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| RESEARCH ARTICLE

Paper Title:

PHENOLOGY OF IRISH POTATOES IN FIVE LGAS IN PLATEAU STATE, NIGERIA USING MODIS SATELLITE IMAGERY AND NDVI

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| ABSTRACT

The in-ability of the vast majority of potato farmers in the five sampled LGAs of Plateau state to properly harness the rich climatic condition and get to know when and where to plant or grow, the required quantity and specific seedling to plant and expected yield with date of harvest; were what motivated this study.

| KEYWORDS

Modis, ndvi, savi, cavi, csavi

| ARTICLE INFORMATION

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Abstract

The in-ability of the vast majority of potato farmers in the five sampled LGAs of Plateau state to properly harness the rich climatic condition and get to know when and where to plant or grow, the required quantity and specific seedling to plant and expected yield with date of harvest; were what motivated this study. This article leveraged on the use of remote sensing data, Moderate Resolution Imaging Spectro-Radiometer and Normalized Difference Vegetation Index (MODIS and NDVI) and models from which a timely calendar for potato farmers in the sampled areas were generated. MODIS was used for modeling and predicting potato farming, while the result of NDVI was used to determine the revealed variation in climate, time, temperature, soil moisture content, greenness of land, extent of crop in term of acreage, etc. The single average vegetation index (SAVI) created a scenario whereby a single NDVI data applied on a specified acreage of potato land under investigation in order to make predictions and model for that particular portion. But, the coefficient of normarlized difference vegetation index (CNDVI) allows for comparing correlation coefficient of two or more NDVIs in order to draw inference and predict/model accurately; while coefficient of single average vegetation index (CSAVI) was used to assert if the coefficient of the phenology calendar for a single crop in a specified location, whether it is true or false, and if it is true, then the hypothesis were inferred and applied as such. Subsequently, the resultwas interpreted into the local languages in order to benefit the vast majority of the local potato farmers that are not literate in English language. This formed a foundation for both the farmers and policy makers to formulate informed decision or policy to harness these inherent potentials.

Introduction:-

This article was poised by the in-ability of the vast majority of Irish potato farmers over many years to accurately predict cyclic and seasonal natural phenomena, especially in relation to climate and Irish potato including other plants. There are two air masses originating from the Atlantic ocean). These two air masses meet at the inter- tropical e(I.TC.Z) [2, 1] and it is the seasonal movement of these fronts that determine the climate of the areas under investigation.

It was further asserted that, the climate of the study area is tropical wet and dry type (Aw–Koppen classification), with evidence of oscillation in climatic elements which are believed to have been in the past [1]. Furthermore, the climate is largely influenced by the movement of trade winds, which are the West Africa Monsoon (the dry desiccating air mass emanating from the Sahara desert and the maritime air mass originating from the Atlantic ocean). These two air masses meet at the inter–tropical continental zone (I.TC.Z) and it is the seasonal movement of these fronts that determine the climate of the areas under investigation [1]. But, the result of the correlation between the NDVI [2,3,4] value per LGA and potato yield or not revealed is positive; therefore the prediction is correct, except otherwise.It is against the aforementioned that, this article seeks to harness all these natural endowment and favourable conditions for potato farmers in order to maximize its production and other leguminous plants and move away from subsistence to full-blown commercial by using a scientifically prepared annual planting calendar [3, 5, 6] (phenology) showing when, where and type of seedling to plant, when and expected yield [7, 8, 9, 10].

