Enhancing Food Security in Anambra State, Nigeria Using Remote Sensing Data

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Abstract
Timely availability of information on food production is vital for taking informed decisions on food security issues. Remote sensing technology and Geographic Information System (GIS) are very effective means for generating regular updates on crop production statistics, early yield prediction and providing inputs to achieve sustainable agriculture. In this study, satellite based crop prediction model was used to estimate crops statistics of major crops which include rice, cassava, yam, and maize in all local government area in Anambra State, South Eastern part of Nigeria. Landsat 7 and 8 images of 2002, 2014 and 2016 were used to generate the Normalized Difference Vegetation Index (NDVI) of the period of study. Regression model was used to predict yield of the crops under study. The NDVI, soil moisture (SM), surface temperature (ST) and rainfall estimate (RFE) were used in the prediction model. 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. Also, the result showed that the total area of cultivated land in 2002 was 78.179 km^2, while the total area in 2014 was 67.3578 km^2. So it was ascertained that there was a decline in the agricultural area between the year 2002 and 2014 with about 10.8207 km^2, this decline might be caused by increase in built-up area, migration from rural to urban etc. The results of the crop area extent reveals that Anambra East Local Government Area has the highest land for agricultural purposes of about 19.25km^2 while Nnewi North has the lowest land area for agricultural purposes of about 0.673km^2. Finally, from the yield prediction made it is observed that there might be a decline in the yield in the year 2016 for most of the crops apart from Cassava which is predicted to have a slight increase.

Keywords: Food security, Remote Sensing, GIS, Vegetation Index

Introduction

This study was informed by the declining food production in Nigeria. Food productions can no longer sustain the increasing population growth. Thus creating a wide gap between the demand and supply of food (Abdulrahaman, 2013). This is evident in the observed food deficit and the upward trend in the price of food stuff in the market over the years. The resulting effect of this imbalance between demand for and supply of food is malnutrition, poverty and deteriorating living conditions (Nadozie and Ibe, 2000). Against this background, the growth of Nigeria economy with reference to agriculture has been import driven rather production driven. Consequently, there is a growing advocacy for improving Nigeria agricultural production so as to achieve sustainable food security. Several efforts has been made towards finding appropriate institutions for organizing millions of small scale farmers towards achieving food security (through increased food production). Agricultural cooperative society has been described as the appropriate vehicle for harnessing and polling the resources of millions of small holder farmers together to enjoy the benefit of large scale production.

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. Several crop condition models have been developed. These includes: (a) direct monitoring models, (b) classification model, (c) same-period comparing model, (d) crop growing process monitoring model, (e) crop growing model, and (f) diagnosis model (Meng and Wu, 2008).

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. In most countries the data become available too late for appropriate actions to be taken to avert food shortage. Thus the monitoring of crop production using GIS and remote sensing based vegetation index is vital. The Vegetation index most commonly used is the Normalized Different Vegetation Index (NDVI), although a number of alternative indices based on the same two spectral bands (NIR-near infrared and VIS-visible usually red) have been developed, mostly with the aim of reducing the sensitivity of the index to extraneous factors such as soil background or the atmosphere Simple ratio indices is a simplest and the most widely used index in remote sensing of vegetation.

Aim and Objectives of the Study

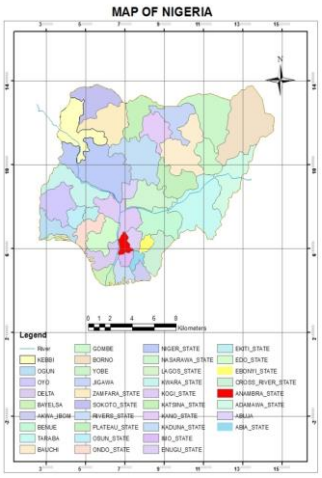
The aim of this study is to monitor crop productions (Rice, Cassava, Yam, Maize) in Anambra state, Nigeria using Remote Sensing and GIS technique. The specific objectives are; to:

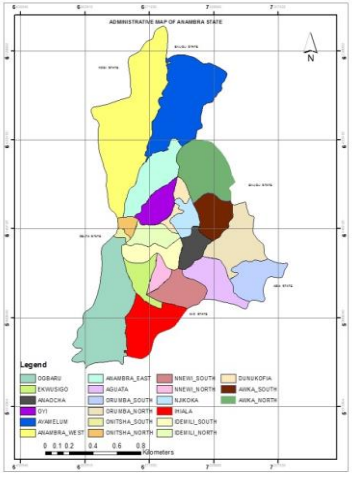
i. Assess the possibility of using multi-temporal images for crop monitoring.
ii. Generate and analyze the NDVI of Anambra State for 2002, 2014 and 2016.
iii. use the NDVI obtained to analyze the change that occurred amongst the crop areas within the period of 2002-2014
iv. evaluate of the cropped area extent in 2016 as well as the types of crops produced
v. Assess the possibility of using NDVI and Agrometeorological data for yield prediction.

Materials and Methods

Study Area

The study area is Anambra State in South Eastern part of Nigeria. It is located between latitudes 5^0 40^1N and 6^0 50^1N, and longitudes $6^0 35^1$E and $7^0 25^1$E (see fig. 1a and 1b).





(Figure 1a: Map of Nigeria showing Anambra State; Figure 1b: Map of Anambra State)

The State is named after the Anambra River (Omambala). Anambra State 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 Fishing activities. Anambra is rich in natural gas, crude oil, bauxite, ceramic and has arable soil. The indigenous ethnic group in Anambra state is 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 industrious and hospitable people of the State are great industrialists, entrepreneurs, and craftsmen.

