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Monitoring And Prediction Of Crop Yield In Anambra State, Nigeria Using Normalized Difference Vegetation Index

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ABSTRACT
The importance of food security in any society cannot be over emphasized, therefore balancing the inputs and outputs on a farm is fundamental to its success and profitability. With the increase in population index food production no longer keep up with population growth, thus creating a wide gap between the demand and supply of food. The study explored the potentials of using remote sensing and GIS in monitoring crop production and yield prediction in Anambra State. The Normalized Difference Vegetation Index was employed in determining the area of cultivated lands in the period of time that this study was focused and subsequently determining the change in the area of this cultivated land. The results showed that the Normalized Difference Vegetation Index was quite efficient for monitoring crop production as it was the major factor for both yield prediction and determination of the extent of cultivated land. From the yield prediction made it was observed that there might be a decline in the yield in the year 2016 for most of the crops apart from yam which was predicted to have a slight increase. Thus monitoring of crop production and early yield prediction should be carried out on an annual basis and predicting yield model should be developed. Data about agricultural production for each year should be collated, gazetted and hosted by the ministry of Agriculture for ease of access.
Keywords: GIS, Remote sensing, Agriculture, NDVI and Crops

1.0 INTRODUCTION

Nigeria is often cited as one of the largest oil exporting countries, never the less agriculture still remains the main employer of over 70 percent of the country's labour force and accounts for about 31 percent of the nation's Gross Domestic Product (GDP). Agriculture serves as a vehicle for diversifying the economy and enabling economic development. In various the literatures reviewed, agriculture was described as the most important economic sector in terms of its contribution to the GDP, after oil (Bakare, 2013; Enoma, 2010). The sector contributed about 41% of the country's Gross Domestic Product (GDP), employed about 65% of the total population and provided employment to about 80% of the rural population(Bakare, 2013; African Development Fund, 2005). Despite the contribution of agriculture to the Gross Domestic Product in Nigeria, food production has not been able to keep pace with population growth, (Abdulrahaman, 2013).

Agriculture was the key development in the rise of sedentary human civilization, whereby farming of domesticated species created food surpluses that nurtured the development of civilization. In the wake of

civilization, various methods have been employed to agricultural to improve outputs and ease labour. Geographic information system (GIS) is an emerging technology, that can collect, manage, analyze and visualize spatial data, with the development of geographical science, computer technology, remote sensing technology and information science. According to actual needs, GIS combines location and associated attribute information to analyze spatial patterns. Therefore, GIS is the ideal choice for management and analysis of spatial information pertaining to crop monitoring and yield prediction.
Early prediction of crop yield is important for planning and taking various policy decisions. Many countries use the conventional technique of data collection for crop monitoring and yield estimation based on ground-based visits and reports. These methods are subjective, very costly and time consuming. Empirical model have been developed using weather data, which is also associated with a number of problems due to the spatial distribution of weather stations. These models are complex in terms of data demand and manipulation resulting in information being available very late, usually after harvesting. Efforts are been done to improve the accuracy and timeliness of yield prediction methods. With the launching of satellites, satellite data is being used for crop monitoring and yield prediction and that is the reason GIS and remote sensing techniques are best employed in this crop production research.
Numerous studies have recognized that plant development; stress and yield capabilities are expressed in the spectral reflectance from crop canopies and could be quantified using spectral vegetation indices (Weigand and Richardson 1990). Vegetation indices (VI), such as the Normalized Difference Vegetation Index (NDVI), are typically a sum, difference or ratio of two or more spectral wavelengths. They are highly correlated with photosynthetic activity in non-wilted plant foliage and are good predictors of plant canopy biomass, vigor or stress (Tucker 1979). Vegetation monitoring using the red and near infrared SPOT VGT channels has been one of the most widely used indices. The Normalized Difference Vegetation Index (NDVI) correlates closely with green biomass and the leaf area index. Despite the spatial resolution of 1 km at nadir, there are many scientific publications documenting the usefulness of SPOT VGT data as a means of monitoring vegetation conditions on a near real-time basis (Philipson and Teng, 1988; Bullock, 1992; Quarmby et al., 1993).
Forecasting crop production yield well before harvest is crucial especially in regions characterized by climate uncertainties. This enables planners and decision makers to predict how much to import in case of shortfall or optionally, to export in case of surplus. It also enables governments to put in place strategic contingency plans for redistribution of food during times of famine. Therefore, monitoring of crop production and crop growth and early yield prediction are generally important

