A Normalised Difference Vegetation Index Model for Maize Crop Performance Monitoring and Cropland Area Mapping in Sudan Ecological Zone of Nigeria.

Abstract:

The monitoring and mapping of crops remotely are critical for easy identification of stressed crop,prompt response to part of the crop field that requires immediate attention and the potential harvest as well as for agricultural field management. Optical remote sensing offers one of the most attractive options for vegetation indices evaluation and some optical remote sensing data are readily available free for this application,especially, Sentinel-2A, which is equipped with a multispectral sensor (MSI), which enables calculation of some vegetation indices and assessment of vegetation health and status. However, serious attention has not been given to the potential of vegetation indices calculated from MSI data in the developing countries, Nigeria inclusive. Thus, the study therefore calculated the time series NDVI for the length of the growing season for the selected crops (Maize) and geometrically calculated area of the farm plot size. In this study. The study used the Normalized Difference Vegetation Index and Supervised Image classification technique for the crop health assessment and cropland area mapping for maize. The result showed the mean, standard deviation, range, minimum and maximum NDVI values for all the farm plots over the growing season from planting period to the harvesting period for the selected crop. The average NDVI value in May which marks the onset of the growing season for maize in the study area ranges from 0.044 to 0.148. In July, which represents the period of the grain filing stage ranges from 0.136 to 0.348 and in August, which is the maturity stage for harvest ranges from 0.110 to 0.450. Also, it was observed that cropland area is 194.973269 Square Km. It is therefore evident that the results of our NDVI analysis and cropland area mapping are good insights into solving national agricultural planning problems and agricultural resources allocation for effective agricultural practices for national food security.Our results showed that vegetation indices had the greatest contributions in identifying specific crop types and crop conditions during the growing season.

Keywords: Crop performance, NDVI, Sentinel-2, cropland area.

1.0 Introduction

The monitoring and mapping of crops remotely are critical for easy identification of stressed crop,prompt response to part of the crop field that requires immediate attention and the potential harvest as well as for agricultural field management. Optical remote sensing offers one of the most attractive options for vegetation indices evaluation and some optical remote sensing data are readily available free for this application,especially, Sentinel-2A, which is equipped with a multispectral sensor (MSI), offers some vegetation indices calculated to assess vegetation status

A Normalised Difference Vegetation Index (NDVI) of a crop or a plant estimated regularly over the growing season periods of a crop can reveal a lot about the changes in that crop conditions(Mkhabela *et al.*, 2011). In other words, we can use NDVI to evaluate plant health remotely. The Normalized Difference Vegetation Index (NDVI) measures the greenness and the density of the vegetation captured in a satellite image. Healthy vegetation is characterized by a spectral reflectance curve in which the value is positive and this can be discovered by

calculating the difference between two bands – visible red and near-infrared. NDVI is that difference expressed as a number ranging from

-1 to 1. A sudden drop in the NDVI values may be a symptom of crop health deterioration.

The value drop can also correspond to normal changes, such as the time of harvesting, which is why NDVI should be counter-checked against other available data. Correct NDVI values interpretation can help agronomists raise healthier yields, save money on fertilizers, and take a better care of the environment. The input data for NDVI are multispectral satellite Image containing Near Infrared band and Red band.

Satellite imagery, is Earth observation imagery. They are images of the Earth, collected by imaging satellites or Unmanned Ariel Vehicle (UAV) called drones, and these pictures form wide or narrow areas for observation. In Nigeria, the agency responsible for taking a wide satellite imagery area is the National Space Research and Development Agency (NASRDA). However, small-area imagery can come from UAV. The images include crops, livestock, building, water bodies, and any object on Earth. The Convolutional Neural Network (CNN) algorithm model can filter and classify these images and estimate the Area covered by each object. Similarly, the CNN algorithm focuses on crops through their chlorophyll contents and data collected through ground truthing and those for crop output for the Area under consideration.

Time series of normalized-difference-vegetation-index (NDVI), derived from the satellite data, have been used for cropyield predictions since the 1980's(Wall, *et al* 2008). Most of the studies that related NDVI measurements to crop yield have been concentrated on staple crops such as wheat maize and rice(Manjunath *at al*. 2002). Many researchers have also found that NDVI variables are very good at grain yield predictors. Although the inter-annual variability of NDVI (probably due to unexpected weather conditions or disasters) can reveal crop yield fluctuations [19,59]; however, remotely sensed NDVI cannot detect those human-induced factors that increased some crop yield.

1.1 Statement of Research Problem

There has been a loss of significant maize yield to pest, disease and climate as a result of a lack of accurate, timely and first-hand information about the crop condition on the farm. The manual survey is laborious and time-consuming. Remote Sensing technology through Normalized Difference Vegetation Index model provides a better alternative to crop monitoring during the growing season especially when a large area is involved for crop optimum yield. Hence, this study.

1.2 The Aim of the Study

The study aims to use satellite imagery to estimate the Normalized Difference Vegetation index for maize crop monitoring in Sudan Ecological Zone of Nigeria.

1.3 The objectives of the study are to:

a. map the cropland area for the study area.

b. Generate the NDVI to monitor the performance of the maize crop from the Earth Observation Satellite Image in sudan ecological zone of Nigeria.

c. Document the technical details of the algorithm for future reference by other users and replications for other crops.

2.0 METHODOLOGY

2.1 Study Area

The study area lies between latitude 11° 8¹ 4.034¹¹ to 11º 53¹ 16.372¹¹ and longitude 7º 21¹ 51.831¹¹ to 8º 10¹ 48.902¹¹. This contains the three states; Kano, Kaduna and Kastina and the selected LGAs in these three States are the six LGAs that lie interface between these three States where they share boundary. These selected LGAs include; Kudan, Markafi, Danja, Rogo Kafur and Karaye. The study area has an area of approximately 3828.49 km^2.