Old Anambra State was created in 1976 from part of East Central State. The Anambra State and Enugu State was carved out of the former, larger Anambra State on August 27, 1991. The capital of the Anambra State is Awka. Most of the industrial base of the state is private sector driven, spanning from agro-allied, automobile and manufacturing situated mostly in the Nnewi industrial belt. Onitsha main market is reputed to be the biggest in West Africa. Onitsha and Nnewi are the biggest commercial and industrial cities. The State's theme is "Light of the Nation". The State has a land mass of about 4,416sq km with 4,182,022 population (NPC, 2006). 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). The climate of Anambra State has two seasons, the wet and dry, with the wet seasons usually starting in March and ending in October, while the dry season usually begins in November and last till February. The average highest rainfall usually recorded around July to October is about 1952mm (Igbokwe, 2008). The temperature pattern has mean daily and annual temperatures as 28^0C and 27^0C respectively. The mean daily temperature can rise to about 320C during hot periods of the year usually in the month of February. Humidity is relatively high between 65-80% throughout the year.

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. Small rivulets and rivers such as Anambra, Nkisi and Idemili rivers empty into the River Niger. The sandstones formations constitute a gradational plain (Ofomata, 1975). The Bende-Ameke and Nanka sands have domey hills and dry valleys as common features, being sandstone formations. It has deep porous red and unconsolidated soils which makes the area to be prone to gully erosion and other associated environmental problems.

The South-east region of Nigeria lies within Awka-Orlu uplands and Enugu-Awgu-Okigwe escarpment where gully erosion is a general problem which reduces the land resource of the area. Anambra State being located within the South-eastern Nigeria is found on the dip section of the east facing scarp slopes of the Awka-Orlu landscape. It is underlain by flood plain deposits, and coarse to fine grained Nanka sands of the Bende-Ameki formation of the Eocene era (Orajaka, 1975).

Data Collection

Data used in this study include both primary and secondary datasets. The primary dataset was obtained through site visitation with the use of Handheld GPS. This primary data includes the coordinates of the location of the sample farm lands of the various crops. Major farms and their location were acquired from Anambra State Agricultural Development Programme (ASADAP). Table 1 shows the geographic location of sample farms.

Table 1: Sample farms and their coordinates

Sample farms	Eastings (m)	Northing(m)	LGA	CROPS	AREA (km2)
S 1	282049.955	657334.623	AGUATA	FRUITS AND VEGETABLES	2.35986
S 2	258529.313	687676.176	ANAMBRA EAST	RICE	3.93152
S 3	262517.785	694767.66	ANAMBRA EAST	CASSAVA	2.82928
S 4	268371.72	696991.806	ANAMBRA EAST	YAM	2.92357
S 5	267963.438	693161.715	ANAMBRA EAST	YAM	2.21717
S 6	271044.017	703966.237	ANAMBRA EAST	MAIZE	7.3497
S 7	262916.001	722952.775	Anambra West	MAIZE	5.67767
S 8	257645.49	711014.751	Anambra West	YAM	1.7944
S 9	251422.478	707522.244	ANAMBRA WEST	RICE	2.27799
S 10	264194.47	735641.159	Anambra West	CASSAVA	7.26005
S 11	289633.051	695892.323	AWKA NORTH	MAIZE	7.0889
S 12	277013.029	706633.242	AWKA NORTH	RICE	9.42843
S 13	279812.326	695859.387	AWKA NORTH	CASSAVA	0.546273
S 14	284516.837	683289.736	AWKA SOUTH	FRUITS AND VEGETABLES	9.9588
S 15	276259.494	737546.162	AYAMELUM	RICE	3.61773
S 16	282450.756	733894.905	AYAMELUM	MAIZE	10.203
S 17	276619.328	725153.054	AYAMELUM	CASSAVA	0.309721
S 18	273875.064	695806.471	DUNUKOFIA	CASSAVA	6.8819
S 19	263243.129	663071.193	EKWUSIGO	MAIZE	6.0098
S 20	272141.309	677954.847	IDEMILI NORTH	FRUITS AND VEGETABLES	1.93047
S 21	273107.709	670524.72	IDEMILI SOUTH	FRUITS AND VEGETABLES	2.43202
S 22	263300.305	640222.858	IHIALA	CASSAVA	0.267088
S 23	255842.381	649165.289	IHIALA	FRUITS AND VEGETABLES	2.7028
S 24	276782.742	689126.299	NJIKOKA	FRUITS AND VEGETABLES	0.603086
S 25	277955.632	679607.426	NJIKOKA	FRUITS AND VEGETABLES	1.82289
S 26	268938.353	662854.15	NNEWI NORTH	FRUITS AND VEGETABLES	0.672943
S 27	262584.027	653593.741	NNEWI SOUTH	MAIZE	0.261341
S 29	249840.38	640988.017	OGBARU	CASSAVA	6.28421
S 30	245337.422	648764.657	OGBARU	RICE	2.04435
S 31	252294.466	662478.042	OGBARU	YAM	9.82726
S 32	290401.529	663382.226	ORUMBA NORTH	MAIZE	1.05584
S 33	292294.235	672467.809	ORUMBA NORTH	CASSAVA	3.18576
S 34	265781.813	684613.389	OYI	Cassava	1.57043

Source: (ASADAP, 2016)

Annual crop yield data for rice, maize, yam and cassava from 2011 to 2015 were acquired from Anambra State Agricultural Development Programme (ASADAP). See table 2 and 3.

Table 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

Table 3: Crop yield data for Yam and Cassava from 2011 to 2015

LGA	YAM (mt)	CASSAVA (mt)	YAM (mt)	CASSAVA (mt)	YAM (mt)	CASSAVA (mt)		CASSAVA (mt)	YAM (mt)	CASSAVA (mt)
YEAR	2011	2011	2012	2012	2013	2013	2014	2014	2015	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
ONITSHA SOUTH	0	0	0	0	0	0	0	0	0	0
ORUMBA NORTH	102603	294641	116286	286196	120163	274721	131117	266340	129104	24
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		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

Surface temperature and Rainfall data were obtained from the Nigeria Meteorological Agency as shown in table 4 and 5 respectively.