1.2 The Study locale

The study area is Anambra State, named after the Anambra River (Omambala). It is located between latitudes 5^0 40′N and 6^0 50′N, then longitudes $6^0$35′E and $7^0$25′E in the South-Eastern part of Nigeria (see fig. 1.1 and 1.2). Anambra has boundaries with Kogi State in the north, Imo State in the south, Delta State in the west, Enugu State in the east.
The climate of the state allows for favourable cultivation and extraction of agricultural and forest products such as Oil Palm, Maize, Rice, Yam, Cassava, and Fish. Anambra is rich in natural gas, crude oil, bauxite, ceramic and has an almost 100 percent arable soil. The indigenous ethnic group in Anambra state are the Igbo (98% of population) and a small population of Igala (2% of the population) who live in the North western part of the state. The State has a land mass of about 4,416sq km with 4,182,022 population. Several raw materials and agro-products are produced in various parts of the State. For example Cassava is widely grown in Orumba South Local Government, Yam in Anambra West and Rice in Anambra East.
Anambra State comprises of 21 Local Government Areas (LGAs) and four Agricultural Zones (AZs) - Aguata, Anambra, Awka and Onitsha. There are 6 blocks in Aguata AZ, 4 blocks in Anambra AZ, 5 blocks in Awka AZ and 6 blocks in Onitsha AZ. The climate is typically equatorial with two main seasons, the dry and the rainy seasons. The state experiences dry season from late October to early May and has at least six dry months in the year. The vegetation consists of rainforest. Other parts consist of wooden savannah and grasslands. The state is drained by five major rivers and their tributaries. These are the River Niger, Anambra River, Mamu/Ezu River, Idemili River and River Ulasi. In addition to these,

there are smaller perennial streams like the Oyi, Nkisi, and Obizi. In-land valley ponds and lake occur, with the Agulu Lake draining a collection of towns in the state. All crop producers in the four Agricultural zones forms the population of the study. Cassava (Ihiala), Maize (Aguata), Rice (Oyi), Yam (Orumba south), Potato (Ogbaru), Plantain/ Banana (Anambra west), Cocoyam (Idemili south), Oil palm fruit (Idemili north). Figure 1.1. Shows the map of the study area.

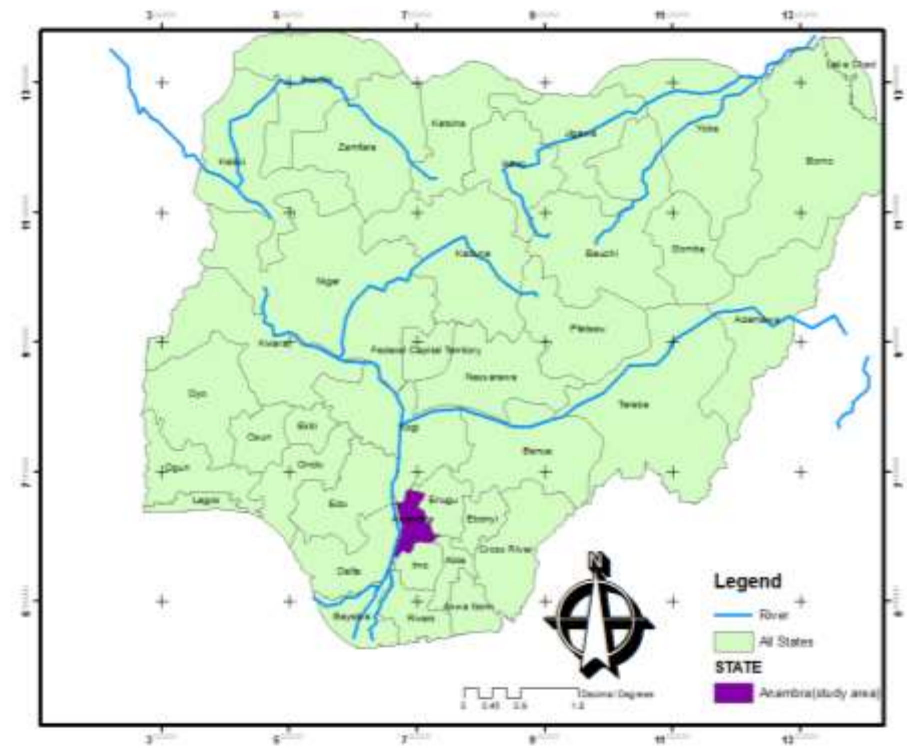
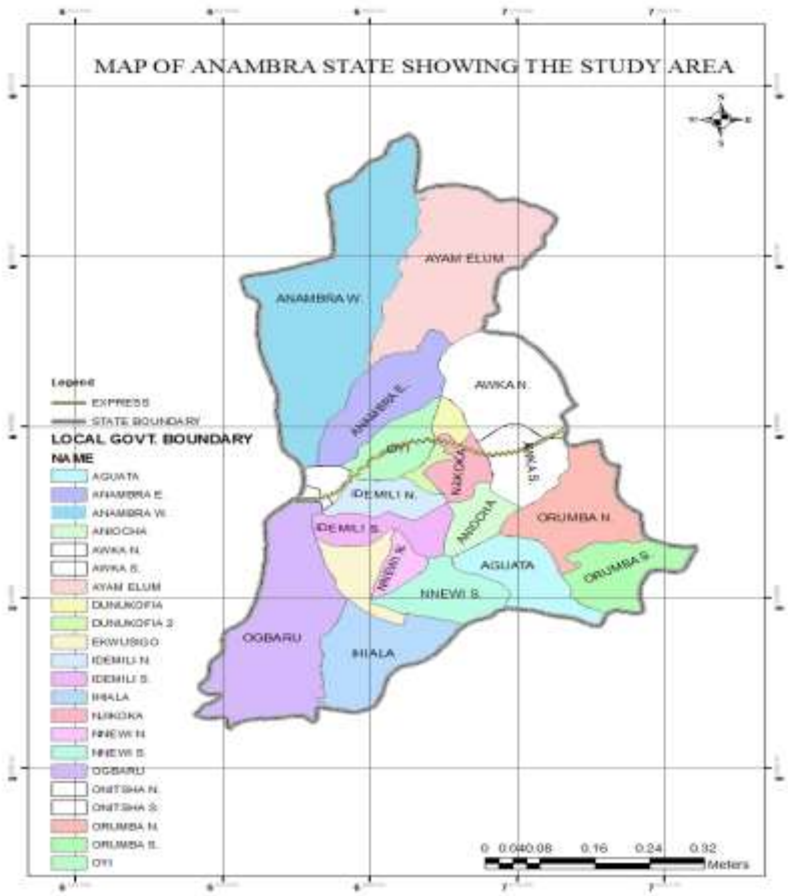