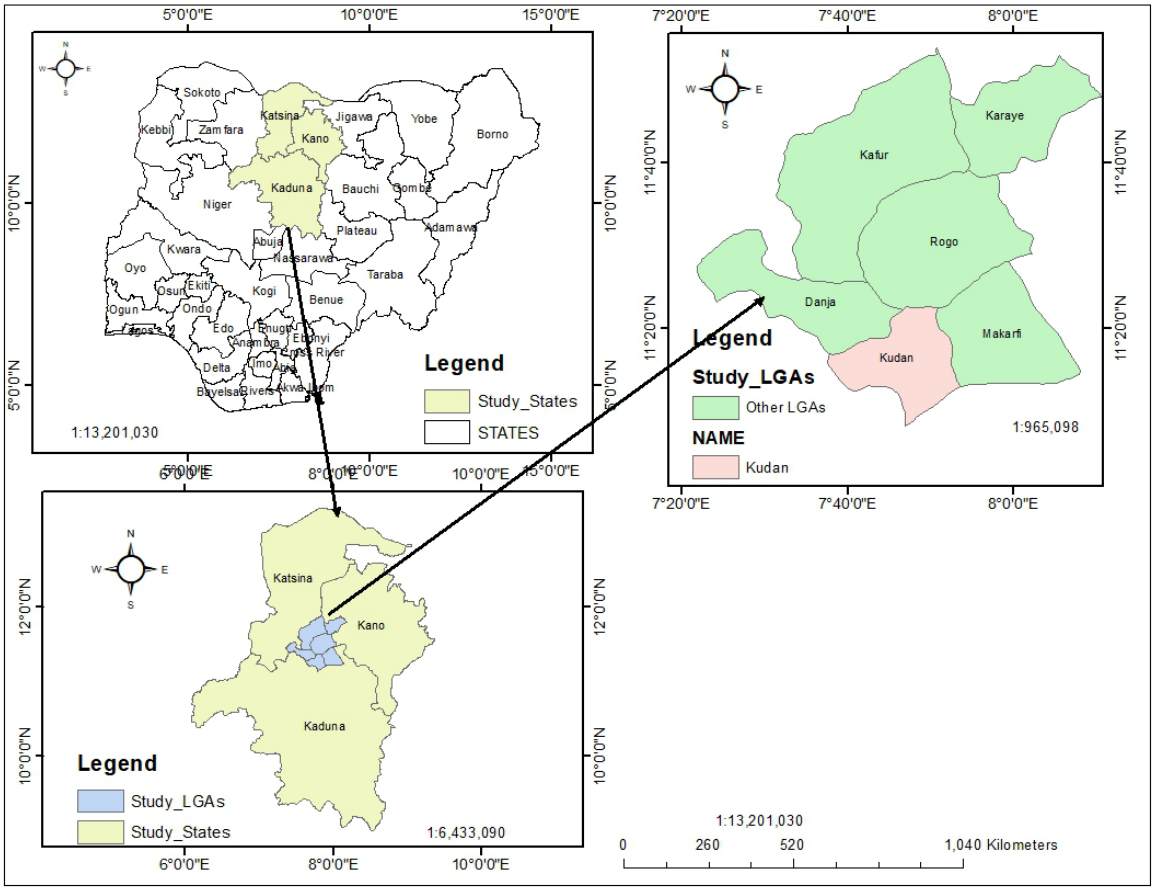


Fig. 1: Study Area Map

2.2 Data Types and Sources

Primary and secondary data were used for the study.

2.3 Primary Data:

These include the use of questionnaires loaded into ODK apps to seek information from the farmers about the conditions of their farm and their agronomic practices. The GPS coordinates of the perimeter of their farm's plots were also collected using Germine GPS receiver. The perimeter coordinates of 1080 farms were collected with the aid of handheld Globe Positioning System Receiver from six local governments (Rogo, kudan, markafi, Ranja) that lies interface between the three selected states, (Kano, Kaduna and Kastina) in Nigeria. The name of the farmer, the planted crop and phone number were documented for follow-up and yield harvest weighing and documentation as one of the major input in the yield estimate model.

2.4 Secondary Data

Satellite Images were acquired for NDVI Analysis. These include Sentinel satellite 2A and 2B and landsat 8 and Landsat 9 satellite image acquired for the study area from the planting period, may 2022 to the period of harvesting, September, 2022.

1.Sentinel satellite image: **Sentinel-2** is an Earth observation mission from the **Copernicus Programme** that systematically acquires optical imagery at high spatial resolution (10 m to 60 m) over land and coastal waters. The mission is currently a constellation with two satellites, **Sentinel-2A** and **Sentinel-2B with the two images having a revist period of 5 days and 10days as single constellation**. The mission supports a broad range of services and applications such as agricultural monitoring, emergency management, land cover classification or water quality.

2.5 Landsat Satellite Image

Since one of the major limitations of the optical remote sensor is cloud cover, we decided to acquire landsat satellite images with 30m spatial resolution that are closer to the needed date of sentinel data and are relatively free from cloud cover as a replacement for date of sentinel data that are affected by cloud. The landsat8 and landsat 9 with path 189 and row 52 and sentinel with upper right and lower left coordinates 12 N, 7E and 11 30’18.84” N and 7 48’19.64” E respectively were acquired.Table 1 below shows the acquired Sentinel and Landsat Satellite Image that were used for the study.