Table 4: Mean Monthly Maximum Temperature for Anambra State in Celsuis from 2005 to 2015.

YR	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 5: Monthly Mean Rainfall values from the year 2005 to 2014
Source: Nigeria meteorological Agency

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

Soil Moisture data was obtained from Civil CAD laboratory Nnamdi Azikiwe University, Awka.

Table 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.

Land Sat 7 and 8 satellite imagery for the three tiles (path, row: 188,056; 189, 056: 189;055) were downloaded from the website (http://earthexplorer.usgs.gov). Bands 7, 4, 3 of Landsat 7(for 2002 and 2014) and bands 7, 5, 3(for 2016) were stacked together using layer stacking tool in ERDAS Imagine 14 Software. The area of interest (the study area) was masked out of the tiles using a digitized shape file of the study area.

Data Analysis

The Normalized Difference Vegetation Index (NDVI) was employed to assess the presence of live green vegetation. NDVI is computed using the formula:

NDVI= (NIR-RED) / (NIR+RED) … (8)

The RED and NIR stand for the spectral reflectance measurements acquired in the red and near-infrared regions of electromagnetic spectrum, respectively. The values of reflectance of agricultural crop-plants in RED and NIR bands and the values of NDVI have relatively permanent

character for given agricultural land and species (Zdimal *et al.,* 2008). 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 value of the study area for 2002, 2014 and 2016 were produced and reclassified using reclass tool in spatial analysis tool in ArcGIS 10.1. 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 was 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 yield prediction for the four crops under study (rice, cassava, yam, and maize) was carried out using the quasi-Newton linear regression model. The regression model uses agro meteorological variables, vegetation indices, weather variables and hybrid combinations of different variables to predict crop yield. Prasad *et al* (2007) summarized the steps involved in the model as follows: (a) identifying an initial model, (b) iteratively 'stepping', ie. repeatedly altering the model at the previous step by adding or removing a predictor variable in accordance with the 'stepping criteria', and (c) terminating the search when either of the limiting conditions reaches its maximum, or stepping is not possible further.

Results and Discussions

Figure 3.1a, 3.1b and 3.1c shows the NDVI for 2002, 2014 and 2016.

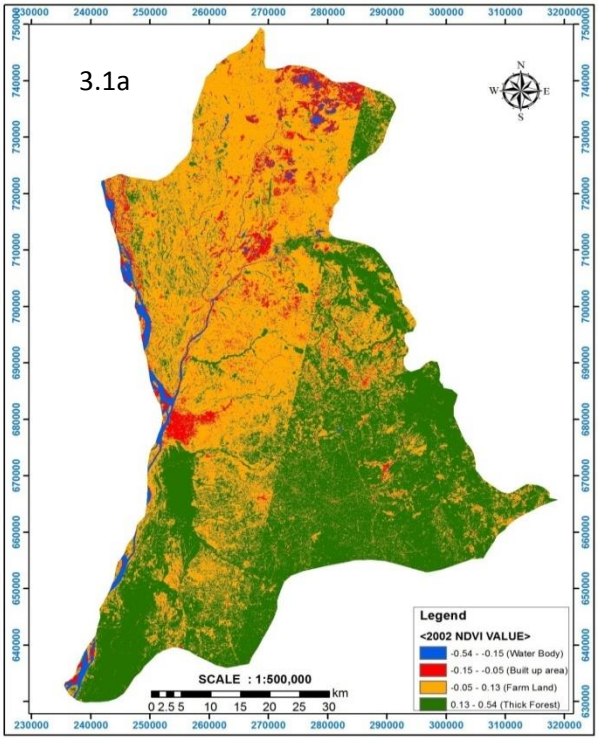


Fig. 3.1a: 2002 NDVI of Anambra State.

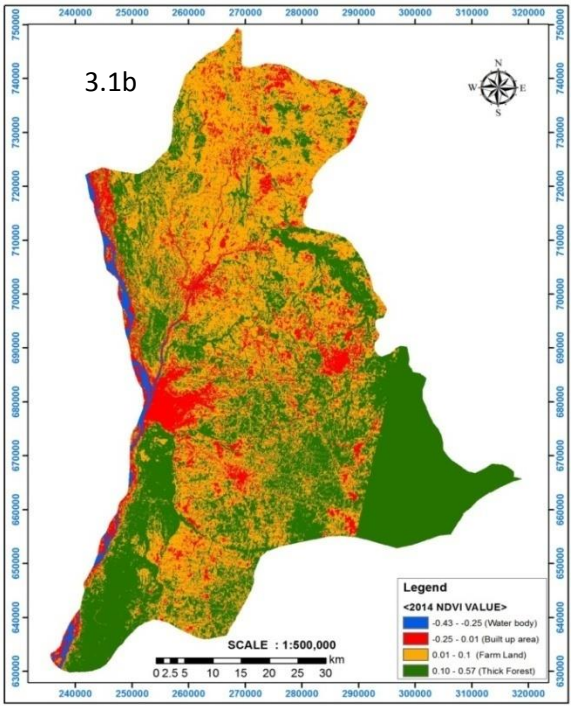


Fig. 3.1b: 2014 NDVI of Anambra State.