Figure 1.1(a) Map Of Nigeria Showing Anambra State (Study Area)



(b) Map Of Anambra State Showing The Local Governments
(Source: extracted from the administrative map of Nigeria)

3.0 MATERIALS AND METHODOLOGY

3.1 Data Requirement

The basic types of data used are primary and secondary data. The primary source of data collection involved direct collection of data that was obtained on the field. The data obtained from primary sources include; GPS coordinates of the sample farm locations (Groundtruthing)

The secondary source of data collection involves sourcing information from existing records. Such data include;

a. LandSat7 satellite imagery of Anambra State.
b. Land Sat8 satellite imagery of Anambra State
c. Administrative Map of Anambra State.
d. Major farms and locational data.
e. Annual Yield Data
f. Surface temperature data
g. Rainfall data
h. Soil moisture data

The data is as shown in tables 3.1, 3.2, 3.4, 3.5 and 3.6, respectively

.

Table 3.1 Landsat 7 and 8 path/row information

Data	Path/Row	Day of Year (DOY)/ Date
Landsat 7	188/056 189/055 189/056	357 (23/12/2002)
Landsat 7	188/056 189/055 189/056	365 (31/12/2014)
Landsat 8	188/056 189/055 189/056	365 (15/03/2014)

Source; (http://earthexplorer.usgs.gov)

Table 3.2: Crop yield data for rice and maize from 2011 to 2015 (S.I unit is in metric tons)

	2011		2012		2013		2014		2015	
L.G.A	RICE	MAIZE	RICE	MAIZE	RICE	MAIZE	RICE	MAIZE	RICE	MAIZE
Anambra West	301123	368	241115	226	224150	197	32011	114	217145	262
Ayamelum	32091	8221	28862	7400	261118	6144	321123	9048	330122	7056
Anambra East	120122	13400	114000	14251	103106	12144	142116	14643	134133	14751
Awka North	240102	12,164	262000	123106	172117	18041	231123	22162	204111	132102
Awka South	12006	16123	10142	15400	9221	12742	11012	16431	11018	14673
Aguata	6	34	5	23	7	38	6.2	42	5.3	62
Aniocha	14	25	42	42	11	33	13	46.3	10.2	38.3
Dunukofia	7	129	7.6	15124	6.5	14112	5.6	19011	7.2	21050
Idemili North	5.1	4000	4.1	3221	4.3	1167	4	772	3	4075
Idemili South	7	120	6.4	186	6.6	176	7.3	189	6.7	152
Njikoka	4	67	3.2	85	3.6	77.3	4.2	84.4	5.1	93
Ogbaru	34	1168	29.2	41200	31	21132	38.2	19161	42.8	34240
Ekwusigo	18	14200	14	12114	9	1804	8.6	12100	8.7	16125
Ihiala	0	141	0	162	0	146.5	0	175.2	0	182.5
Orumba North	146	16722	162	34167	144.5	62123	158.2	42201	162.5	38144
Orumba South	46	132	67	183	78.5	169.2	67.2	194	54.8	2115
Nnewi North	0	10	0	7.1	0	7.4	0	6.2	0	6
Nnewi South	4	74	4.2	69	3.1	73	3	66	3.1	55
Onitsha North	0	2	0	2	0	2.1	0	2	0	2
Onitsha South	0	1	0	1	0	2	0	1	0	1
Oyi	7	1172	6.5	2168	6.5	2142	6.5	2162	5.2	3081