Table 1: Satellite Data Acquisition for the Study with dates

S/N	Satellite Image Date	Satellite Image Type	Revisit Period
1	02/05/2022	Sentinel 2A	5 days with 2B

2	07/05/2022	Sentinel 2B	5 days with 2A
3	22/05/2022	Sentinel 2A	5 days with 2B
4	27/05/2022	sentinel 2B	5 days with 2A
5	03/05/2022	Landsat 8 (OLI)	8 days with landsat 9
6	11/05/2022	Landsat 9 (OLI)	8 days with landsat 8
7	19/05/2022	Landsat 8 (OLI)	8 days with landsat 9
8	27/05/2022	Landsat 9 (OLI)	8 days with landsat 8
9	01/06/2022	Sentinel 2A	5 days with 2B
10	04/06/2022	Landsat 8 (OLI)	8 days with landsat 9
11	12/06/2022	Landsat 9 (OLI)	8 days with landsat 8
12	20/06/2022	Landsat 8 (OLI)	8 days with landsat 9
13	28/06/2022	Landsat 9 (OLI)	8 days with landsat 8
14	06/07/2022	Landsat 8 (OLI)	8 days with landsat 9
15	14/07/2022	Landsat 9 (OLI)	8 days with landsat 8
16	22/07/2022	Landsat 8 (OLI)	8 days with landsat 9
17	07/08/2022	Landsat 8 (OLI)	8 days with landsat 9
18	05/08/2022	sentinel 2A	5 days with 2B
19	10/08/2022	Sentinel 2B	5 days with 2A
20	30/08/2022	sentinel 2A	5 days with 2B
21	08/09/2022	Landsat 8 (OLI)	8 days with landsat 9
22	24/09/2022	Landsat 8 (OLI)	8 days with landsat 9

3.0 DATA ANALYSIS

The perimeter coordinates of all the farm plots were plotted as points and these were used to digitize all the farm plots as polygon using geographic information system platform. For accuracy purposes, the GPS coordinates of the perimeters of each plot taken on the field were labelled in Excel as A1, B1, C1, D1 to An, Bn, Cn, Dn. This means plot one was labelled as A1, B1, C1, D1 to plot 1080 which was labelled as A1080, B1080, C1080, D1080.

3.1 Normalized Difference Vegetation Index(NDVI)Analysis

Since one of the objectives of the study is to generate the indices that simplify Ag-statistics estimation, we therefore analysed the time series Normalised Difference Vegetation Index (NDVI) value per farm plot from planting period to harvest period.

The Normalized Difference Vegetation Index(NDVI) for the entire study area was calculated using the NDVI algorithm.

The following equation was used.

$$NDVI = \frac{\text{NIR} - \text{RED}}{NIR + RED}$$

NIR = Near infrared band of the satellite image

RED = RED band of the satellite image

In sentinel satellite image, band 8 represents Near Inrared (NIR) while band 4 represents RED. Therefore, NDVI calculation for sentinel data = band 8 - band 4/ band 8 - band 4 and for landsat data, NDVI = (band 5 - band 4)/(band 5 - band 4). This implies that NIR for landsat correspond to band 5 while RED corresponds to band 4. For the generation of average NDVI for farm plots, all the digitized farm plot polygons were overlaid on the NDVI layer for the selected LGAs and the average NDVI was generated for each plot for maize, using the zonal statistics tool within Geographic Information System Platform.

4.0 RESULTS AND DISCUSSION

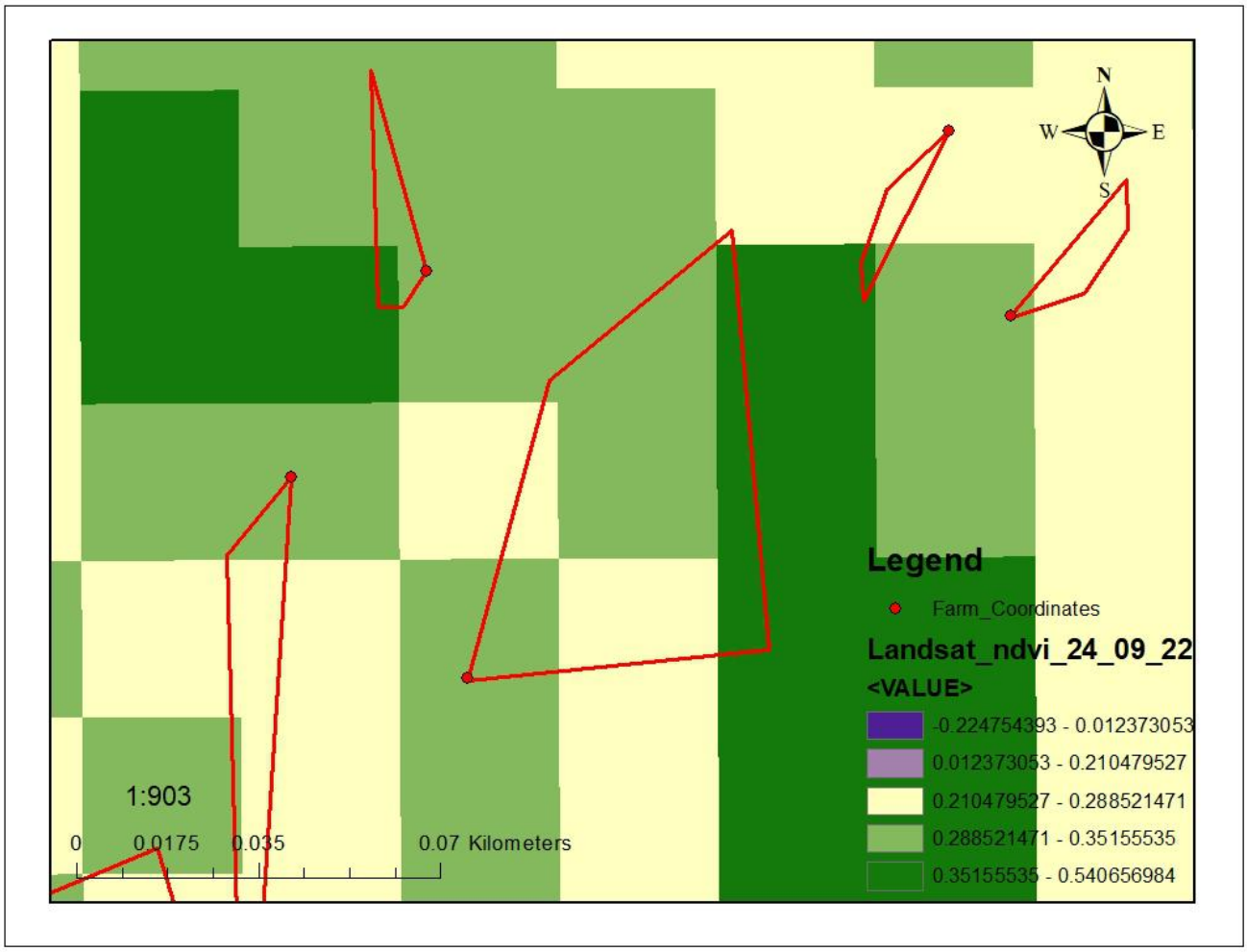
The study showed the time series NDVI for the length of the growing season for the selected crops (Maize) and the geometrically calculated area of the farm plot size. The study showed the NDVI statistics for maize from may, 2022 (day of planting period) to September 2022 (Day of harvesting period). These statistics include the mean, standard deviation, range, minimum and maximum NDVI values for all the farm plots over the growing season from the planting period to the harvesting period for the selected crops. The average NDVI value in May which marks the onset of the growing season for maize in the study area ranges from 0.044 to 0.148. In july, which represents the period of the grain filing stage ranges from 0.136 to 0.348 and in August, which is the maturity stage for harvest ranges from 0.110 to 0.450. These approaches assume that measures of the photosynthetic capacity from spectral-vegetation indices are directly related to crop yield. This assumption is used because many of the conditions that affect crop growth, development and ultimately yield could be captured through spectra measurements such as the NDVI (Tucker, (1979).