2. Related Work

The study areas had soil properties that vary both in spatial and temporal dimension; and it was said such variations depicted systematic changes as a function of geology and derived from landforms, soil parent materials and soil management practices [34]; and it was also asserted the effects of partial replacement of soil sand with lateritic soil [1]. Therefore, soil derived from basaltic rocks under tropical and sub – tropical environments such as the study areas were reported [26] to have contained kaolinite and sesquioxide as the major clay constituents and are variously classified as oxisols, Utisols and Alfisols. There are parent rocks in the five LGAs of study responsible majorly for the rich mineral soils which is responsible for the growth of potatoes; and these parent rocks include basaltic rocks, biotite-granites, Alluvium and unconsolidated quartz deposits and granite – geiss says, [29]. Whereas, the vegetation of the study areas was largely determined by the climatic condition which include soil, topography and rainfall; that is why vegetation of the study areas are of different species of plants grown possessing certain general physical appearance [33]. While the species composition is important, it is the spatial arrangement of the different plants that really defines the vegetation [35]. However, the natural vegetation of the study areas in question is the savannah type and it lies within what is known as the guinea savannah vegetation. It is mostly characterized with tall trees and leaf foliage which protects the soils from excessive direct heat of the sun and also serve as control of erosion [2, 30]. Moreover, topography and the type of drainage pattern of the study areas is perculiar and its unique physical features are its high relief. There are great peaks like the Shere hills (1829m), extinct volcanoes crater lakes like the Miango twin hills (Bassa LGA) and the Kerang volcanoes and crater lakes (Mangu LGA).

3. Study area, Material and Method:-

3.1. Study Area

The study areas were located in the two contiguous senatorial districts of Plateau State (i.e. Northern and Central), Nigeria where potato survival is guaranteed with a high yield and favorable weather conditions. The LGAs are: Jos South, Barkin Ladi, Riyom (Northern zone), Bokkos and Mangu (Central district).Jos South LGA was carved out of the then Jos LGA in 1991. It is situated 15km south of the state capital with its headquarter located in Bukuru at $9^0$48'00"N$8^0$52'00"E. It has an area of 510km^2 and a population of 311,392 by the 2006 census. It is upland with undulating hills, mountains, forest reserves, rivers, settlements, fertile agricultural land for dry and wet season farming. The people are predominantly farmers for subsistence and commercial purposes. Barkin Ladi LGA is located at $9^0$32'00"N$8^0$54'00"E. It has land area of 1032km2 and a population of 311,392 as at the 2006 census. The area enjoys a temperate climate with two seasons; the rainy and dry seasons which falls from March to October and from November to February of each year. The people of Riyom LGA are mainly farmers of all seasons. Assop waterfalls was a great advantage to potato farmers all throughout the year. It is located along 9^0 36'N and 8^0 40'E.Bokkos LGA is located in the central zone of the state at 9^0 18' 00''N and 9^0 00' 00''E with a total land area of 1,682kmsq and population of 178,454 as at 2006 census. It is approximately 78km away from the state capital (Jos). Majority of the inhabitants are potato farmers over the years and in the late 1990s, because of the peculiarity in weather condition, a popular type of tomatoes are grown in commercial quantity in addition to potatoes. While Mangu LGA is approximately located along longitude 9^0 31' 00''N and latitude 9^0 06' 00''E, with a total land area of 1,653kmsq and a population of 294,931as at 2006 population and housing census. The vast majority of the inhabitants are actively engaged in farming of grains and potatoes in commercial quantity that are being transported to the southern part of Nigeria and even outside Nigeria. Figure 1 below revealed the geographical location of the study on the map of Plateau State.

