

# 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 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 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 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 represent the period of the grain filling 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 insight 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 condition 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 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, are Earth observation imagery. They are images of the Earth, collected by imaging satellites or Unmanned Ariel Vehicle (UAV) called drones, and these pictures form a 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 crop yield 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 and maize and rice (Manjunath *et 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 resulted in increase of some crop yield.

### **1.1 Statement of Research Problem**

There has been loss of significant maize yield to pest, disease and climate as a result of lack of improper, 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 aim of the study is to use satellite imagery to estimate 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  $11^{\circ} 8' 4.034''$  to  $11^{\circ} 53' 16.372''$  and longitude  $7^{\circ} 21' 51.831''$  to  $8^{\circ} 10' 48.902''$ . This contains the three states; Kano, Kaduna and Katsina 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  $3828.49 \text{ km}^2$ .

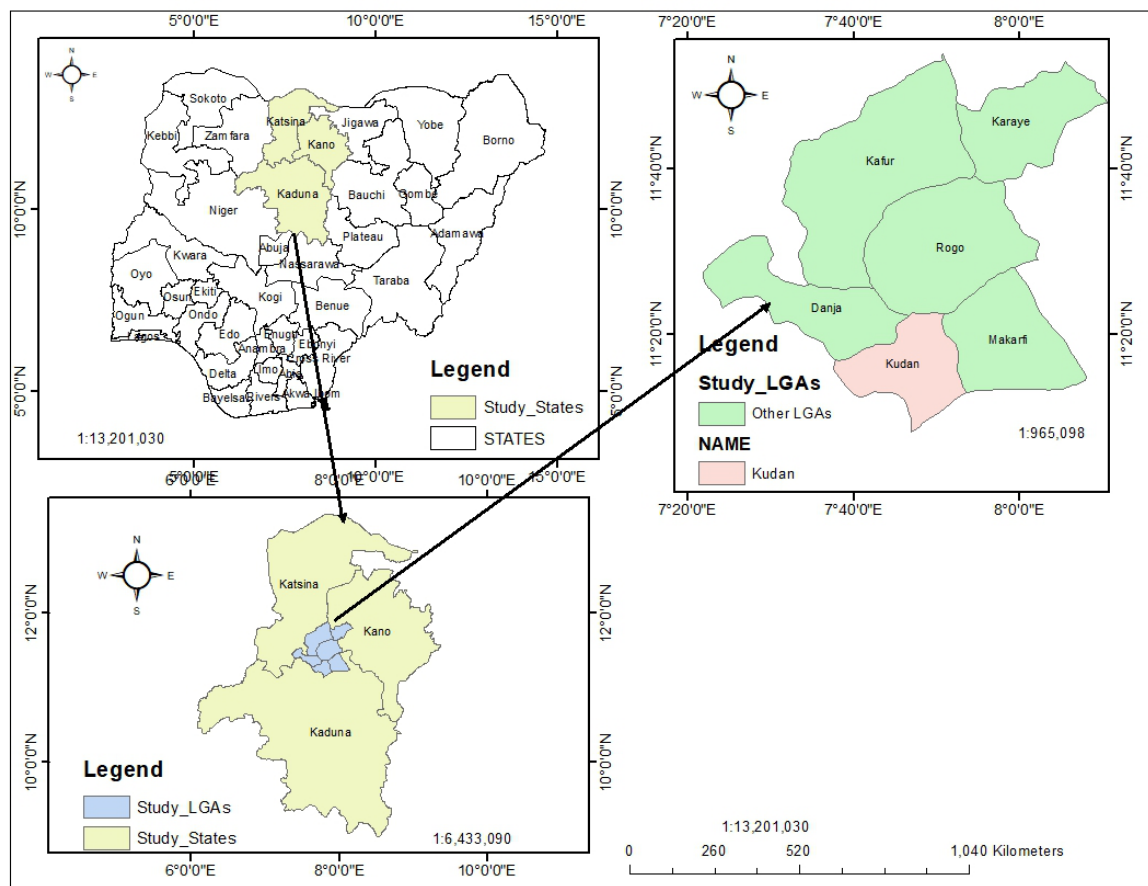


Fig. 1: Study Area Map

### 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 Germin 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 revisit period of 5 days and 10 days as single constellation**. The mission supports a broad range of services and applications such as agricultural monitoring, emergencies management, land cover classification or water quality.