The supervised classification of the satellite image for land use landcover reveals that the cropland area for the cultivation of arable crops in the selected six LGAs is 194.973269 square Kilometer. These areas are found mostly along rivers network and near the dam area; the area with sufficient water for farming. This cropland area and other landcover classes are documented in the table 2. The figure2 below is the map showing the area for arable crop farming otherwise known as cropland area in the study area.

4.1 Limitation to the generation of the NDVI Statistical values for all the farm plots

Thetotal number of farm plots selected for the study and whose coordinates were collected are 1080 plots for the three selected crops. The zonal statistics tool within Geographic Information System platform was able to generate the NDVI statistical values for plots whose sizes are greater than the pixel size of each of the two satellite images used for the study. Landsat image has 30m by 30m spatial resolution while sentinel image has 10m by 10m

spatial resolution. This means that a single pixel of Landsat satellite image measures 30m x30m as a square pixel and sentinel measures 10m x 10m as a square pixel. NDVI values were not generated for many farm plot that is not big enough to accommodate minimum of a single pixel within it. The area of some farm plots are less than 30 meter by 30 meter in size. For that reason, the Zonal statistics tool could not generate NDVI statistics for those plots. This accounts for variations in the number of plots whose NDVI were generated. For, Sentinel image, between 250 to 327 plots were generated for the selected crop. This number becomes lesser for Landsat images because of its lower spatial resolution (30m X30m) which does not allow NDVI statistical values generation from zonal statistics for many farm plots smaller than the image pixel size of 30m by 30m as some of the farm plots sizes are lesser than 30m by 30m in area. It should be noted that for the successful generation of average NDVI for a polygon using zonal statistics, minimum of a pixel or more must fall within the polygon that represents farm plots. This is not the case for some plots in some of our plots. see picture 1 below



Picture 1 : Farm plots overlay on the landsat Pixel of 30m by 30m resolution

The bigger farm plot at the centre contains more than one pixel and average NDVI value can be calculated for it using zonal statistics, other surrounding pixels were omitted from the calculation automatically by the GIS platform tool used.

Table 2: Landuse Landcover for Mapping for Cropland Area and other land cover Estimation

Landuse Landcover classes	Area in Square Kilometer
Cropland Area	194.973269
Vegetation Area	901.76134
Grassland Area	200.8880
waterbody coverage	48.1059
Bareland Area	2417.4291
Settlement Area	64.8444
Total	3828.0021

