muhammad et al 2016 quantified sugarcane production as critical for a wide range of applications, including crop management and decision making processes such as harvesting, storage, and forward selling.

Estimating sugarcane biomass is difficult to achieve when working with highly variable spatial distributions of growing conditions, like on Reunion Island. Which used a dataset of in-farm fields with contrasted climatic conditions and farming practices to compare three methods of yield estimation based on remote sensing: (1) an empirical relationship method with a growing season-integrated Normalized Difference Vegetation Index NDVI, (2) the Kumar-Monteith efficiency model, and (3) a forced-coupling method with a

sugarcane crop model (MOSICAS) and satellite-derived fraction of absorbed photosynthetically active radiation Julien et al July2014

Earlier estimation of sugarcane yield is a main requirement for sugar production. Many operations of sugar production are based on yield estimation, such as planning for the season management including manpower, transportation, storage, marketing Abdelrahim et al 2018

Robson et al 2012 discussed the accuracies of remote sensing and GIS as yield prediction tools at both a regional and crop scale over three Australian cane growing regions; Bundaberg, Burdekin and the Herbert.

Raham et al states that Sugarcane yield prediction is critical for in season crop management and decision making processes such as harvest scheduling, storage and milling, and forward Selling.

For the purpose of this study, estimating the yield of sugarcane for some selected years was researched on extensively. Mapping was done in the two plantations namely Donga and Lau which serves as a basis in predicting yield yearly and also determining some certain issues related to sugarcane yield as years goes by.

Sugarcane in parts of Taraba takes 6-7 months to mature, Donga and Lau were used because they both plantations have unique agricultural practices in various fields, which aided comparism, while Lau uses rainfall and irrigation as well as fertilizer, Donga uses majorly rainfall.

.The information gathered will allow users (students, farmers, academicians) mainly those in Taraba state to solve issues such as disaster management through timely intervention, assist in precision agriculture, disaster control and pest invasion. The study covers two areas Donga and Lau. Data that covers 15 years was used. The study made use of Landsat Time series on two different software namely Erdas and Arc Gis. It attempts to develop a localized Comprehension of the issues of Yield estimation using Geospatial techniques. Different theories were applied as validation checks in this Research, but the main aim is to get the attention of farmers, government researchers and students

II. MATERIALS AND METHODS

Crop yield estimation in many countries are based on conventional techniques of data collection for crop and yield estimation based on ground based field visits and reports. Such reports are often subjective costly, time consuming and are prone to large errors due to incomplete ground, observations, leading to poor crop yield assessment and crop area estimations (Reynolds et al 2000)

Geospatial techniques were applied in data processing. The results were displayed subsequently

2.1 STUDY AREA

The area monitored by this Research is Donga in Southern Taraba and Lau in Northern Taraba both in North-East geo political zone of Nigeria. Donga and Lau are one of the largest producers of sugarcane (Saccharum officinarum) in Nigeria. While Lau is dominated by the Hausa-Fulanis, the people resident in Donga are predominantly farmers and business men.

2.2 METHODOLOGY

An empirical model which directly relates the crop yield to the derived vegetation indices of NDVI from the Landsat multi-spectral satellite data used in this study was used to carry out yield estimation. In this procedure the NDVI at 1 week before the time of harvest of the sugarcane is related to the weight through regression technique. Ten numbers of 30m x 30m plots in the Donga and Lau Plantation study fields were stratified on the basis of age of sugarcane planted to obtain accurate estimates. Fields nearer to the River Donga which have nearly similar soil types and drainage density were used. This was intended to minimize variability that would otherwise be caused by varied topography, soil and drainage.

Field data was collected for sugarcane at the sixth month of growth which is the stage of maturity and senescence. For each plot, the whole sugarcane was harvested and the weight of the sugarcane was weighted and recorded in Kg.

Hand held Global Positioning System (GPS) reading was obtained at the center of each sampling plot to establish plot locations in the Plantation. The geographic location of each sample site was recorded within a positional accuracy of 5 m.

The NDVI values for each plot were interpolated using a nearest neighbor resampling approach and the data were output to a 30 x 30 m pixel size.