Source; Anambra State Agricultural Development Programme (ASADAP),2016

Table 3.3: Crop yield data for Yam and Cassava from 2011 to 2015

L.G.A	Yam (Mt) 2011	Cassava (Mt) 2011	Yam (Mt) 2012	Cassava (Mt) 2012	Yam (Mt) 2013	Cassava (Mt) 2013	Yam (Mt) 2014	Cassava (Mt) 2014	Yam (Mt) 2015	Cassava (Mt) 2015
Anambra West	226015	442350	242141	328106	220107	342119	236115	352130	242124	356020
Anambra East	8140	37200	7162	34655	6128	37243	9102	42114	8276	38362
Aniocha	9240	15728	6114	12488	7216	13262	5628	14420	4567	12923
Aguata	4643	24672	4763	22678	4364	34766	5664	37482	4784	35342
Awka North	14683	168115	16322	159292	15631	129264	12896	142161	14887	138172
Awka South	146	839	138.5	978	149	1462	151	1588	148.6	1698
Idemili North	1987	7763	1882	8723	1963	6566	2116	8664	1894	7871
Idemili South	1348	9642	1463	8943	1594	14624	1478	16122	1686	15632
Onitsha North	4	2	3	2	4.2	2	3.3	1.8	3	1.6
Onitha South	0	0	0	0	0	0	0	0	0	0
Orumba North	102603	294641	116286	286196	120163	274721	131117	266340	129104	281124
Orumba South	2891	141204	169	136114	266	142633	358	132164	396	144262
Ekwusigo	172	6182	168	5843	186	7982	178.5	6764	182.6	8109
Ihiala	14682	122103	16251	126291	13722	115114	18742	123116	16110	119204
Ogbaru	140891	296741	161626	261372	143644	242110	152015	234621	168793	265293
Ayamelum	9158	16466	9823	15794	9643	14653	8876	16119	9783.6	17241
Dunukofia	2164	12623	2018	10156	2141	11231	3122	9846	2641	11164
Njikika	962	12625	897	14662	874	14125	986	13782	871	14241
Nnewi North	109	288	116	269	124	257	96	272	122	289
Nnewi South	2680	6492	3564	6892	2942	7241	2744	6675	2840	6547
Oyi	6366	23109	6742	22641	7940	23725	6121	24216	7215	25103

Source; Anambra State Agricultural Development Programme (ASADAP),2016

Table 3.4: Mean Monthly Maximum Temperature for Anambra State in Celsuis from 2005 to 2015.

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2005	33.3	35.1	34.4	34.7	32.5	31.3	29.3	29.7	30.7	31	33.6	33.7
2006	35.1	36.1	35.3	35.4	31.8	31.9	30.8	29.9	30	31.9	33.7	34.5
2007	35	36.8	36.9	34.4	32.7	31.5	30.4	29.6	30.1	31.5	32.3	33.8
2008	33.7	36.3	35.5	32.6	31.8	31	29.9	29.4	30.5	32.5	34.2	34.5
2009	33.9	34.6	35.8	33.9	33.1	31.9	30.2	30	30.5	31.3	33.5	35.7
2010	35.5	36	36.3	34.7	32.8	31.2	30.3	30.7	30.9	31.3	32.6	34.5
2011	35.3	36.4	35.7	33.6	32.8	30.2	29	29.3	30	31.8	33.8	33.7
2012	35.4	36.5	34.8	34	32.9	30.2	28.7	28.9	29.7	31.4	33.8	33.8
2013	35.4	36.4	34.9	34	33	30	28.3	29.4	30.2	30.9	33.9	33.8
2014	32.8	34.3	35.2	35.5	35.1	33.9	32.3	30.4	29.2	29.3	30.1	31.6
2015	33.5	34.9	34.7	33.6	32.0	30.5	29.5	29.6	30.2	31.2	32.6	32.9

(Source: Nigeria Meteorological Agency)

Table 3.5: Monthly Mean Rainfall values from the year 2005 to 2014

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2005	0	0	22	42.9	90.5	207.8	132.4	112.7	159.4	91.6	0	0
2006	10.6	-	101.7	200.3	326.2	331.8	98.7	94.5	333	406.9	6.8	0
2007	0	5	34.7	71.7	301.4	355.2	311.5	312.7	322.7	260.4	59.1	2.4
2008	3.5	1.7	52.8	105	239.4	298.9	180.9	173.3	271.7	249.6	22	0.8
2009	4.7	2.2	63.1	125.6	289	328.6	197	193.5	309.1	302.3	29.3	1.1
2010	2.9	2.9	50.2	100.8	276.6	327.6	229.8	226.5	301.2	267.4	36.8	1.4
2011	0	7.1	27.4	120.7	274.8	231.9	153.5	115.4	213.5	172	71.9	10.4
2012	5.3	0	90.6	116.6	241.1	309.6	237.1	297.3	253.1	117.9	18.6	0
2013	0	153.2	53.8	121.6	186.1	289.1	230.4	276.8	308.3	335.5	79.7	32
2014	0	0	83.4	16.9	216.8	232.4	294.2	114.4	342.2	72.4	6.5	Trace

Table 3.6: Annual Mean Soil Moisture values for the year 2012 to 2015

Year	**Average SM Values**
2012	1.632
2013	1.380
2014	0.630
2015	0.844

Source: Prof Oranika Civil Cad Laboratory, Nnamdi Azikiwe University, Awka.