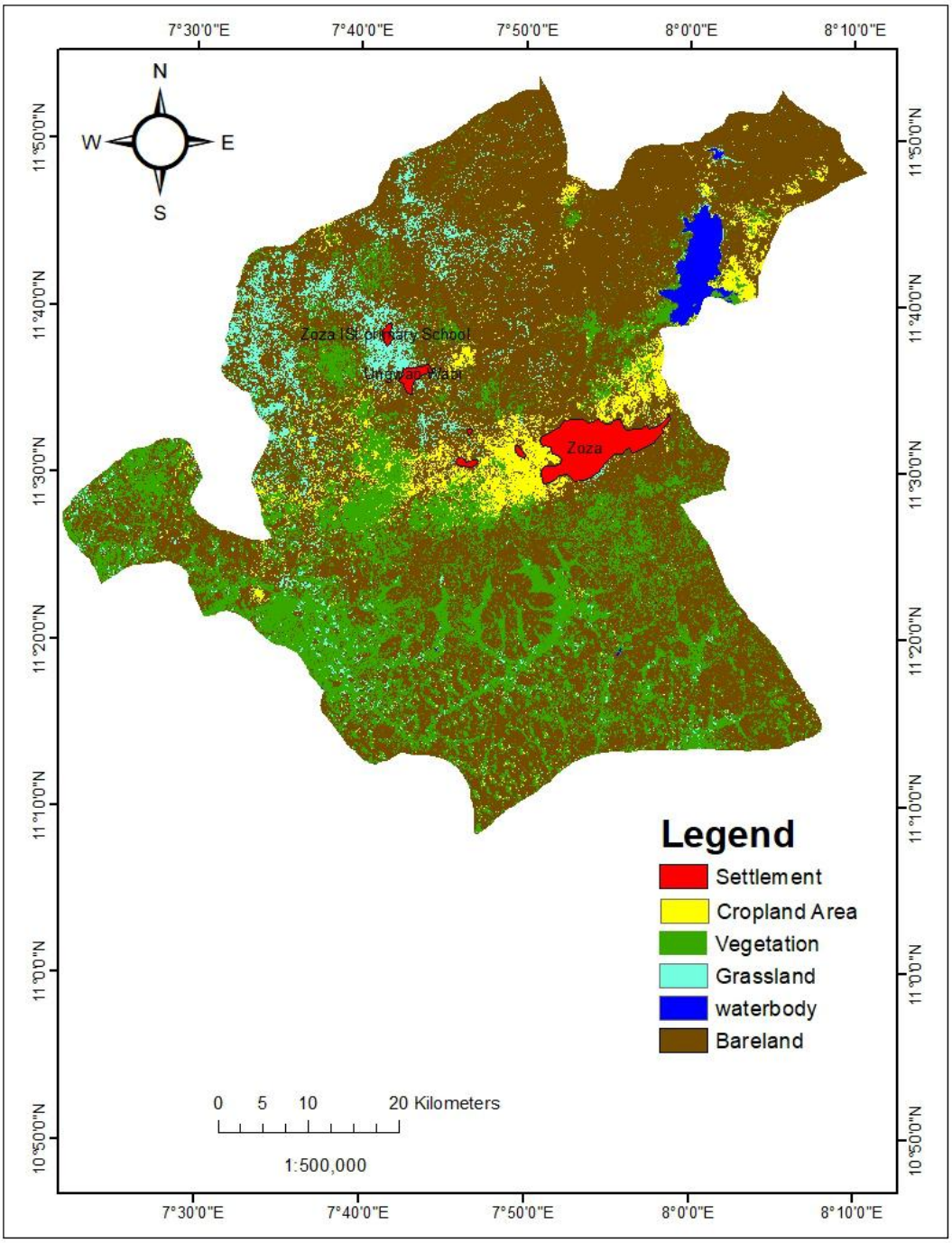


Fig2: Landcover Area Showing Cropland Area (July, 2022)

4.2. CONCLUSION

The study has successfully demonstrated the capability of NDVI model for crop monitoring and has given a guide into the calculation of cropland area quantification and yield value estimation from the field. It is therefore evident that the results of our NDVI analysis and cropland area mapping are good insights into solving national agricultural planning problems and agricultural resources allocation for effective agricultural practices for national food security.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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4.4 APENDIX: NDVI FOR 7th AUGUST 2022 of the GROWING SEASON FOR MAIZE PLOTS

PLOT_ID	MEAN	PLOT AREA	MIN	MAX	STD
A1	0.1392632	899.4543645860	0.139263212	0.139263212	0.000000000
A10	0.1417430	899.4543645860	0.141743004	0.141743004	0.000000000
A100	0.1414707	1798.908729170	0.141433715	0.141507700	0.000036992
A1004	0.1514022	1798.908729170	0.150694623	0.152109816	0.000707596
A101	0.1539230	899.4543645860	0.153923064	0.153923064	0.000000000
A1015	0.1560087	2698.363093760	0.155714184	0.156353130	0.000263219
A1016	0.1564924	899.4543645860	0.156492412	0.156492412	0.000000000
A1018	0.1466231	1798.908729170	0.145133644	0.148112699	0.001489527
A102	0.1485580	899.4543645860	0.148558035	0.148558035	0.000000000
A104	0.1770735	899.4543645860	0.177073538	0.177073538	0.000000000
A105	0.1467898	899.4543645860	0.146789848	0.146789848	0.000000000
A1054	0.1640354	1798.908729170	0.163405939	0.164665028	0.000629544
A106	0.1794838	2698.363093760	0.179123401	0.179877161	0.000308602
A108	0.2010996	899.4543645860	0.201099678	0.201099678	0.000000000
A110	0.1789280	899.4543645860	0.178928077	0.178928077	0.000000000
A113	0.1879067	1798.908729170	0.186595395	0.189218074	0.001311339
A116	0.1869886	899.4543645860	0.186988666	0.186988666	0.000000000
A118	0.1736673	1798.908729170	0.173356354	0.173978373	0.000311009
A119	0.1795077	899.4543645860	0.179507717	0.179507717	0.000000000
A12	0.1688641	1798.908729170	0.168236672	0.169491529	0.000627428