The linear regression based model was developed with crop yield (y) as dependent variable and one independent variable, namely NDVI (x_1). The model was developed using April 2018

III. RESULTS AND DISCUSSION

Yield Estimation for Donga Plantation between 2003 and 2018

Table 1.0 show the tabulation of the weight of sugarcane and the mean NDVI of the plots where they were harvested. Most often the relationship between the NDVI values and yield was that an increase in NDVI values signifies higher yield. For example, for Lau plantation, Plot 4 had the lowest NDVI value and also had the lowest yield while Plot 3 had both the highest NDVI and yield. For Donga plantation, Plot 6 had the lowest NDVI value and the lowest yield while Plot 8 had both the highest NDVI value and yield estimate.

Table 1.0 Tabulation of Weighted Sugarcane versus NDVI values in 2018

	LAU PLANTATION			DONGA PLANTATION		
Location	NDVI Value	Field Weight ($Kg/900m^2$)	Conversion to (tonne/ha)	NDVI Value	($Kg/900m^2$)	tonne/ha
Plot 1	1.89	536.75	6.57	1.89	527.25	6.46
Plot 2	1.99	551	6.75	1.72	498.75	6.11
Plot 3	2.02	617.5	7.56	1.84	503.5	6.17
Plot 4	1.42	427.5	5.24	1.85	522.5	6.40
Plot 5	1.82	494	6.05	1.7	484.5	5.93
Plot 6	1.84	513	6.28	1.53	451.25	5.53
Plot 7	1.85	541.5	6.63	1.64	446.5	5.47
Plot 8	1.76	532	6.52	1.89	551	6.75
Plot 9	1.71	503.5	6.17	1.71	517.75	6.34
Plot 10	1.95	532	6.52	1.82	494	6.05