3.2 Computation of NDVI

NDVI, the normalized difference vegetation index, is a quantity used to assess the presence of live green vegetation. NDVI is computed using the formula:

NDVI= (NIR-RED) / (NIR+RED)…………………………………………….. (1)

The RED and NIR stand for the spectral reflectance measurements acquired in the red and near-infrared regions of electromagnetic spectrum, respectively. NDVI takes values from -1 to 1. The higher the NDVI, higher the fraction of live green vegetation present. Landsat band 4 (0.77-0.90 µm) measures the reflectance in NIR region and Band 3 (0.63-0.69 µm) measures the reflectance in the Red region. The NDVI of 2002, 2014 and 2016 satellite image of the study area was calculated to be able to carry out the analysis on green vegetation of Anambra state. To calculate NDVI, the radiance of each of the bands (i.e. 4 and 5) for the three tiles was calculated separately, for the two separate years.

3.2.1 Radiance and Reflectance Computation

L_λ = (gain$_\lambda$ * DN7) + bias$_\lambda$………………………………………………………(2)

L_λ = (0.621654 * "LE71890562014365SG100_B3_fill.TIF")-5.62

The radiance value obtained was used to calculate the 'reflectance' of band 3 and 4 of the three tiles for the different years. Reflectance is defined as the fraction of incoming radiation that is reflected back to the surface.

$$R_\lambda = \frac{\pi * L_\lambda * d^2}{E_{sun,\lambda} * \sin(\theta_{SE})} \quad \text{……………………………… (3)}$$

R_λ = reflectance; $E_{sun,\lambda}$ =is the band-specific radiance emitted by the sun; and θ_{SE} = solar elevation Angle (see fig. 4.7).

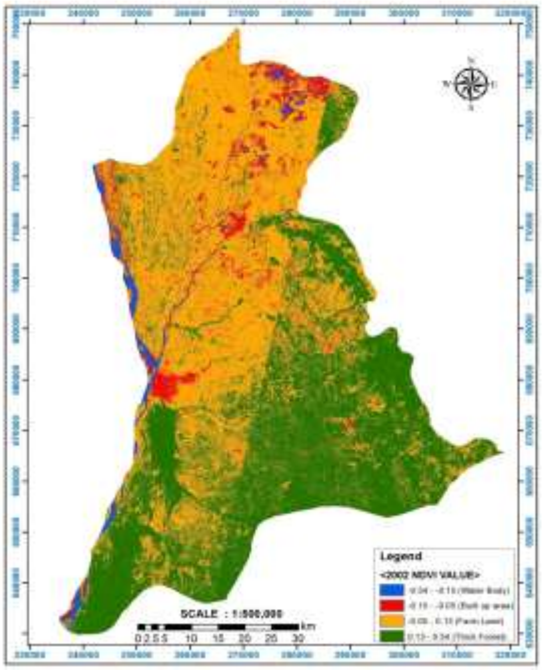
3.2.3 Classification of NDVI Value and Computation of Statistic Value

The NDVI value of the study area for 2002, 2014 and 2016 were reclassified using reclass tool in spatial analysis tool in ArcGIS 10.1, in this process four major classes were identified (Water body, Built up area, Farm land and Forest). The Area with forest cover including green vegetation area with heavy and light forest were classified under NDVI with high Value (value close to 1). the Area with No forest Cover including Built Up area, Farm Land, water Body, Bare Land etc, and were classified under NDVI with

Low Value (Value Close to -1). The Microsoft Excel was used to arrange the table extracted from the NDVI attribute table and produce various statistical result

4.0 PRESENTATION OF RESULTS AND DISCUSSION

The figure 4. 1 (a,b,c) shows the NDVI for the Vegetation of Anambra State for 2002, 2014 and 2016 respectively.