	0117	00	88	47	29
	0.1078240	1798.908729170	0.107581444	0.108066581	0.000242568
A121	1264	00	09	19	55
	0.1054482	899.4543645860	0.105448268	0.105448268	0.000000000
A132	6835	0	35	35	00
	0.1119336	899.4543645860	0.111933633	0.111933633	0.000000000
A140	3369	0	69	69	00
	0.1142557	899.4543645860	0.114255741	0.114255741	0.000000000
A144	4124	0	24	24	00
	0.1153256	899.4543645860	0.115325629	0.115325629	0.000000000
A146	2971	0	71	71	00
	0.1117607	899.4543645860	0.111760787	0.111760787	0.000000000
A148	8767	0	67	67	00
	0.1008380	899.4543645860	0.100838072	0.100838072	0.000000000
A151	7260	0	60	60	00
	0.1023880	899.4543645860	0.102388016	0.102388016	0.000000000
A152	1688	0	88	88	00
	0.0989712	899.4543645860	0.098971225	0.098971225	0.000000000
A154	2532	0	32	32	00
	0.1022058	899.4543645860	0.102205894	0.102205894	0.000000000
A157	9489	0	89	89	00
	0.1059859	899.4543645860	0.105985954	0.105985954	0.000000000
A162	5440	0	40	40	00
	0.1118674	899.4543645860	0.111867412	0.111867412	0.000000000
A164	1293	0	93	93	00
	0.2676727	899.4543645860	0.267672747	0.267672747	0.000000000
A176	4737	0	37	37	00
	0.2944973	899.4543645860	0.294497370	0.294497370	0.000000000
A18	7072	0	72	72	00
	0.2578923	899.4543645860	0.257892340	0.257892340	0.000000000
A181	4042	0	42	42	00
	0.2564497	899.4543645860	0.256449729	0.256449729	0.000000000
A184	2920	0	20	20	00
	0.2944599	1798.908729170	0.287953764	0.300966084	0.006506159
A185	2410	00	20	00	90
	0.2639781	1798.908729170	0.246442347	0.281514018	0.017535835
A188	8327	00	77	77	50
	0.3481092	1798.908729170	0.339059829	0.357158660	0.009049415
A190	4530	00	71	89	59
	0.2432977	899.4543645860	0.243297740	0.243297740	0.000000000
A2	4082	0	82	82	00
	0.2468256	899.4543645860	0.246825665	0.246825665	0.000000000
A20	6524	0	24	24	00
	0.2940159	899.4543645860	0.294015914	0.294015914	0.000000000
A209	1420	0	20	20	00
	0.2435687	899.4543645860	0.243568792	0.243568792	0.000000000
A215	9294	0	94	94	00
	0.1786318	1798.908729170	0.177984967	0.179278746	0.000646889
A217	5704	00	83	25	21
A218	0.1907712	899.4543645860	0.190771207	0.190771207	0.000000000

	0721	0	21	21	00
	0.1065455	899.4543645860	0.106545567	0.106545567	0.000000000
A219	6751	0	51	51	00
	0.1060377	899.4543645860	0.106037795	0.106037795	0.000000000
A220	9554	0	54	54	00
	0.1083665	899.4543645860	0.108366534	0.108366534	0.000000000
A221	3411	0	11	11	00
	0.1119507	899.4543645860	0.111950710	0.111950710	0.000000000
A225	1042	0	42	42	00
	0.2239962	1798.908729170	0.221857368	0.226135045	0.002138838
A228	0712	00	95	29	17
	0.2362202	899.4543645860	0.236220270	0.236220270	0.000000000
A23	7040	0	40	40	00
	0.2351121	899.4543645860	0.235112190	0.235112190	0.000000000
A231	9025	0	25	25	00
	0.1933149	1798.908729170	0.193166017	0.193463966	0.000148974
A245	9189	00	53	25	36
	0.1772187	899.4543645860	0.177218779	0.177218779	0.000000000
A248	7992	0	92	92	00
	0.1582608	899.4543645860	0.158260867	0.158260867	0.000000000
A251	6700	0	00	00	00
	0.1663357	1798.908729170	0.165015935	0.167655646	0.001319855
A256	9135	00	90	80	45
	0.1544700	899.4543645860	0.154470026	0.154470026	0.000000000
A258	2649	0	49	49	00
	0.1603875	899.4543645860	0.160387560	0.160387560	0.000000000
A26	6073	0	73	73	00
	0.0900994	899.4543645860	0.090099498	0.090099498	0.000000000
A269	9863	0	63	63	00
	0.0923493	899.4543645860	0.092349335	0.092349335	0.000000000
A27	3555	0	55	55	00
	0.0941597	1798.908729170	0.093175880	0.095143526	0.000983823
A271	0370	00	61	79	09
	0.1024291	899.4543645860	0.102429158	0.102429158	0.000000000
A276	5899	0	99	99	00
	0.0819646	899.4543645860	0.081964679	0.081964679	0.000000000
A29	7906	0	06	06	00
	0.0900202	2698.363093760	0.087844498	0.092035189	0.001714617
A292	5425	00	46	27	52
	0.0862409	1798.908729170	0.085977122	0.086504779	0.000263828
A294	5097	00	19	76	78
	0.0896488	899.4543645860	0.089648887	0.089648887	0.000000000
A295	8752	0	52	52	00
	0.0888814	899.4543645860	0.088881447	0.088881447	0.000000000
A30	4791	0	91	91	00
	0.0850185	899.4543645860	0.085018515	0.085018515	0.000000000
A300	1559	0	59	59	00
	0.2763887	1798.908729170	0.268026798	0.284750729	0.008361965
A32	6438	00	96	80	42
A327	0.3019443	899.4543645860	0.301944375	0.301944375	0.000000000