LAU PLANTATION DATA PLOTS

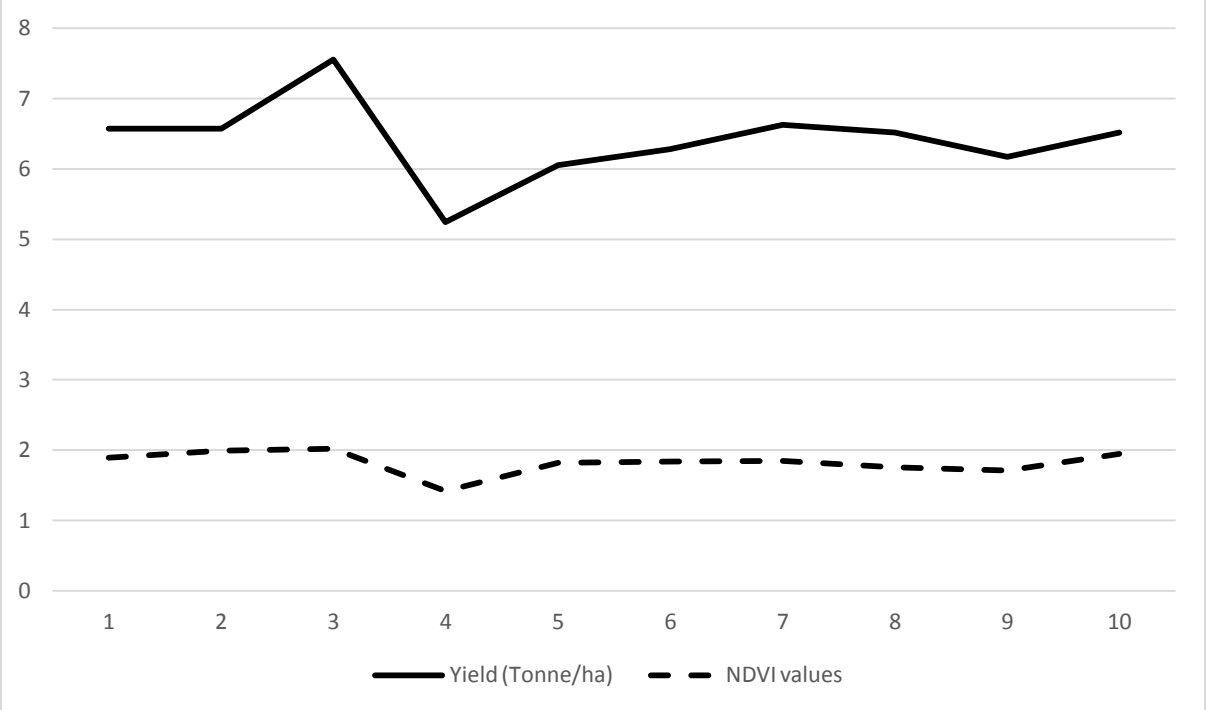


Figure 1.0: Trend plot of the NDVI and Yield values for Lau plantation

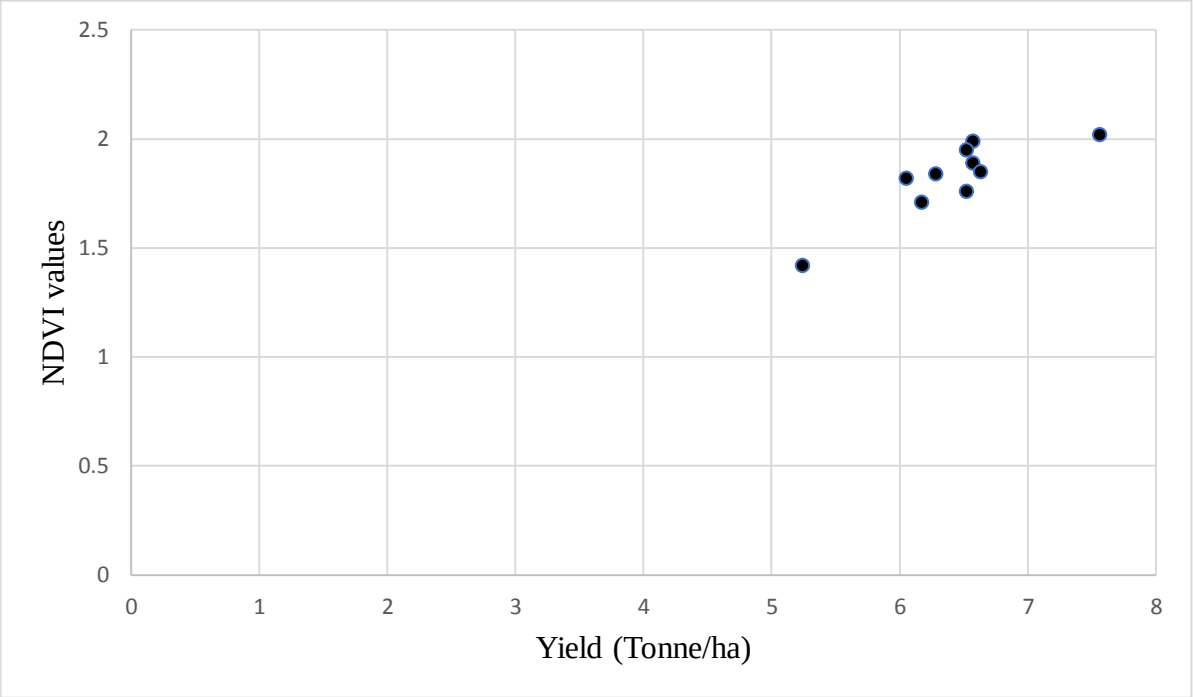


Figure 1.1: Scatter-plot for NDVI versus Yield values for Lau plantation

DONGA PLANTATION

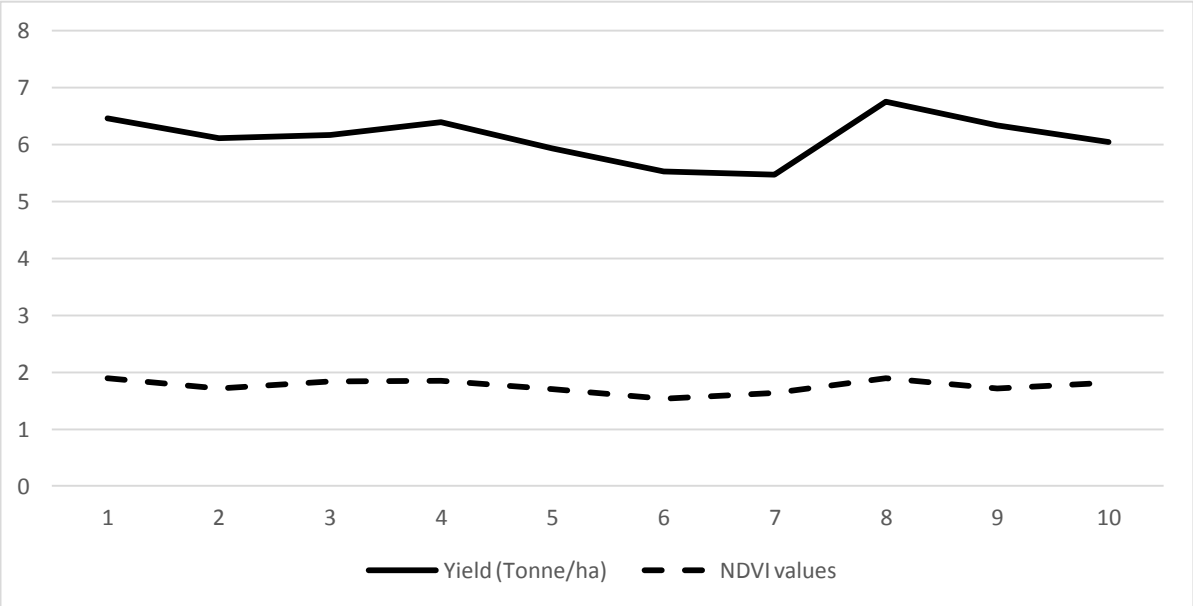


Figure 1.2: Trend plot of the NDVI and Yield values for Donga plantation

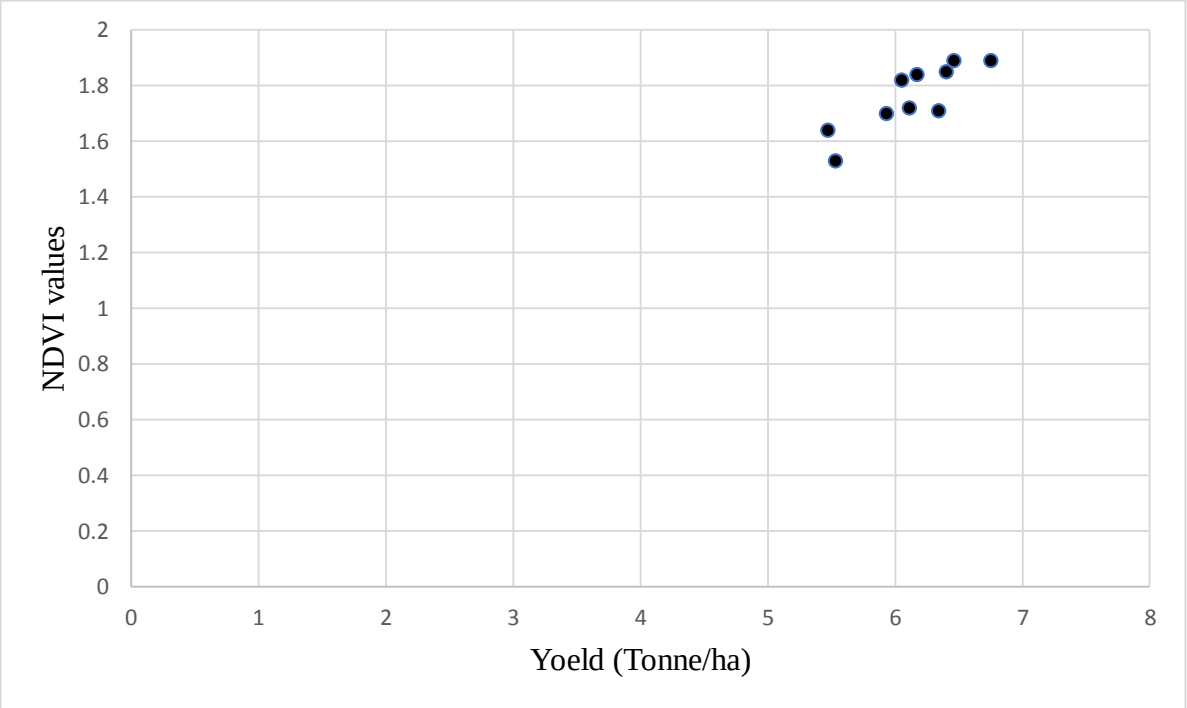


Figure 1.3: Scatter-plot for NDVI versus Yield values for Donga plantation