3.1c

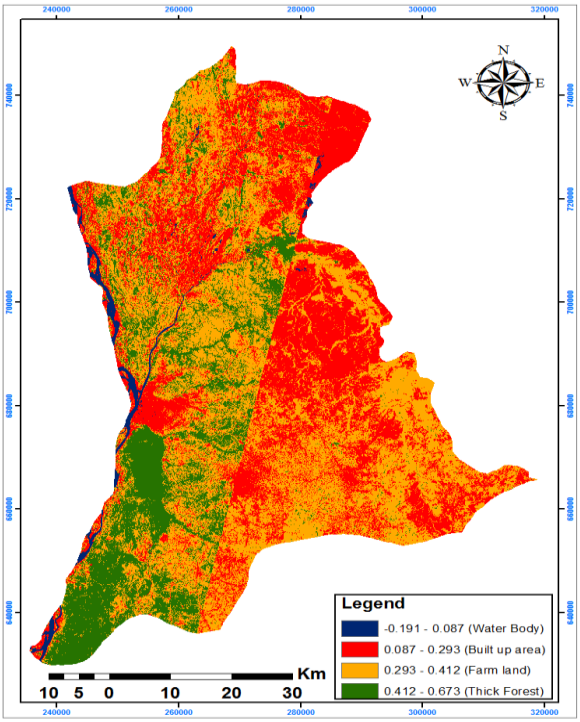


Fig. 3.1c: 2016 NDVI of Anambra State.

The percentage area for the different landuse/ landcover for 2002, 2014 and 2016 were presented in table 7, 8 and 9 respectively.

Table 7: 2002 Land use/landcover percentage areas derived from the NDVI 2002

S/N	2002 NDVI Value	Classes	Count	Area (Km^2)	Percentage (%)
1	-0.54 - -0.15	Water Body	110875	99.7875	1.96
2	-0.15 - -0.05	Built up area	279160	251.244	4.94
3	-0.05 - 0.13	Farm Land	2755305	2479.7745	48.73
4	0.13 - 0.54	Forest	2508768	2257.8912	44.37
Total			**5654108**	**5088.6972**	**100.00**

From the NDVI results obtained for the year 2002, it can be seen that the area occupied by waterbody is least while that of farmland is the highest. The percentage of the area occupied by farmland is 48.73%, while that of forest is 44.37%, built up area is 4.94% and waterbody is 1.96%. From this result, one can conclude that if other factors that affect the total agricultural output is assumed to be positive constant, the output for this year would be relatively high.

Table 8: 2014 Landuse/ landcover percentage areas derived from the NDVI 2014

S/N	2014 NDVI Value	Classes	Count	Area (Km2)	Percentage (%)
1	-0.43 - -0.25	Water Body	62930	56.64	1.23
2	-0.25 - 0.01	Built up area	603185	542.87	11.82
3	0.01 - 0.1	Farm Land	2190334	1971.30	42.92

4	0.10 - 0.57	Forest	2246378	2021.74	44.02
Total			**5102827**	**4592.54**	100.00

The result of NDVI classification of 2014 shows that 42.92% of the total landmass was classified as farmlands, 44.02% as forest, 11.82% for built-up and 1.23% for waterbody. Comparing the result obtained with that of 2014, it is seen that built up area increased greatly by 6.88% while that of farmlands decreased by 5.8%. This shows that the developments in the State in terms of real estate had negative implications on the agricultural land-use.

Table 9: 2016 Landuse/ landcover percentage areas

S/N	2016 NDVI Value	Classes	Count	Area (Km2)	Percentage (%)
1	-0.191 - 0.087	Water Body	77446	69.70	1.52
2	0.087 - 0.293	Built up area	1808398	1627.56	35.44
3	0.293 - 0.412	Farm Land	2303049	2072.74	45.13
4	0.412 - 0.673	Forest	913937	822.54	17.91
Total			**5102830**	**4592.55**	**100.00**

In 2016, the landuse/ landcover classification of the study area shows that 45.13% of the area was classified as farmlands, 17.19% for forest, and 35.44% for built-up and 1.52% for waterbody. From the NDVI result obtained in 2016, it is seen that built up area increased greatly by 23.62% while farmlands increased by 2.21% when compared to year 2014. The NDVI obtained for the year 2002 and 2014 was used to analyze the change in area for agricultural purposes between the periods of this study, from 2002 to 2014. Table 2.0 shows the variance in area between the periods of study.

Table 10: shows the change in the area occupied by farm lands in the 2002 and 2014 NDVI

Sample Code	Crops	LGA	Crop Area (2002) km^2	Crop Area (2014) km^2	Change
S1	fruits and Vegetables	Aguata	0.1098	0.2619	**0.1521**
S2	Rice	Anambra East	3.3948	1.8567	**-1.5381**
S3	Cassava		2.6118	1.6803	**-0.9315**
S4	Yam		2.7783	2.5614	**-0.2169**
S5	Yam		2.0745	1.296	**-0.7785**
S6	Maize		6.2802	5.2443	**-1.0359**
S7	Maize	Anambra West	4.9212	1.4364	**-3.4848**
S8	Yam		1.575	1.4364	**-0.1386**
S9	Rice		1.8567	1.4364	**-0.4203**
S10	Cassava		7.0452	6.0246	**-1.0206**
S11	Maize	Awka North	4.1274	4.0824	**-0.045**
S12	Rice		8.739	7.8048	**-0.9342**
S13	Cassava		0.4401	0.1485	**-0.2916**
S14	fruits and Vegetables	Awka South	2.0691	3.555	**1.4859**
S15	Rice	Ayamelum	2.4237	2.3319	**-0.0918**
S16	Maize		7.2864	6.2163	**-1.0701**