	7504	0	04	04	00
	0.3133049	899.4543645860	0.313304990	0.313304990	0.000000000
A331	9053	0	53	53	00
	0.2940585	2698.363093760	0.282645732	0.300700575	0.008106140
A34	2159	00	16	11	85
	0.3607175	899.4543645860	0.360717505	0.360717505	0.000000000
A340	0522	0	22	22	00
	0.0781956	1798.908729170	0.078014723	0.078376621	0.000180948
A381	7248	00	96	01	53
	0.3311539	1798.908729170	0.327625274	0.334682554	0.003528639
A382	1433	00	66	01	67
	0.3810048	899.4543645860	0.381004869	0.381004869	0.000000000
A385	6994	0	94	94	00
	0.4048418	1798.908729170	0.396306335	0.413377404	0.008535534
A386	7007	00	93	21	14
	0.3711358	1798.908729170	0.358738005	0.383533775	0.012397885
A387	9048	00	16	81	32
	0.2969544	2698.363093760	0.290275961	0.300701379	0.004734117
A39	4306	00	16	78	74
	0.3525764	899.4543645860	0.352576434	0.352576434	0.000000000
A391	3461	0	61	61	00
	0.3849338	899.4543645860	0.384933888	0.384933888	0.000000000
A394	8891	0	91	91	00
	0.1832554	899.4543645860	0.183255448	0.183255448	0.000000000
A4	4894	0	94	94	00
	0.2487865	899.4543645860	0.248786509	0.248786509	0.000000000
A42	0904	0	04	04	00
	0.2050148	899.4543645860	0.205014884	0.205014884	0.000000000
A421	8447	0	47	47	00
	0.3005682	899.4543645860	0.300568282	0.300568282	0.000000000
A436	8260	0	60	60	00
	0.3143346	899.4543645860	0.314334601	0.314334601	0.000000000
A441	0116	0	16	16	00
	0.2723106	899.4543645860	0.272310674	0.272310674	0.000000000
A445	7419	0	19	19	00
	0.2368475	899.4543645860	0.236847504	0.236847504	0.000000000
A448	0497	0	97	97	00
	0.2230758	899.4543645860	0.223075881	0.223075881	0.000000000
A452	8160	0	60	60	00
	0.2262417	899.4543645860	0.226241797	0.226241797	0.000000000
A453	9721	0	21	21	00
	0.2515502	1798.908729170	0.250167310	0.252933114	0.001382902
A454	1250	00	24	77	26
	0.2666009	899.4543645860	0.266600996	0.266600996	0.000000000
A458	9626	0	26	26	00
	0.2461911	899.4543645860	0.246191173	0.246191173	0.000000000
A465	7379	0	79	79	00
	0.2629489	899.4543645860	0.262948960	0.262948960	0.000000000
A476	6007	0	07	07	00
A478	0.2552485	899.4543645860	0.255248546	0.255248546	0.000000000

	4660	0	60	60	00
	0.2644546	899.4543645860	0.264454633	0.264454633	0.000000000
A487	3300	0	00	00	00
	0.2653537	1798.908729170	0.256460547	0.274246990	0.008893221
A49	6906	00	45	68	62
	0.3056749	1798.908729170	0.298307180	0.313042700	0.007367759
A490	4035	00	41	29	94
	0.2710623	899.4543645860	0.271062374	0.271062374	0.000000000
A491	7412	0	12	12	00
	0.1675620	1798.908729170	0.166769966	0.168354094	0.000792063
A494	3026	00	48	03	77
	0.1779323	1798.908729170	0.177152320	0.178712412	0.000780045
A503	6673	00	74	72	99
	0.3604594	899.4543645860	0.360459417	0.360459417	0.000000000
A509	1711	0	11	11	00
	0.3294100	1798.908729170	0.323461085	0.335359036	0.005948975
A510	6124	00	56	92	68
	0.2677836	899.4543645860	0.267783641	0.267783641	0.000000000
A52	4182	0	82	82	00
	0.1921641	899.4543645860	0.192164137	0.192164137	0.000000000
A520	3796	0	96	96	00
	0.1932516	899.4543645860	0.193251699	0.193251699	0.000000000
A522	9921	0	21	21	00
	0.1934270	899.4543645860	0.193427011	0.193427011	0.000000000
A523	1137	0	37	37	00
	0.1519773	1798.908729170	0.151560425	0.152394294	0.000416934
A531	6025	00	76	74	49
	0.1727667	899.4543645860	0.172766700	0.172766700	0.000000000
A535	0039	0	39	39	00
	0.1891041	1798.908729170	0.189000591	0.189207702	0.000103555
A537	4726	00	64	88	62
	0.0747897	899.4543645860	0.074789740	0.074789740	0.000000000
A557	4015	0	15	15	00
	0.0978068	899.4543645860	0.097806803	0.097806803	0.000000000
A56	0388	0	88	88	00
	0.0954830	899.4543645860	0.095483064	0.095483064	0.000000000
A560	6465	0	65	65	00
	0.0972578	899.4543645860	0.097257867	0.097257867	0.000000000
A562	6746	0	46	46	00
	0.0974495	2698.363093760	0.096965327	0.097856141	0.000367796
A565	6593	00	86	63	03
	0.0812341	899.4543645860	0.081234112	0.081234112	0.000000000
A57	1238	0	38	38	00
	0.0780402	1798.908729170	0.077896580	0.078183963	0.000143691
A572	7200	00	10	89	90
	0.0775295	899.4543645860	0.077529564	0.077529564	0.000000000
A574	6450	0	50	50	00
	0.2648599	899.4543645860	0.264859914	0.264859914	0.000000000
A580	1478	0	78	78	00
A586	0.2627624	899.4543645860	0.262762486	0.262762486	0.000000000

	8694	0	94	94	00
	0.3283474	899.4543645860	0.328347444	0.328347444	0.000000000
A596	4453	0	53	53	00
	0.2475049	1798.908729170	0.243904471	0.251105517	0.003600522
A598	9427	00	40	15	88
	0.3010495	899.4543645860	0.301049500	0.301049500	0.000000000
A612	0070	0	70	70	00
	0.2795512	899.4543645860	0.279551267	0.279551267	0.000000000
A619	6762	0	62	62	00
	0.2820754	899.4543645860	0.282075464	0.282075464	0.000000000
A627	6473	0	73	73	00
	0.2473604	899.4543645860	0.247360438	0.247360438	0.000000000
A631	3811	0	11	11	00
	0.2106220	899.4543645860	0.210622012	0.210622012	0.000000000
A645	1262	0	62	62	00
	0.2458127	4497.271822930	0.211835518	0.268080741	0.020584682
A65	3794	00	48	17	46
	0.2925016	899.4543645860	0.292501688	0.292501688	0.000000000
A653	8800	0	00	00	00
	0.3618157	3597.817458350	0.315601646	0.382260501	0.026882473
A655	2825	00	90	39	89
	0.2521100	899.4543645860	0.252110064	0.252110064	0.000000000
A664	6403	0	03	03	00
	0.2967952	1798.908729170	0.291230738	0.302359700	0.005564481
A669	1918	00	16	20	02
	0.3822846	899.4543645860	0.382284671	0.382284671	0.000000000
A670	7107	0	07	07	00
	0.4115418	899.4543645860	0.411541819	0.411541819	0.000000000
A671	1957	0	57	57	00
	0.3747045	899.4543645860	0.374704569	0.374704569	0.000000000
A679	6958	0	58	58	00
	0.3482075	899.4543645860	0.348207563	0.348207563	0.000000000
A695	6316	0	16	16	00
	0.3626184	899.4543645860	0.362618476	0.362618476	0.000000000
A702	7615	0	15	15	00
	0.3240834	1798.908729170	0.319859355	0.328307479	0.004224061
A703	1765	00	69	62	97
	0.3675680	899.4543645860	0.367568075	0.367568075	0.000000000
A704	7566	0	66	66	00
	0.3483874	899.4543645860	0.348387479	0.348387479	0.000000000
A708	7978	0	78	78	00
	0.3468554	899.4543645860	0.346855491	0.346855491	0.000000000
A716	9140	0	40	40	00
	0.3318323	899.4543645860	0.331832319	0.331832319	0.000000000
A718	1950	0	50	50	00
	0.3213692	2698.363093760	0.277039974	0.357625067	0.033390361
A723	3075	00	93	23	39
	0.3304028	899.4543645860	0.330402880	0.330402880	0.000000000
A736	8091	0	91	91	00
A752	0.2657377	1798.908729170	0.262022048	0.269453495	0.003715723