### 2.5 Landsat Satellite Image

Since one of the major limitations of optical remote sensor is cloud cover, we decided to acquire Landsat satellite image 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 Landsat 8 and Landsat 9 with path 189 and row 52 and Sentinel with upper right and lower left coordinates 12°N, 7°E and 11°30'18.84"N and 7°48'19.64"E respectively were acquired. The table 2 below shows the acquired Sentinel and Landsat Satellite Image that were used for the study.

**Table 2: 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 purpose, 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 objective of the study is to generate the indices that simplify Ag-statistics estimation, we therefore analysed 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 were calculated using the NDVI algorithm.

The following equation was used.

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

NIR = Near infrared band of the satellite image

RED = RED band of the satellite image

In sentinel satellite image, band 8 represents Near Infrared (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 plots polygon 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.

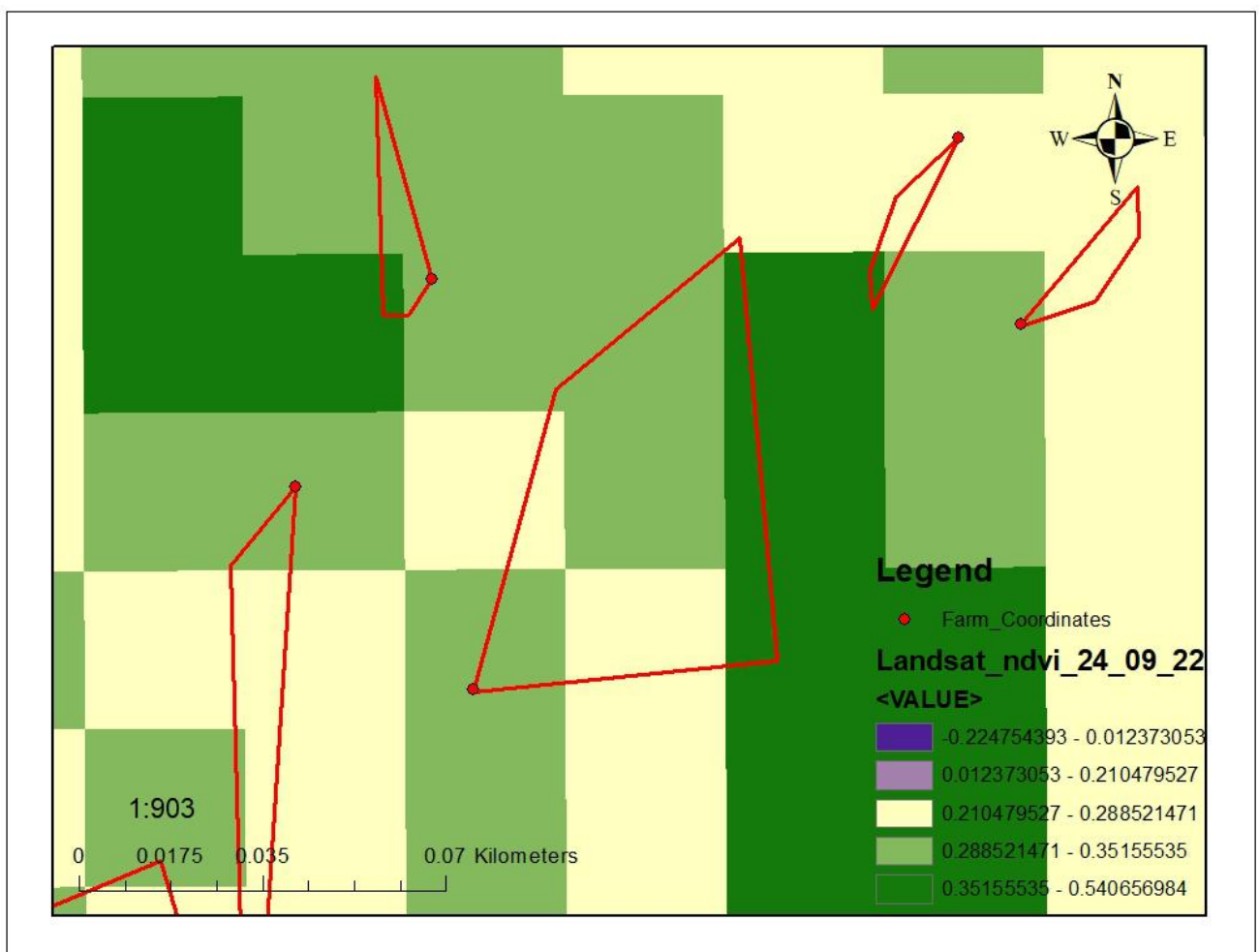
#### 4.0 RESULTS AND DISCURSION

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). This statistics include the mean, standard deviation, range, minimum and maximum NDVI values for all the farm plots over the growing season from planting period to 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 represent 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 table3. 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

The total 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 were 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 x 30m 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 account 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 image because of its lower spatial resolution (30m X 30m) 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.