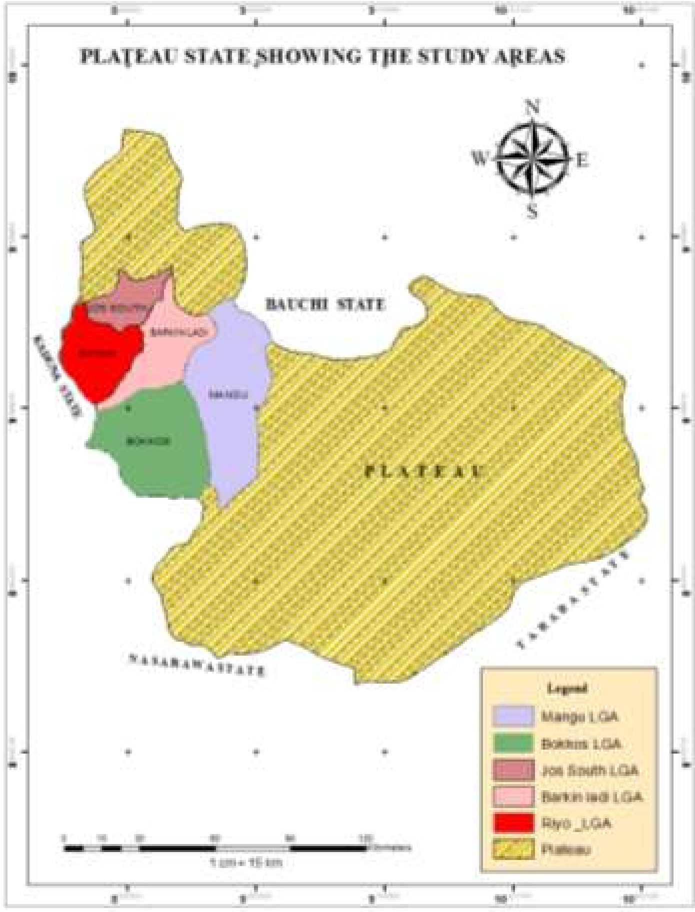

Figure 1. Geographic Location of the Study
Source: Author's Field Work (2025)

3.2. Material:-

The material used for phenological stages must be defined exactly in order to have comparable observations. There is difference between phenological stage and phonological phase. Phenological stage is a single point during development, such as full bloom, while phenological phase is the time between two stages, such as grain filling of wheat. Data from a single location can be valuable if they exist for a long run of years (usually more than 20 years). Phenological data often exist in a paper form, not in the format suitable for scientific work, particularly for this study areas. Therefore, moderate resolution imaging spectro-radiometer (MODIS) dataat 250meter resolution was used for the study from January, February, March and April of the year of study acquired from NASA web site. Figure 2 below shows the process of MODIS image downloading.

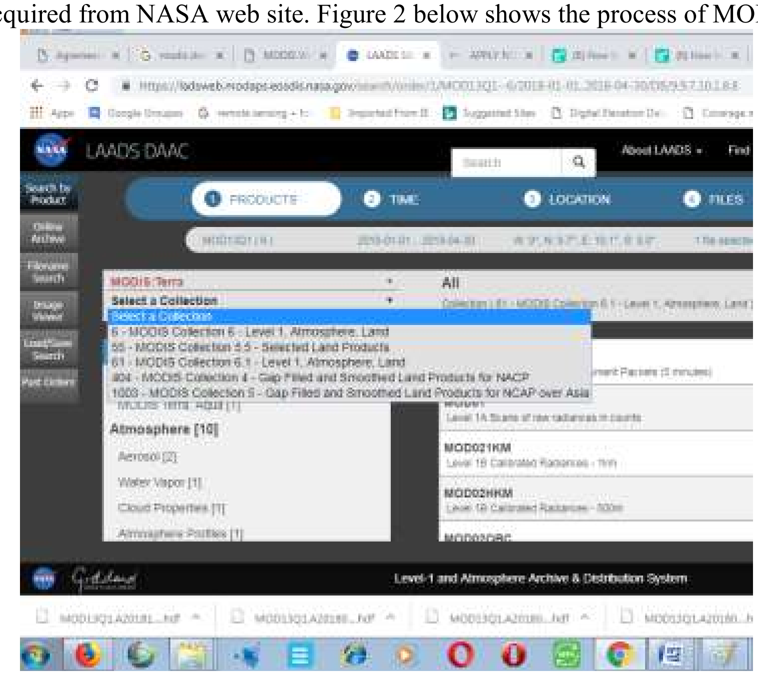

Figure 2.MODIS Satellite Image Download of the study areas

Source: Author’s Labwork (2025)

Figure 3 below is the Level-1 andAtmosphere Archive & distribution system at prompt of the LandSat web page. This was where time was set before the extraction of data was carried out pixel by pixel according to zone within the study areas.