There was a strong relationship between yield and NDVI for both plantations after successfully performing regression analysis of yield on NDVI values for both plantations. The correlation was a strong (r2 = 0.779 and 0.724) for Lau plantation and Donga Plantation respectively as shown in the Regression Model Summary Table (Table 4.7). Therefore considering that mean r2 of both models being 0.757, NDVI shows a strong positive relation to Yield.

Table 1.1 Linear Regression Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Lau	0.883	0.779	0.752	23.96974
Donga	0.851	0.724	0.689	18.28860

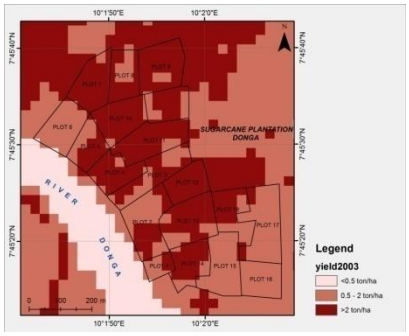
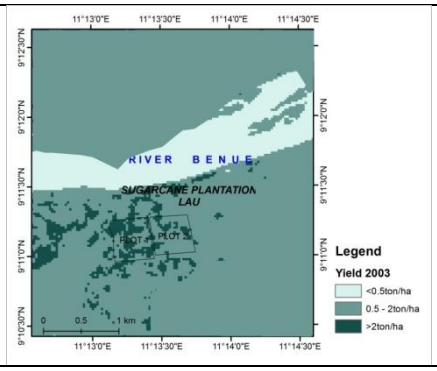