**Table3: 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                |



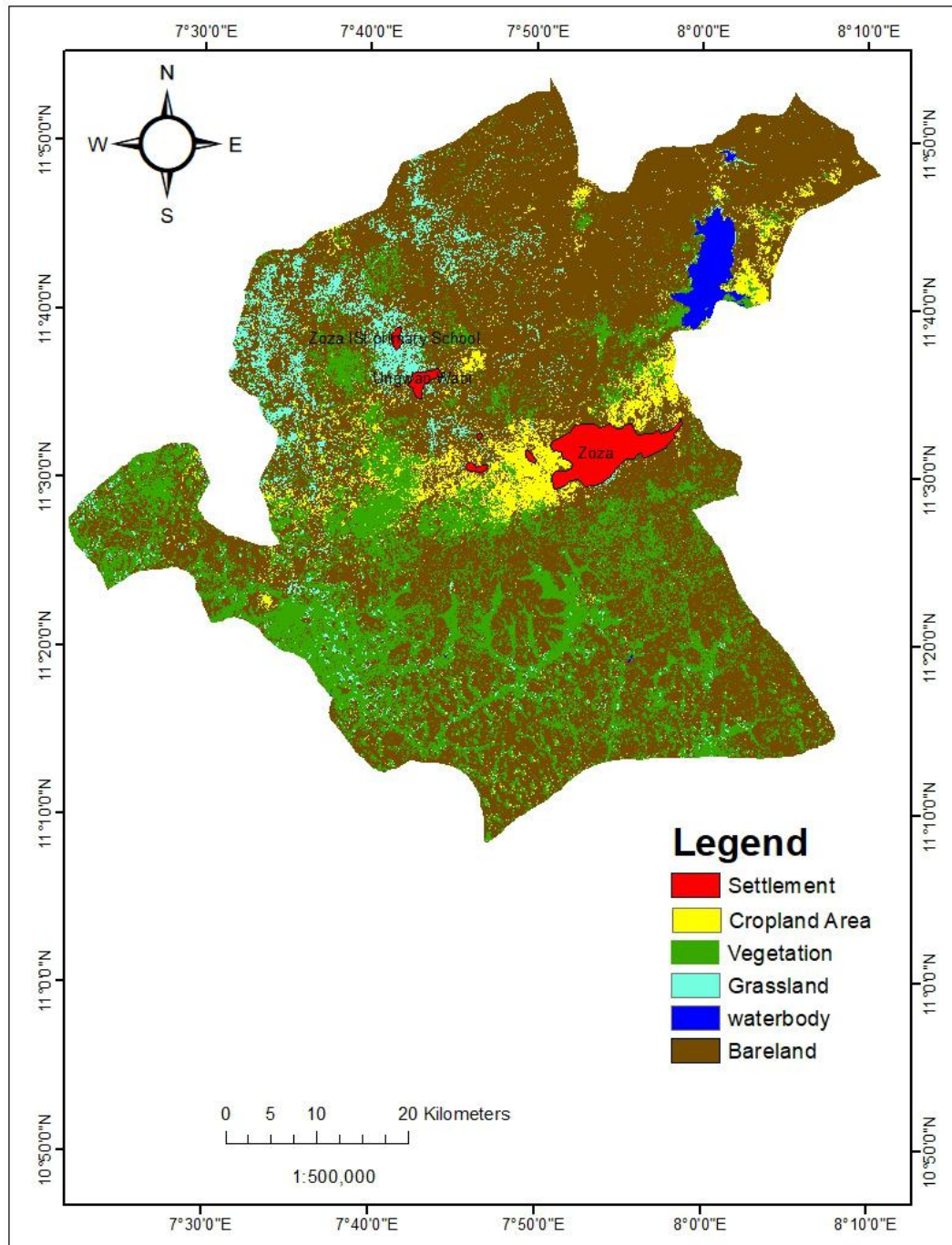


Fig2: Landcover Area Showing Cropland Area (July, 2022)

## 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 insight into solving national agricultural planning problems and agricultural resources allocation for effective agricultural practices for national food security.

#### 4.3. REFERENCE:

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#### 4.4 APENDIX: NDVI FOR 7<sup>th</sup> AUGUST 2022 of the GROWING SEASON FOR MAIZE PLOTS

| PLOT_ID | MEAN              | PLOT AREA            | MIN               | MAX               | STD               |
|---------|-------------------|----------------------|-------------------|-------------------|-------------------|
| A1      | 0.1392632<br>1268 | 899.4543645860<br>0  | 0.139263212<br>68 | 0.139263212<br>68 | 0.000000000<br>00 |
| A10     | 0.1417430<br>0432 | 899.4543645860<br>0  | 0.141743004<br>32 | 0.141743004<br>32 | 0.000000000<br>00 |
| A100    | 0.1414707<br>0795 | 1798.908729170<br>00 | 0.141433715<br>82 | 0.141507700<br>09 | 0.000036992<br>13 |
| A1004   | 0.1514022<br>2013 | 1798.908729170<br>00 | 0.150694623<br>59 | 0.152109816<br>67 | 0.000707596<br>54 |
| A101    | 0.1539230<br>6447 | 899.4543645860<br>0  | 0.153923064<br>47 | 0.153923064<br>47 | 0.000000000<br>00 |
| A1015   | 0.1560087<br>3530 | 2698.363093760<br>00 | 0.155714184<br>05 | 0.156353130<br>94 | 0.000263219<br>34 |
| A1016   | 0.1564924<br>1209 | 899.4543645860<br>0  | 0.156492412<br>09 | 0.156492412<br>09 | 0.000000000<br>00 |
| A1018   | 0.1466231<br>7187 | 1798.908729170<br>00 | 0.145133644<br>34 | 0.148112699<br>39 | 0.001489527<br>52 |