S17	Cassava		0.2286	0.0333	**-0.1953**
S18	Cassava	Dunukofia	5.3154	3.7512	**-1.5642**
S19	Maize	Ekwusigo	3.0996	3.9591	**0.8595**
S20	fruits and Vegetables	Idemili North	0.7911	0.3321	**-0.459**
S21	fruits and Vegetables	Idemili South	0.2538	1.1124	**0.8586**
S22	Cassava	Ihiala	0.0702	0.1296	**0.0594**
S23	fruits and Vegetables		0.9252	2.2365	**1.3113**
S24	fruits and Vegetables	Njikoka	0.2376	0.3168	**0.0792**
S25	fruits and Vegetables		0.4536	0.9648	**0.5112**
S26	fruits and Vegetables	Nnewi North	0.369	0.5085	**0.1395**
S27	Maize	Nnewi South	0.2493	0.1125	**-0.1368**
S28	Rice		0.0675	0.8325	**0.765**
S29	Cassava	Ogbaru	1.9629	1.4607	**-0.5022**
S30	Rice		0.3132	0.3573	**0.0441**
S31	Yam		3.42	1.7748	**-1.6452**
S32	Maize	Orumba North	0.7236	0.7182	**-0.0054**
S33	Cassava		0.4995	0.8622	**0.3627**
S34	Cassava	Oyi	1.4652	0.522	**-0.9432**
Total			**78.179**	**67.3578**	**- 10.8207**

From the result obtained above, the total area of cultivated land in 2002 was 78.179 km^2, while the total area in 2014 was 67.3578 km^2. So it was ascertained that there was a decline in the agricultural area between the year 2002 and 2014 with about 10.8207 km^2. The crop area extent of each types of crop produced in the Local Government Area was determined and presented in table 11.

Table 11: shows the sample farms in different Local Govt. Area, their Extent and product.

Sample Code	**Crops**	**LGA**	**Area (Km^2)**	**Crops Coverage per LGA**
S1	fruits and Vegetables	Aguata	2.360	2.360km^2
S2	Rice	Anambra East	3.932	19.251 Km^2
S3	Cassava		2.829	
S4	Yam		2.924	
S5	Yam		2.217	
S6	Maize		7.350	
S7	Maize	Anambra West	5.678	17.010 km^2
S8	Yam		1.794	
S9	Rice		2.278	
S10	Cassava		7.260	
S11	Maize	Awka North	7.089	17.064 km^2
S12	Rice		9.428	
S13	Cassava		0.546	
S14	fruits and Vegetables	Awka South	9.959	9.959 km^2
S15	Rice	Ayamelum	3.618	14.130 km^2
S16	Maize		10.203	

S17	Cassava		0.310	
S18	Cassava	Dunukofia	6.882	6.882 km^2
S19	Maize	Ekwusigo	6.010	6.010 km^2
S20	fruits and Vegetables	Idemili North	1.930	1.930 km^2
S21	fruits and Vegetables	Idemili South	2.432	2.432 km^2
S22	Cassava	Ihiala	0.267	
S23	fruits and Vegetables		2.703	2.970 km^2
S24	fruits and Vegetables	Njikoka	0.603	
S25	fruits and Vegetables		1.823	2.426 km^2
S26	fruits and Vegetables	Nnewi North	0.673	0.673 km^2
S27	Maize	Nnewi South	0.261	
S28	Rice		2.216	2.478 km^2
S29	Cassava	Ogbaru	6.284	
S30	Rice		2.044	
S31	Yam		9.827	18.156 km^2
S32	Rice	Orumba North	9.196	
S33	Maize		3.838	
S34	Maize		1.056	
S35	Cassava		3.186	17.276 km^2
S36	Yam	Orumba South	2.630	
S37	Rice		0.473	
S38	Maize		2.736	
S39	Cassava		1.326	7.165 km^2
S40	Cassava	Oyi	1.570	1.570 km^2
Total			**149.742**	**149.742Km^2**

It can be observed from table 11 that Anambra East has the highest land for agricultural purposes of about 19.25km^2 while Nnewi North has the lowest land area for agricultural purposes of about 0.673km^2.

The regression model used was based on the following parameters, NDVI, SM, ST and RF parameters for crop yield assessment and prediction, using the pairwise regression model with breakpoint. These parameters are the major variables controlling crop yield (Prasad *et al.,* 2007). NDVI, SM, ST and RF are the independent variables while crop yield is the dependent variable.

The model equation is given by Prasad *et al* (2007) as:

Crop Yield = $c_1 + (a_1 * NDVI) + (a_2 * SM) + (a_3 * ST) + (a_4 * RF)$ … (1)

Where NDVI is the Normalized Difference Vegetation Index (unit less), SM is the Soil Moisture (unit less), ST is the Surface temperature (in Kelvin), and RF is the Rainfall estimate. c1, c2, a1, a2, for i=1 to 4 are the coefficients of crop yield obtained from historical data given in table 13.

The total crop yield of the selected crops from 2011 to 2015 is shown in table 12.

Table 12: 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 the crop yield for rice, maize, yam and cassava from 2011 to 2015 are shown in fig. 3.3a, 3.3b, 3.3c and 3.3d respectively.