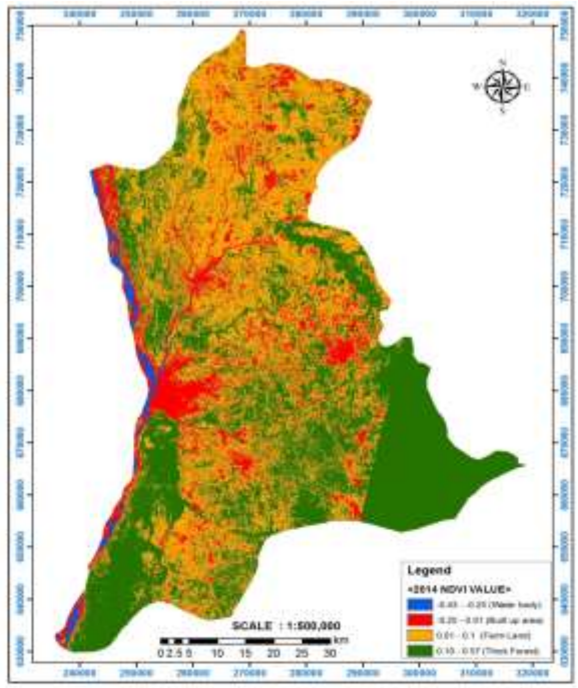
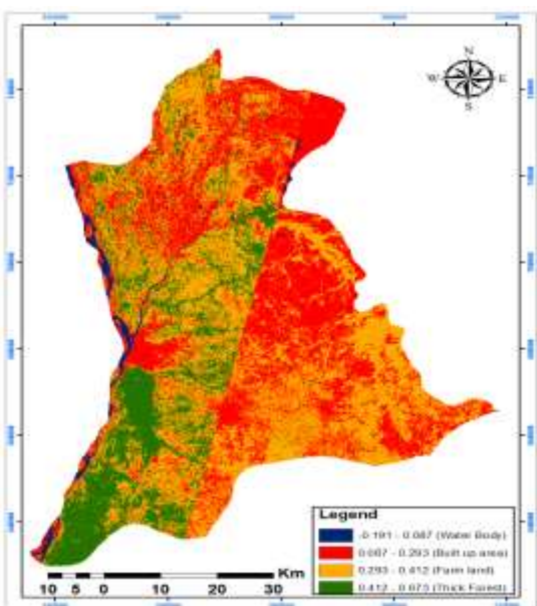


Figure 4.1: (a) NDVI of Anambra State vegetation 2002. (b) 2014



(**c) 2016; Source; Ibekwute I. S. (2016)**

4.1 To Assess the Possibility of Using NDVI and Agrometeorological Data for Yield Prediction

Agrometeorological crop yield forecasting methods provide a quantitative estimate of the expected crop yield over a given area, in advance of the harvest and in a way that constitutes an improvement over trends; provided no extreme conditions occur (Okeke et al, 2010). For this study, the regression Model was used. Regression model uses linear equations and non-linear equations between crop yield, Agrometeorological variables, Vegetation indices, Weather variables and Hybrid combinations of different variables. The regression model used was based on the following parameters, NDVI, SM, ST and RF parameters for crop yield assessment and prediction, using the piecewise regression model with breakpoint.

The model is given by the equation below.

Crop Yield = $c_1 + (a_1 * NDVI) + (a_2 * SM) + (a_3 * ST) + (a_4 * RFE)$…………………. (4)

Where; NDVI is the Normalized Difference Vegetation Index

SM is the Soil Moisture

ST is the Surface temperature, and

RFE is the Rainfall Estimate.

In this model, NDVI, SM, ST, RFE data are considered major variables that affects crop growth. Coefficients used in the derived equation largely depends on a pool of historical data (Okeke et al). For the scope of this study, crop yield prediction was carried out for four crops namely, rice, cassava, yam, and maize (see table 4.1).

Table 4.1: Total Crop yield of the sample crops in Anambra state from 2011 to 2015.

YEAR	RICE	MAIZE	YAM	CASSAVA
2011	705742.1	88273	548884	1638785
2012	656470.2	269137.1	597648.5	1462095
2013	770023.6	152472.5	558801.2	1433100
2014	737707	158611.1	597508.8	1448598
2015	896843.6	288265.8	616427.8	1498599

Charts showing these previous yield data (i.e rice, maize, yam and cassava) are shown below.