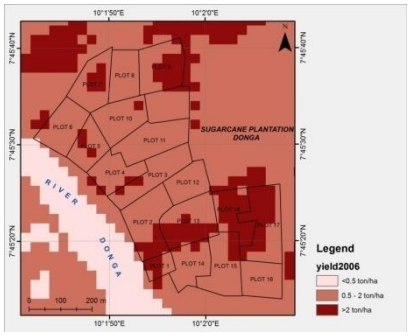
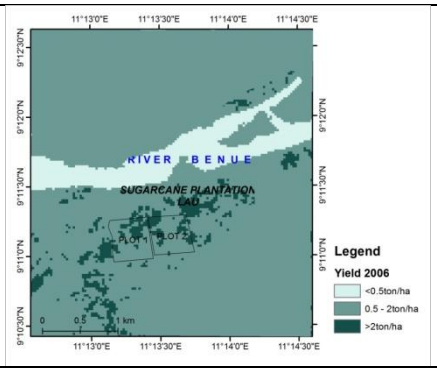
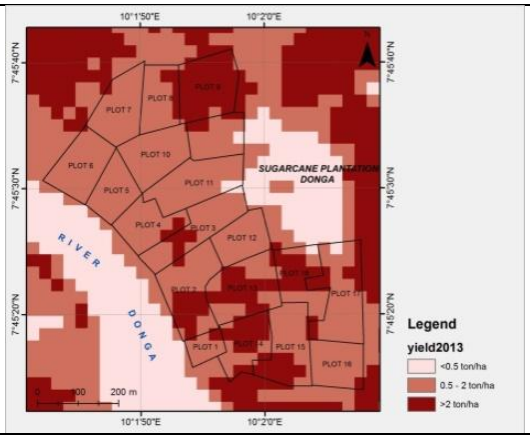
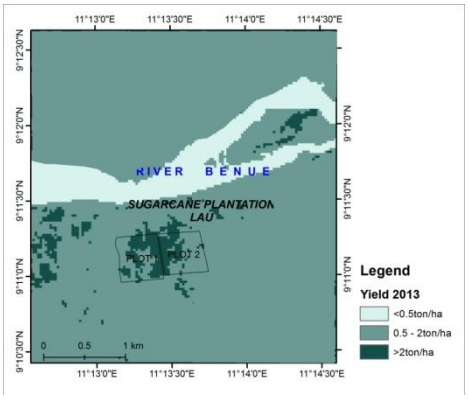
Table 1.2 show the Coefficients derived from the regression analysis from the two plantations namely, Lau and Donga. The absolute value in terms of unstandardized regression coefficient represented by the variable NDVI shows a positive beta values of 235.160 and 246.247 and hence a strong statistical relation to yield. The model is significant at 5% level of significance which implies that the model can be used for estimation.