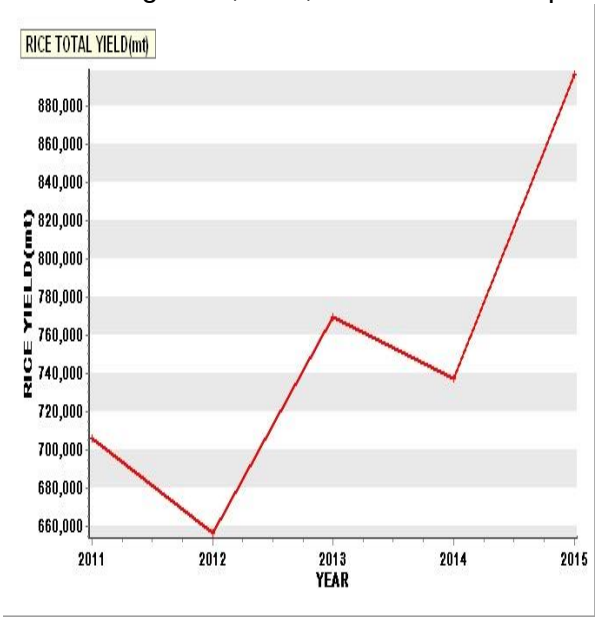


Fig. 3.3a: Crop yield chart for Rice from 2011 to 2015

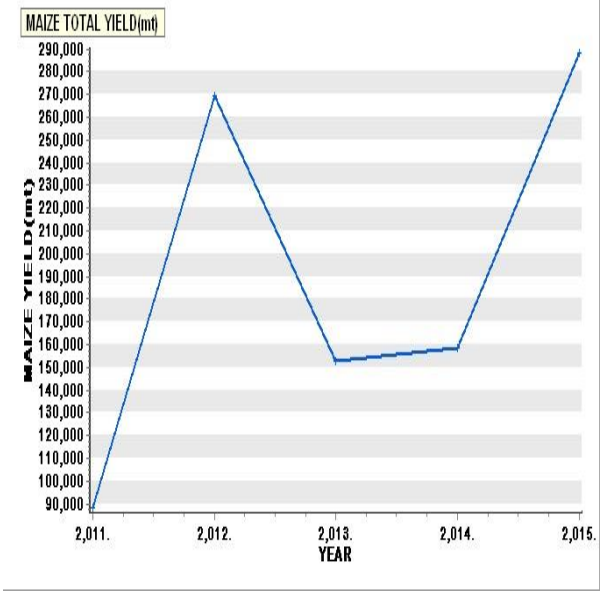


Fig. 3.3b: Crop yield chart for Maize from 2011 to 2015

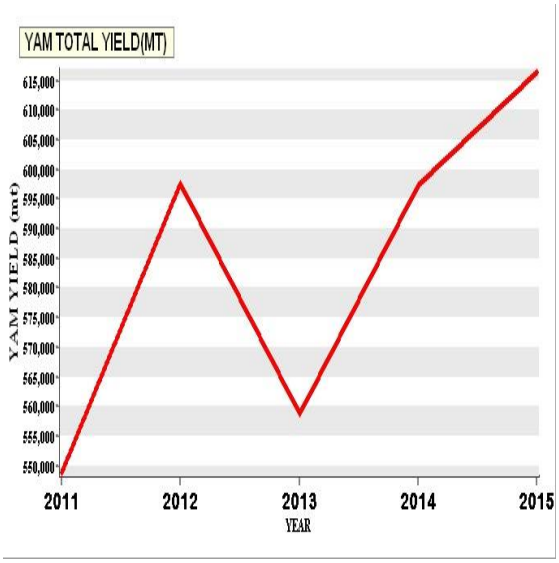


Fig. 3.3c: Crop yield chart for Yam from 2011 to 2015

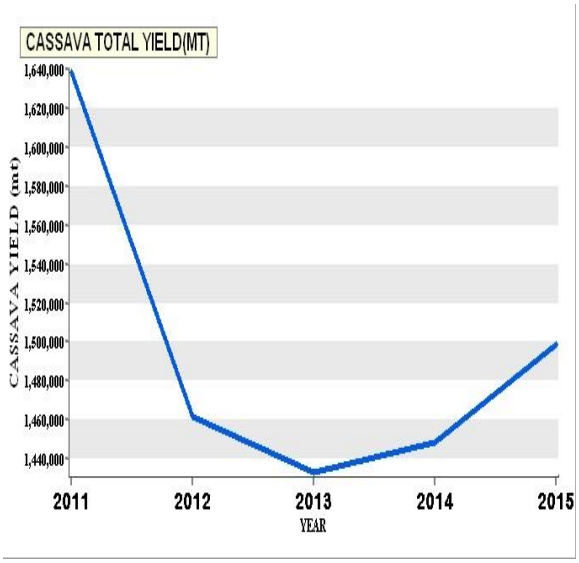


Fig. 3.3d: Crop yield chart for Cassava from 2011 to 2015

The 2016 yield prediction for rice was calculated as follows:

Table 13: Coefficients of rice yield model (based on a pool of historical data)

RICE VARIABLES	Coefficients	Average	2016 variables
Constant	c_1	753357.3	?
NDVI	a_1	0.0475	0.34
SM	a_2	1.1215	0.879

ST	a_3	32.65606061	32.34651515
RFE	a_4	141.1673032	147.3043097

CROP $YIELD_{RICE} = c_1 + (a_1 * NDVI) + (a_2 * SM) + (a_3 * ST) + (a_4 * RFE)$
CROP $YIELD_{RICE}$ **=** 753357.3 + (0.0475 * 0.34) + (1.1215 * 0.879) + (32.65606061 * 32.34651515) + (141.1673032 * 147.3043097)
CROP $YIELD_{RICE\ for}$ **2016= 775209.164** metric tonnes

The 2016 yield prediction for maize was calculated as follows:
Table 14: Coefficients of maize yield model (based on a pool of historical data)

MAIZE VARIABLES	Coefficients	average	2016 variables
Constant	c_1	191351.9	?
NDVI	a_1	0.0475	0.34
SM	a_2	1.1215	0.879
ST	a_3	32.65606061	32.34651515
RFE	a_4	141.1673032	147.3043097

CROP $YIELD_{MAIZE}$ **=** 191351.9 + (0.0475 * 0.34) + (1.1215 * 0.879) + (32.65606061 * 32.34651515) + (141.1673032 * 147.3043097)
CROP $YIELD_{MAIZE}$ **for 2016 = 213203.764** metric tonnes