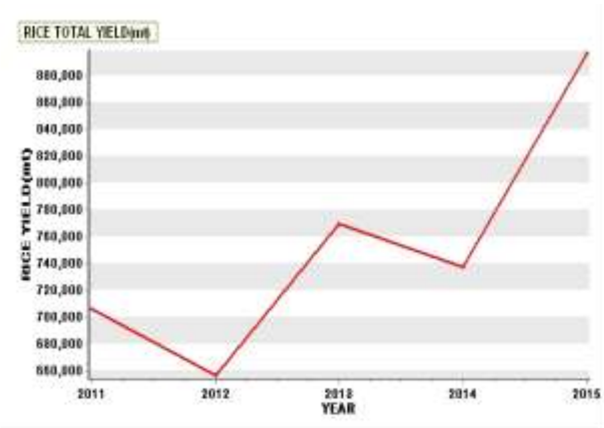


Chart 4.1: Crop yield chart for Rice from 2011 to 2015

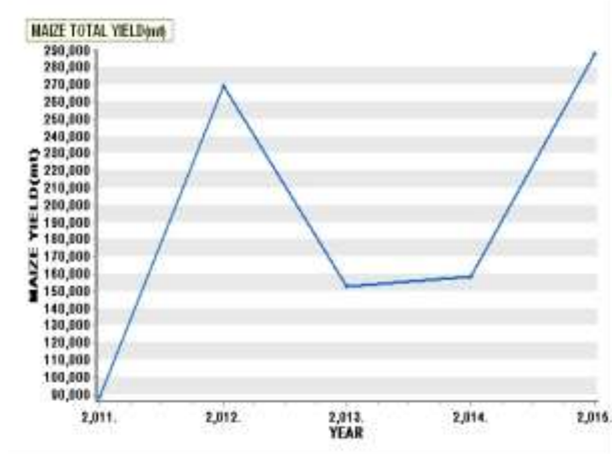
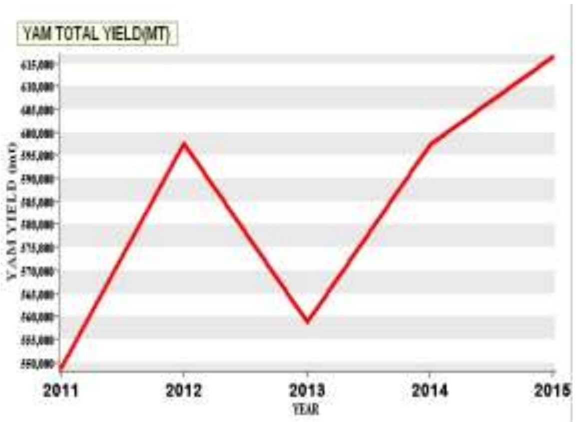


Chart 4.2: Crop yield chart for Maize from 2011 to 2015



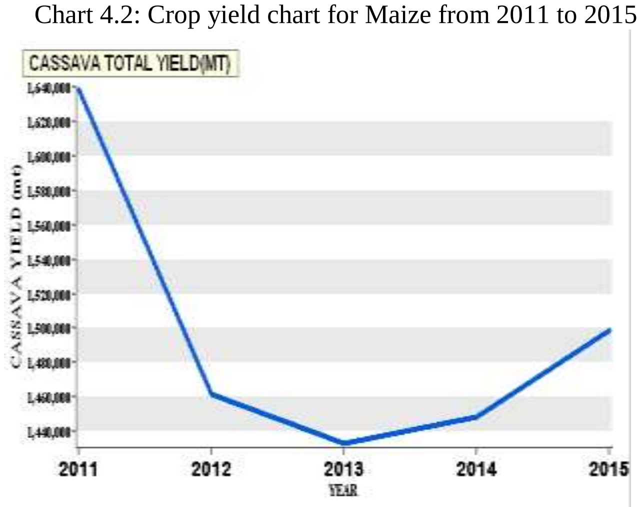


Chart 4.3: Crop yield chart for Yam from 2011 to 2015 Chart 4.4: Crop yield chart for Cassava from 2011 to 2015

Source; Ibekwute I.S. (2016)

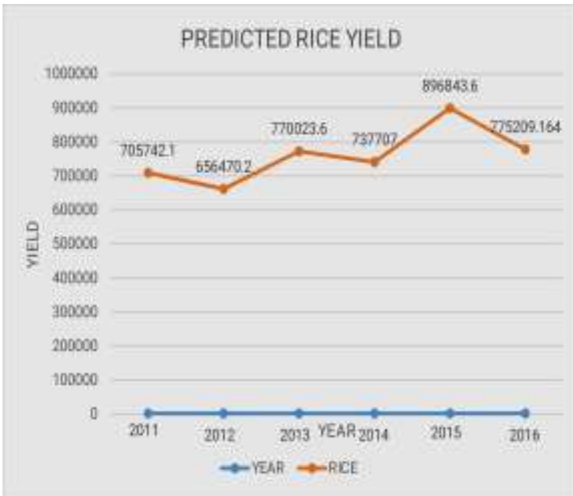
Below is the table showing the predicted crop yield of the sample crops as well as previous yield data.

Table 4.2: Shows the predicted yield for the sample crops.

YEAR	RICE	MAIZE	YAM	CASSAVA
2011	705742.1	88273	548884	1638785
2012	656470.2	269137.1	597648.5	1462095
2013	770023.6	152472.5	558801.2	1433100
2014	737707	158611.1	597508.8	1448598
2015	896843.6	288265.8	616427.8	1498599
2016	775209.164	213203.764	605705.924	1518087.264

Source: Ibekwute I. S. (2016)

Also, charts showing the prediction for the various sample crops as well as previous yield data is shown (see chart 5.8, 5.9, 5.10, and 5.11).