| A102    | 0.1485580<br>3549 | 899.4543645860<br>0  | 0.148558035<br>49 | 0.148558035<br>49 | 0.000000000<br>00 |
| A104    | 0.1770735<br>3830 | 899.4543645860<br>0  | 0.177073538<br>30 | 0.177073538<br>30 | 0.000000000<br>00 |
| A105    | 0.1467898<br>4880 | 899.4543645860<br>0  | 0.146789848<br>80 | 0.146789848<br>80 | 0.000000000<br>00 |
| A1054   | 0.1640354<br>8420 | 1798.908729170<br>00 | 0.163405939<br>94 | 0.164665028<br>45 | 0.000629544<br>26 |
| A106    | 0.1794838<br>0609 | 2698.363093760<br>00 | 0.179123401<br>64 | 0.179877161<br>98 | 0.000308602<br>24 |
| A108    | 0.2010996<br>7887 | 899.4543645860<br>0  | 0.201099678<br>87 | 0.201099678<br>87 | 0.000000000<br>00 |
| A110    | 0.1789280<br>7722 | 899.4543645860<br>0  | 0.178928077<br>22 | 0.178928077<br>22 | 0.000000000<br>00 |
| A113    | 0.1879067<br>3465 | 1798.908729170<br>00 | 0.186595395<br>21 | 0.189218074<br>08 | 0.001311339<br>44 |
| A116    | 0.1869886<br>6665 | 899.4543645860<br>0  | 0.186988666<br>65 | 0.186988666<br>65 | 0.000000000<br>00 |
| A118    | 0.1736673<br>6382 | 1798.908729170<br>00 | 0.173356354<br>24 | 0.173978373<br>41 | 0.000311009<br>59 |
| A119    | 0.1795077<br>1749 | 899.4543645860<br>0  | 0.179507717<br>49 | 0.179507717<br>49 | 0.000000000<br>00 |
| A12     | 0.1688641<br>0117 | 1798.908729170<br>00 | 0.168236672<br>88 | 0.169491529<br>47 | 0.000627428<br>29 |
| A121    | 0.1078240<br>1264 | 1798.908729170<br>00 | 0.107581444<br>09 | 0.108066581<br>19 | 0.000242568<br>55 |
| A132    | 0.1054482<br>6835 | 899.4543645860<br>0  | 0.105448268<br>35 | 0.105448268<br>35 | 0.000000000<br>00 |
| A140    | 0.1119336<br>3369 | 899.4543645860<br>0  | 0.111933633<br>69 | 0.111933633<br>69 | 0.000000000<br>00 |