The 2016 yield prediction for cassava was calculated as follows:
Table 15: Coefficients of cassava yield model (based on a pool of historical data)

CASSAVA VARIABLES	Coefficients	average	2016 variables
Constant	c_1	1496235.4	?
NDVI	a_1	0.0475	0.34
SM	a_2	1.1215	0.879
ST	a_3	32.65606061	32.34651515
RFE	a_4	141.1673032	147.3043097

CROP $YIELD_{CASSAVA}$ **=** 1496235.4+ (0.0475 * 0.34) + (1.1215 * 0.879) + (32.65606061 * 32.34651515) + (141.1673032 * 147.3043097)
CROP $YIELD_{CASSAVA}$ **for 2016= 1518087.264** metric tonnes

The 2016 yield prediction for yam was calculated as follows:
Table 16: Shows the coefficients of yam yield model (based on a pool of historical data)

YAM VARIABLES	Coefficients	average	2016 variables
Constant	c_1	583854.06	?
NDVI	a_1	0.0475	0.34
SM	a_2	1.1215	0.879
ST	a_3	32.65606061	32.34651515
RFE	a_4	141.1673032	147.3043097

CROP $YIELD_{YAM}$ = 583854.06 + (0.0475 * 0.34) + (1.1215 * 0.879) + (32.65606061 * 32.34651515) + (141.1673032 * 147.3043097). CROP $YIELD_{YAM}$ for 2016= 605705.924 metric tonnes

The results show that rice yield is expected to increase slightly while cassava and yam yield are expected to decrease slightly. Maize is also expected to decrease. Cassava and yam is expected to be just lower than the previous highest yield being that of 2011 and 2015 respectively. Table 17 shows the predicted crop yield of the sample crops as well as previous yield data.

Table 17: 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**

Charts showing the prediction for the various sample crops as well as previous yield data are shown in Fig. 3.4a, 3.4b, 3.4c and 3.4d.