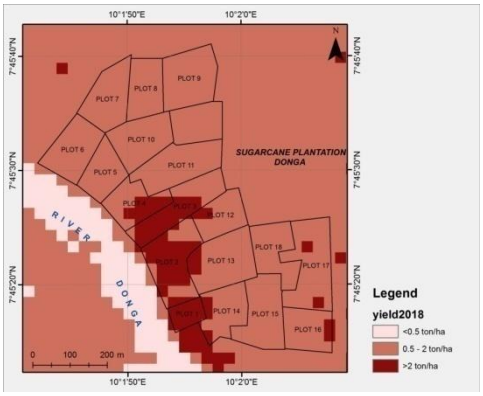
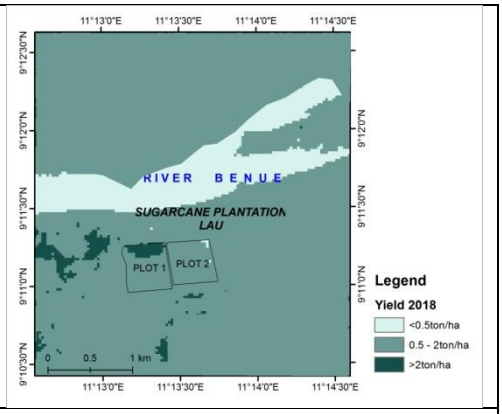
Table 1.2 **Coefficientsof Regression Analysis**

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
1(Constant)	86.053	90.494		.951	.369
NDVI_Donga	235.160	51.341	.851	4.580	.002
2(Constant)	75.474	84.926		.889	.400
NDVI_lau	246.247	46.349	.883	5.313	.001

Here, we conclude from the performance of the regression model that NDVI has an explanatory power on yield i.e. it can predict sugarcane yield. Following this, the following yield quantification model was developed for estimating yield using the parameters computed by taking the average of the two models. The model developed for quantifying biomass yield in t/ha for a sugar cane crop at harvest stage was derived as;

YIELD (kg/900m^2)= 80.76 + 240.70 NDVI + U
YIELD (ton/ha) = 0.0122479035 * (80.76 + 240.70 NDVI +U)
Where U are other factors not included in the model and are thought to behave in a random manner.
The Raster Calculator tool of ArcGIS 10.3 Spatial Analyst Toolbox was used to develop the model and was run on 2003, 2006, 2013 and 2018 images of Lau and Donga Plantation. The map given in the Figure4.13a and 4.13b are the yield quantification map for Donga and Lau Plantations and surrounding areas showing three levels of production; high, medium and sparse areas without sugarcane crop.

	DONGA	LAU
2003		
2006		
2013		

2018		

Map Statistics generated from the map were used to generate the trend of yield in both plantations from 2003 to 2006. Table 4.9 shows a tabulation of yield in the study years while Figure1.4 shows the trend of increase/decrease across the study years.