|      |           |                |             |             |              |
|------|-----------|----------------|-------------|-------------|--------------|
|      | 0.1142557 | 899.4543645860 | 0.114255741 | 0.114255741 | 0.0000000000 |
| A144 | 4124      | 0              | 24          | 24          | 00           |
|      | 0.1153256 | 899.4543645860 | 0.115325629 | 0.115325629 | 0.0000000000 |
| A146 | 2971      | 0              | 71          | 71          | 00           |
|      | 0.1117607 | 899.4543645860 | 0.111760787 | 0.111760787 | 0.0000000000 |
| A148 | 8767      | 0              | 67          | 67          | 00           |
|      | 0.1008380 | 899.4543645860 | 0.100838072 | 0.100838072 | 0.0000000000 |
| A151 | 7260      | 0              | 60          | 60          | 00           |
|      | 0.1023880 | 899.4543645860 | 0.102388016 | 0.102388016 | 0.0000000000 |
| A152 | 1688      | 0              | 88          | 88          | 00           |
|      | 0.0989712 | 899.4543645860 | 0.098971225 | 0.098971225 | 0.0000000000 |
| A154 | 2532      | 0              | 32          | 32          | 00           |
|      | 0.1022058 | 899.4543645860 | 0.102205894 | 0.102205894 | 0.0000000000 |
| A157 | 9489      | 0              | 89          | 89          | 00           |
|      | 0.1059859 | 899.4543645860 | 0.105985954 | 0.105985954 | 0.0000000000 |
| A162 | 5440      | 0              | 40          | 40          | 00           |
|      | 0.1118674 | 899.4543645860 | 0.111867412 | 0.111867412 | 0.0000000000 |
| A164 | 1293      | 0              | 93          | 93          | 00           |
|      | 0.2676727 | 899.4543645860 | 0.267672747 | 0.267672747 | 0.0000000000 |
| A176 | 4737      | 0              | 37          | 37          | 00           |
|      | 0.2944973 | 899.4543645860 | 0.294497370 | 0.294497370 | 0.0000000000 |
| A18  | 7072      | 0              | 72          | 72          | 00           |
|      | 0.2578923 | 899.4543645860 | 0.257892340 | 0.257892340 | 0.0000000000 |
| A181 | 4042      | 0              | 42          | 42          | 00           |
|      | 0.2564497 | 899.4543645860 | 0.256449729 | 0.256449729 | 0.0000000000 |
| 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 | 0.0000000000 |
| A2   | 4082      | 0              | 82          | 82          | 00           |
|      | 0.2468256 | 899.4543645860 | 0.246825665 | 0.246825665 | 0.0000000000 |
| A20  | 6524      | 0              | 24          | 24          | 00           |
|      | 0.2940159 | 899.4543645860 | 0.294015914 | 0.294015914 | 0.0000000000 |
| A209 | 1420      | 0              | 20          | 20          | 00           |
|      | 0.2435687 | 899.4543645860 | 0.243568792 | 0.243568792 | 0.0000000000 |
| A215 | 9294      | 0              | 94          | 94          | 00           |
|      | 0.1786318 | 1798.908729170 | 0.177984967 | 0.179278746 | 0.000646889  |
| A217 | 5704      | 00             | 83          | 25          | 21           |
|      | 0.1907712 | 899.4543645860 | 0.190771207 | 0.190771207 | 0.0000000000 |
| A218 | 0721      | 0              | 21          | 21          | 00           |
|      | 0.1065455 | 899.4543645860 | 0.106545567 | 0.106545567 | 0.0000000000 |
| A219 | 6751      | 0              | 51          | 51          | 00           |
|      | 0.1060377 | 899.4543645860 | 0.106037795 | 0.106037795 | 0.0000000000 |
| A220 | 9554      | 0              | 54          | 54          | 00           |
|      | 0.1083665 | 899.4543645860 | 0.108366534 | 0.108366534 | 0.0000000000 |
| A221 | 3411      | 0              | 11          | 11          | 00           |