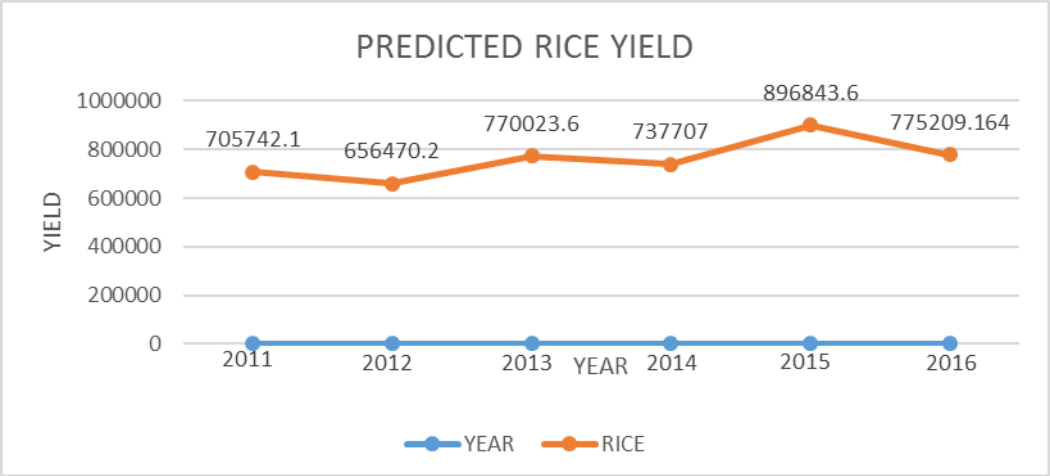


Fig. 3.4a: Rice yield prediction for 2016

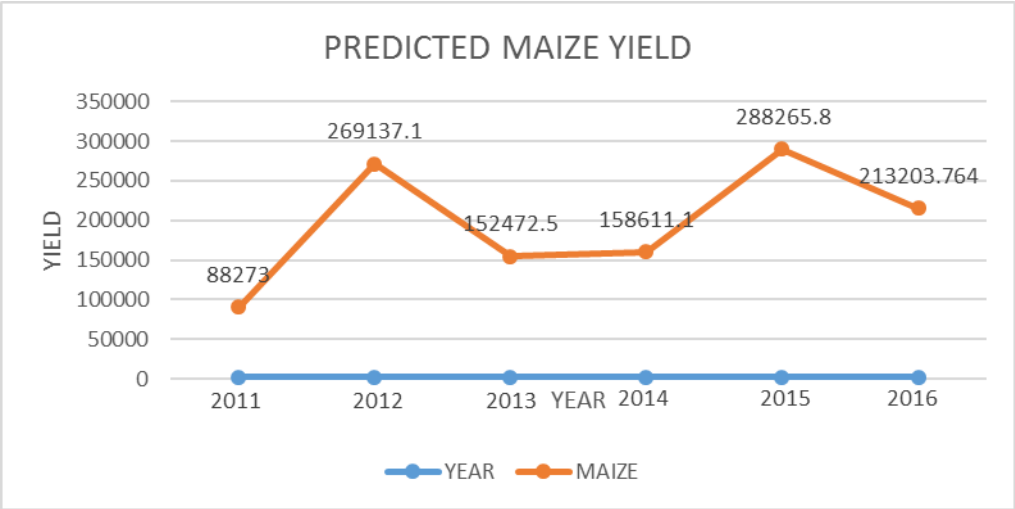


Fig. 3.4b: Maize yield prediction for 2016

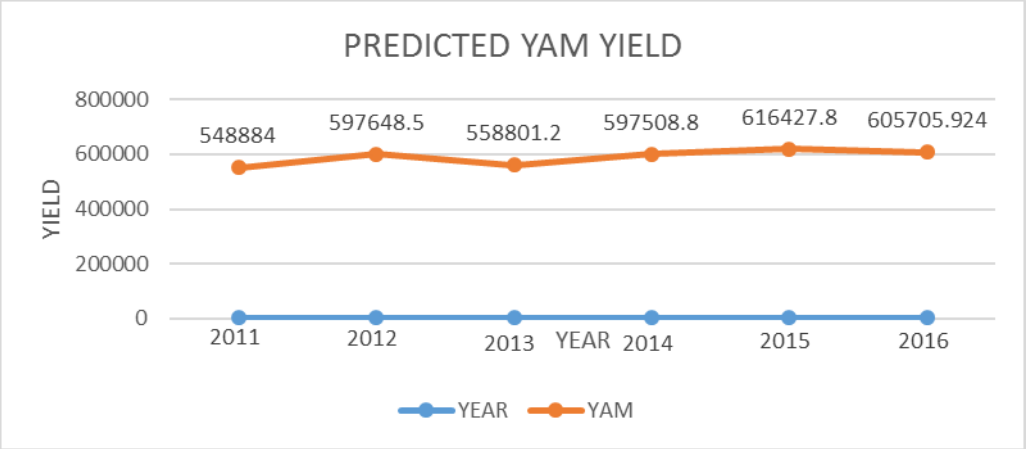


Fig. 3.4c: Yam yield prediction for 2016

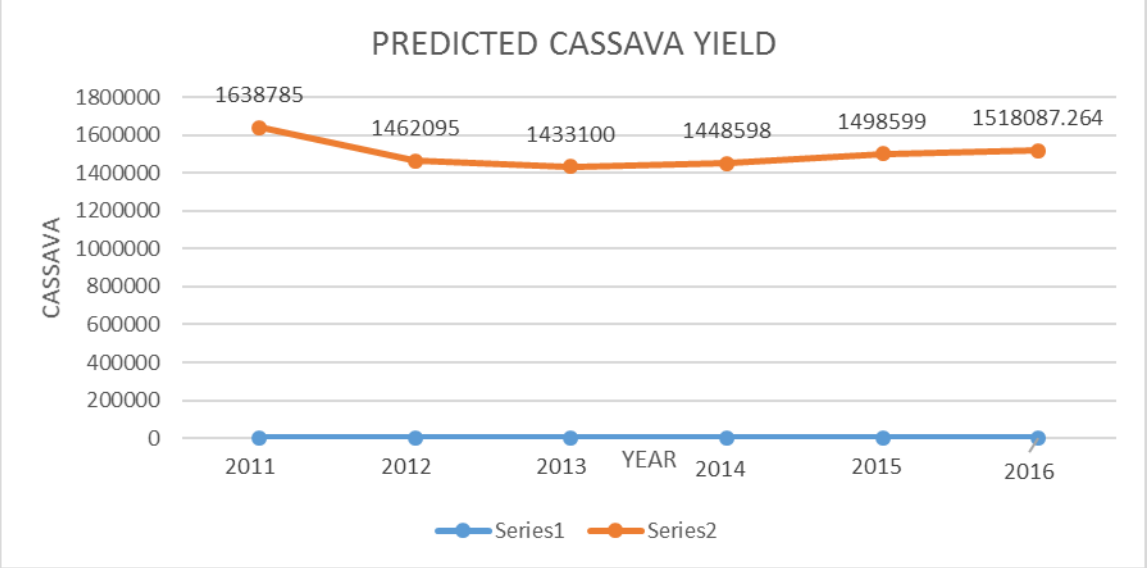


Fig. 3.4d: Cassava yield prediction for 2016

From fig. 3.4a-3.4c, predicted yield for rice in the year 2016 is 775209.164, maize is 213203.764, yam is 605705.924 while cassava is 1518087.264. These shows a decline in the rice, maize and yam production compared to previous year 2015. There was an increase in the Cassava production compared to previous year 2015. This 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).

Conclusion

This study explored the potentials of using remote sensing and GIS in monitoring crop production in Anambra State. The Normalized Difference Vegetation Index was employed in determining the area of cultivated lands and subsequently determining the change in the area of this cultivated land. Also, the NDVI with other variables such as previous annual yield

data, weather/climate data e.t.c can be integrated in an empirical equation and employed for crop yield prediction. This model has proven to be effective for predicting crop yield especially in countries where crop production is primarily dependent on weather and climatic conditions (Prasad *et al*., 2007). The strength of this crop yield prediction model is that it uses input data for the current year to predict final crop yield rather than pure mathematical equations. This makes the results obtained to be close to reality as can be seen from the result of the 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. Also, the result showed that the total area of cultivated land in 2002 was 78.179 km^2, while the total area in 2014 was 67.3578 km^2. So it was ascertained that there was a decline in the agricultural area between the year 2002 and 2014 with about 10.8207 km^2. Finally, from the yield prediction result, it was observed that there might be a decline in the crop yield in the year 2016 for most of the crops apart from cassava which is predicted to have a slight increase.

Recommendation

Monitoring crop production well before harvest is crucial especially in regions characterized by climate uncertainties. This monitoring helps us to forecast crop yield in the proposed harvest. Crop yield estimation based on conventional techniques of data collection for crop and yield estimation based on ground-based field visits and 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. Thus monitoring of crop production and early yield prediction using Remote Sensing and GIS technique is more accurate, cheaper and saves time. Hence it is recommended that:

i. Satellite imageries obtained during pre-planting and harvest period should be used to better analyze the crop health and production
ii. A high resolution satellite imagery can be obtained to serve as a guide during classification of the NDVI image
iii. Finally an annual basis predicting yield model should be developed.

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