Table 1.3 Tabulation of yield in Lau and Donga Plantation for 2003, 2006, 2013 and 2018

Year	Donga Yield (ton/ha)	Lau Yield (ton/ha)
2003	5624.18	1172.63
2006	5830.66	1722.37
2013	6922.49	2015.18
2018	5367.98	2181.29

From 2003, when the analysis was started, the average yield was 5624.18t/ha for Donga and 1172.63t/ha for Lau area. The sugarcane yield increased to 5830.66 and 1722.37 t/ha for Donga and Lau Plantation respectively in 2006. There was increase further to 6922.49t/ha and 2015.18t/ha in 2013 for both plantations of Donga and Lau respectively, however the decrease in yield between 2013 and 2018 for Donga Plantation can be mainly explained by the incidence of abnormal nature of the cropping season and poor management practices considering a change in weather conditions. The continued increase in yield in the Lau plantation area can be explained by the intervention of Taraba state government in the better cultivation of sugarcane within 2013 and 2018..

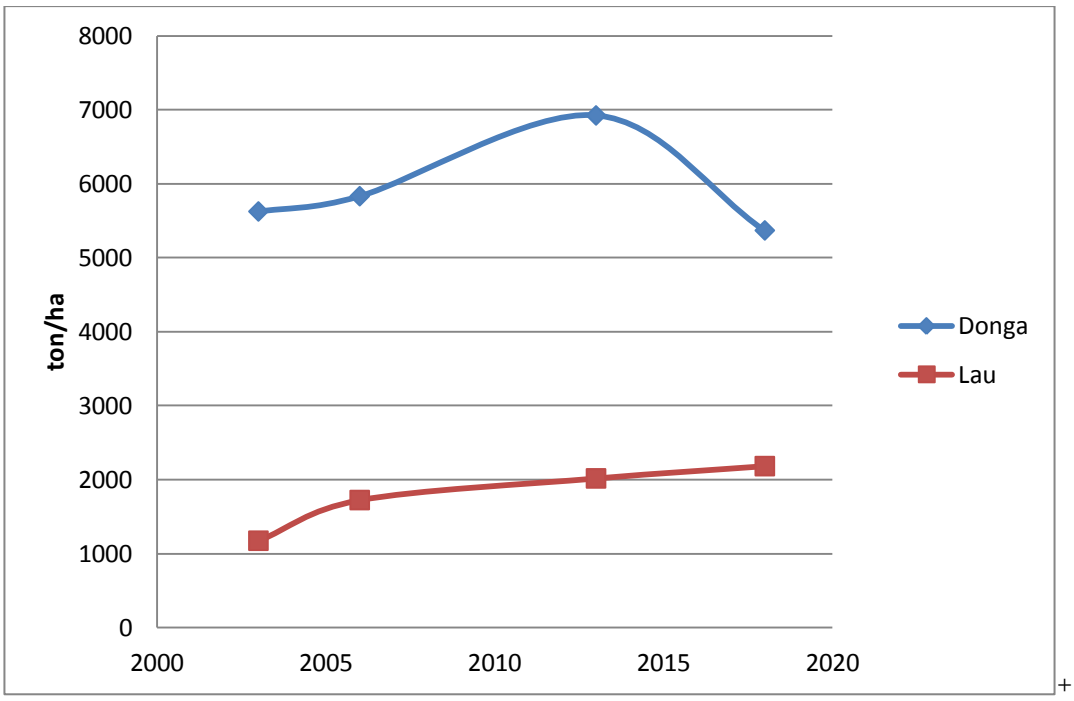


Figure 1.5: Trend of increase/decrease in Lau a

IV. CONCLUSION

During the field work, the plantations in Donga were found to be close to a river which supplied water while that of Lau used artificial irrigation as seen in the analysis. Finally for yield estimation 30x30 m was used while 15 per bunch for sugarcane were collected. This schedule is very essential because it shows how geospatial techniques can be used efficiently in sugarcane farms in Taraba State.

It is advisable that every sugar cane plantation across the country should have proper yield assessment studied over time, output should be recorded and cause of damages noted. I believe that more sugar cane will be produced for industries and these will boast the economy of the country which will also be a source of revenue.

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