|      |           |                |             |             |              |
|------|-----------|----------------|-------------|-------------|--------------|
|      | 0.1119507 | 899.4543645860 | 0.111950710 | 0.111950710 | 0.0000000000 |
| 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 | 0.0000000000 |
| A23  | 7040      | 0              | 40          | 40          | 00           |
|      | 0.2351121 | 899.4543645860 | 0.235112190 | 0.235112190 | 0.0000000000 |
| 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 | 0.0000000000 |
| A248 | 7992      | 0              | 92          | 92          | 00           |
|      | 0.1582608 | 899.4543645860 | 0.158260867 | 0.158260867 | 0.0000000000 |
| 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 | 0.0000000000 |
| A258 | 2649      | 0              | 49          | 49          | 00           |
|      | 0.1603875 | 899.4543645860 | 0.160387560 | 0.160387560 | 0.0000000000 |
| A26  | 6073      | 0              | 73          | 73          | 00           |
|      | 0.0900994 | 899.4543645860 | 0.090099498 | 0.090099498 | 0.0000000000 |
| A269 | 9863      | 0              | 63          | 63          | 00           |
|      | 0.0923493 | 899.4543645860 | 0.092349335 | 0.092349335 | 0.0000000000 |
| 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 | 0.0000000000 |
| A276 | 5899      | 0              | 99          | 99          | 00           |
|      | 0.0819646 | 899.4543645860 | 0.081964679 | 0.081964679 | 0.0000000000 |
| 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 | 0.0000000000 |
| A295 | 8752      | 0              | 52          | 52          | 00           |
|      | 0.0888814 | 899.4543645860 | 0.088881447 | 0.088881447 | 0.0000000000 |
| A30  | 4791      | 0              | 91          | 91          | 00           |
|      | 0.0850185 | 899.4543645860 | 0.085018515 | 0.085018515 | 0.0000000000 |
| A300 | 1559      | 0              | 59          | 59          | 00           |
|      | 0.2763887 | 1798.908729170 | 0.268026798 | 0.284750729 | 0.008361965  |
| A32  | 6438      | 00             | 96          | 80          | 42           |
|      | 0.3019443 | 899.4543645860 | 0.301944375 | 0.301944375 | 0.0000000000 |
| A327 | 7504      | 0              | 04          | 04          | 00           |
|      | 0.3133049 | 899.4543645860 | 0.313304990 | 0.313304990 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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          |
|      | 0.2552485 | 899.4543645860 | 0.255248546 | 0.255248546 | 0.000000000 |
| A478 | 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 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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 | 0.0000000000 |
| A52  | 4182      | 0              | 82          | 82          | 00           |
|      | 0.1921641 | 899.4543645860 | 0.192164137 | 0.192164137 | 0.0000000000 |
| A520 | 3796      | 0              | 96          | 96          | 00           |
|      | 0.1932516 | 899.4543645860 | 0.193251699 | 0.193251699 | 0.0000000000 |
| A522 | 9921      | 0              | 21          | 21          | 00           |
|      | 0.1934270 | 899.4543645860 | 0.193427011 | 0.193427011 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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 | 0.0000000000 |
| A557 | 4015      | 0              | 15          | 15          | 00           |
|      | 0.0978068 | 899.4543645860 | 0.097806803 | 0.097806803 | 0.0000000000 |
| A56  | 0388      | 0              | 88          | 88          | 00           |