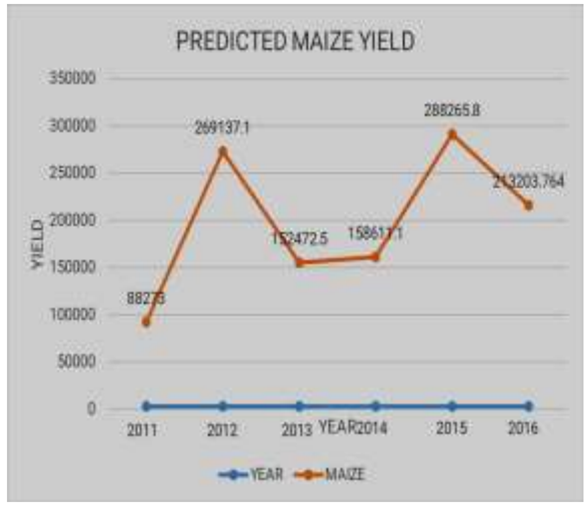
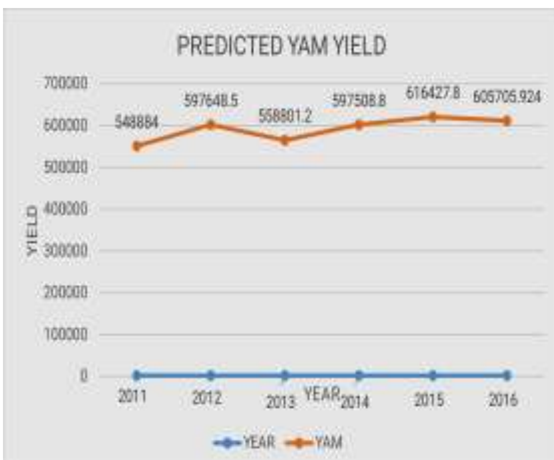


Chart 4.5: Rice yield prediction for 2016 Chart 4.6: Maize yield prediction for 2016



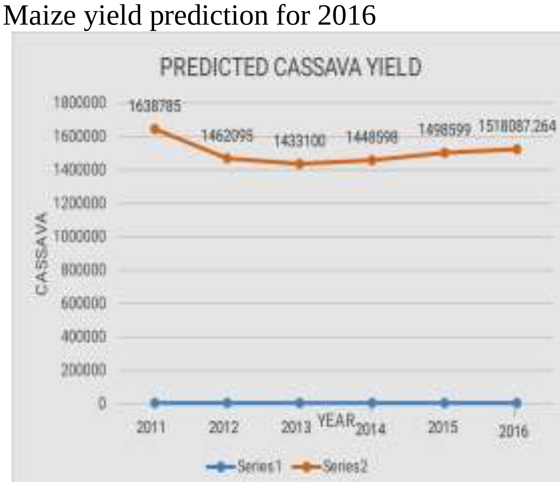


Chart 4.7: Yam yield prediction for 2016 Chart 4.8: Cassava yield prediction for 2016

From the charts(4.5-4.8) above, we can ascertain that the predicted yield for rice in the year 2016 is 775209.164, the predicted yield for maize in the year 2016 which is 213203.764, the predicted yield for Yam in the year 2016 which is 605705.924, which shows a decline in the productions compared to previous year 2015. These decline in the yield might be probably caused by increase in built-up areas for commercial and residential purposes, and decrease in the agricultural sector or decrease in the practice of mechanized farming system (fertilizer, improved seeds etc).The predicted yield for Cassava in the year 2016 which is 1518087.264, on the other hand showed an increase in the Cassava production compared to previous year 2015.

5.0 CONCLUSION AND RECOMMENDATION

This study explored the potentials of using NDVI and Agrometeorological Data for Yield Prediction. The results showed that The Normalized Difference Vegetation Index was quite efficient for monitoring crop production as it was the major factor for both yield prediction and determination of the extent of cultivated land. From the yield prediction results it was seen that the predicted yield for rice in the year

2016 is 775209.164, this shows a decline in the rice production compared to previous year 2015. The predicted yield for maize in the year 2016 which is 213203.764, which shows a decline in the maize production compared to previous year 2015. The predicted yield for Yam in the year 2016 which is 605705.924, which shows a decline in the Yam production compared to previous year 2015. The predicted yield for Cassava in the year 2016 which is 1518087.264, which shows an increase in the Cassava production compared to previous year 2015. This monitoring helps us to forecast crop yield in the proposed harvest year. Hence it is recommended that monitoring of crop production and early yield prediction should be carried out on an annual basis and prediction yield model should be developed. It is also recommended that data about agricultural production for each year should be collated, gazetted, hosted by the ministry of Agriculture for ease of access.

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