	7199	00	24	74	75
	0.2905255	899.4543645860	0.290525585	0.290525585	0.000000000
A764	8541	0	41	41	00
	0.2852194	1798.908729170	0.284469991	0.285968840	0.000749424
A767	1602	00	92	12	10
	0.2740775	899.4543645860	0.274077534	0.274077534	0.000000000
A770	3468	0	68	68	00
	0.2446091	899.4543645860	0.244609147	0.244609147	0.000000000
A771	4731	0	31	31	00
	0.3586227	899.4543645860	0.358622729	0.358622729	0.000000000
A775	2978	0	78	78	00
	0.2960911	1798.908729170	0.287462621	0.304719597	0.008628487
A777	0951	00	93	10	59
	0.2555826	899.4543645860	0.255582690	0.255582690	0.000000000
A778	9024	0	24	24	00
	0.2663235	899.4543645860	0.266323506	0.266323506	0.000000000
A783	0683	0	83	83	00
	0.3097887	1798.908729170	0.308473497	0.311104059	0.001315280
A800	7842	00	63	22	80
	0.3380616	1798.908729170	0.307378441	0.368744879	0.030683219
A801	6053	00	10	96	43
	0.3530162	899.4543645860	0.353016227	0.353016227	0.000000000
A81	2748	0	48	48	00
	0.3437301	899.4543645860	0.343730181	0.343730181	0.000000000
A811	8146	0	46	46	00
	0.3010810	899.4543645860	0.301081061	0.301081061	0.000000000
A812	6136	0	36	36	00
	0.3283136	899.4543645860	0.328313678	0.328313678	0.000000000
A817	7850	0	50	50	00
	0.3169731	899.4543645860	0.316973179	0.316973179	0.000000000
A818	7958	0	58	58	00
	0.3204720	899.4543645860	0.320472002	0.320472002	0.000000000
A830	0203	0	03	03	00
	0.2739541	1798.908729170	0.272949188	0.274959087	0.001004949
A832	3816	00	95	37	21
	0.2685847	899.4543645860	0.268584787	0.268584787	0.000000000
A835	8785	0	85	85	00
	0.3853896	1798.908729170	0.378596663	0.392182707	0.006793022
A836	8563	00	48	79	16
	0.2523885	899.4543645860	0.252388566	0.252388566	0.000000000
A840	6673	0	73	73	00
	0.2637764	1798.908729170	0.263487577	0.264065235	0.000288829
A841	0665	00	44	85	21
	0.3231395	899.4543645860	0.323139548	0.323139548	0.000000000
A843	4830	0	30	30	00
	0.2965815	899.4543645860	0.296581506	0.296581506	0.000000000
A844	0673	0	73	73	00
	0.3260810	899.4543645860	0.326081007	0.326081007	0.000000000
A848	0772	0	72	72	00
A859	0.2603861	899.4543645860	0.260386198	0.260386198	0.000000000

	9876	0	76	76	00
	0.2207778	899.4543645860	0.220777869	0.220777869	0.000000000
A88	6923	0	23	23	00
	0.2404508	899.4543645860	0.240450888	0.240450888	0.000000000
A885	8887	0	87	87	00
	0.2532237	899.4543645860	0.253223717	0.253223717	0.000000000
A888	1721	0	21	21	00
	0.2650983	899.4543645860	0.265098392	0.265098392	0.000000000
A89	9296	0	96	96	00
	0.2359290	899.4543645860	0.235929027	0.235929027	0.000000000
A906	2720	0	20	20	00
	0.3683323	899.4543645860	0.368332386	0.368332386	0.000000000
A914	8602	0	02	02	00
	0.3973098	899.4543645860	0.397309839	0.397309839	0.000000000
A921	3973	0	73	73	00
	0.2309571	899.4543645860	0.230957135	0.230957135	0.000000000
A963	3556	0	56	56	00
	0.2126801	899.4543645860	0.212680175	0.212680175	0.000000000
A966	7590	0	90	90	00
	0.1891135	899.4543645860	0.189113572	0.189113572	0.000000000
A975	7224	0	24	24	00
	0.1855442	1798.908729170	0.180842235	0.190246284	0.004702024
A978	5985	00	68	01	16
	0.1752572	899.4543645860	0.175257235	0.175257235	0.000000000
A991	3577	0	77	77	00
	0.1692145	1798.908729170	0.168023973	0.170405104	0.001190565
A675	3923	00	70	76	53