|      | 0.0954830 | 899.4543645860 | 0.095483064 | 0.095483064 | 0.0000000000 |
| A560 | 6465      | 0              | 65          | 65          | 00           |
|      | 0.0972578 | 899.4543645860 | 0.097257867 | 0.097257867 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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 | 0.0000000000 |
| A574 | 6450      | 0              | 50          | 50          | 00           |
|      | 0.2648599 | 899.4543645860 | 0.264859914 | 0.264859914 | 0.0000000000 |
| A580 | 1478      | 0              | 78          | 78          | 00           |
|      | 0.2627624 | 899.4543645860 | 0.262762486 | 0.262762486 | 0.0000000000 |
| A586 | 8694      | 0              | 94          | 94          | 00           |
|      | 0.3283474 | 899.4543645860 | 0.328347444 | 0.328347444 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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          |
|      | 0.2657377 | 1798.908729170 | 0.262022048 | 0.269453495 | 0.003715723 |
| A752 | 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 | 0.0000000000 |
| A771 | 4731      | 0              | 31          | 31          | 00           |
|      | 0.3586227 | 899.4543645860 | 0.358622729 | 0.358622729 | 0.0000000000 |
| 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 | 0.0000000000 |
| A778 | 9024      | 0              | 24          | 24          | 00           |
|      | 0.2663235 | 899.4543645860 | 0.266323506 | 0.266323506 | 0.0000000000 |
| 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 | 0.0000000000 |
| A81  | 2748      | 0              | 48          | 48          | 00           |
|      | 0.3437301 | 899.4543645860 | 0.343730181 | 0.343730181 | 0.0000000000 |
| A811 | 8146      | 0              | 46          | 46          | 00           |
|      | 0.3010810 | 899.4543645860 | 0.301081061 | 0.301081061 | 0.0000000000 |
| A812 | 6136      | 0              | 36          | 36          | 00           |
|      | 0.3283136 | 899.4543645860 | 0.328313678 | 0.328313678 | 0.0000000000 |
| A817 | 7850      | 0              | 50          | 50          | 00           |
|      | 0.3169731 | 899.4543645860 | 0.316973179 | 0.316973179 | 0.0000000000 |
| A818 | 7958      | 0              | 58          | 58          | 00           |
|      | 0.3204720 | 899.4543645860 | 0.320472002 | 0.320472002 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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 | 0.0000000000 |
| 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 | 0.0000000000 |
| A843 | 4830      | 0              | 30          | 30          | 00           |
|      | 0.2965815 | 899.4543645860 | 0.296581506 | 0.296581506 | 0.0000000000 |
| A844 | 0673      | 0              | 73          | 73          | 00           |
|      | 0.3260810 | 899.4543645860 | 0.326081007 | 0.326081007 | 0.0000000000 |
| A848 | 0772      | 0              | 72          | 72          | 00           |
|      | 0.2603861 | 899.4543645860 | 0.260386198 | 0.260386198 | 0.0000000000 |
| A859 | 9876      | 0              | 76          | 76          | 00           |
|      | 0.2207778 | 899.4543645860 | 0.220777869 | 0.220777869 | 0.0000000000 |
| A88  | 6923      | 0              | 23          | 23          | 00           |
|      | 0.2404508 | 899.4543645860 | 0.240450888 | 0.240450888 | 0.0000000000 |
| A885 | 8887      | 0              | 87          | 87          | 00           |
|      | 0.2532237 | 899.4543645860 | 0.253223717 | 0.253223717 | 0.0000000000 |
| 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          |