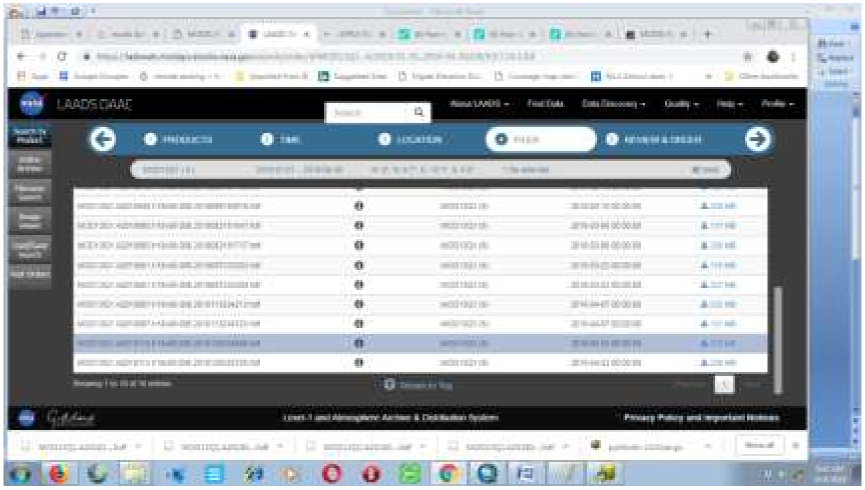

Figure 3.Level-1 and Atmosphere Archive & Distribution System

Source: Author’s Labwork (20245

3.3. Method:-

At prompt of NASA web page, Terra, land products be selected and the time was setfrom January to April. Cennter coordinate of thestudy area was set at the download option window and it was chosen for image download on my web browser.The next step is to importinto ArcGIS by saving the MODIS import dataas a hierarchical data format (HDF) in order to make data integration accessible in the ArcGIS enviroment. The HDF file contains multiple datasets from January to Apriland their NDVIs. At least one must be selected at a time for a single raster layer, but selecting multiple data sets allows display of group layer or RGB/NIR. However, selection of one month after the other at an interval of sixteen (16) days for VI weeks was carried out before data extraction by pixel. Each data set reveals the resolution, reflectance value and the grid. The MODIS and the NDVI chosen for this study is shown below in figure 4;

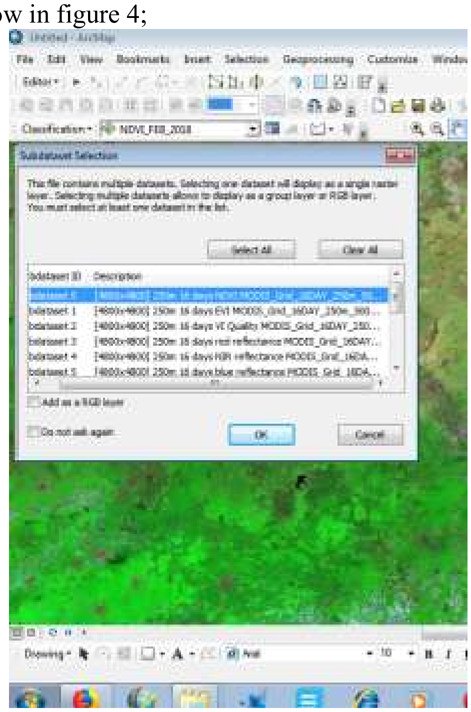

Figure 4.MODIS and NDVI selected for the study.

Source: Author’s Labwork (2025)

Extracting the study area

The bounday shapefile of the study area was used to clip out the MODIS and NDVI portion of the study area fromthe option 'Clip Tool from 'Raster' processing in ArcGIS 10.1 The data management was carried out in order to operate the clipping of MODIS data. Figure 5 is the result of the clipped data sets of the study areas as revealed below

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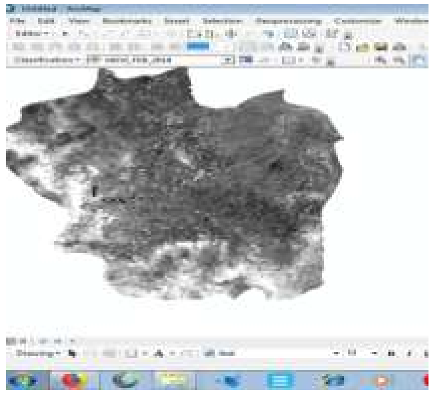


Figure 5.Clipped Dataset of the study areas.

Source:Author's Labwork (2025).

Data filtering

The high level of noise present in MODIS data often makes it difficult to determine the number of annual seasons and for this reason, smoothened NDVI data was used instead of raw NDVI series. The noise may be due to instrumentation behavioral, changes in sensor angle, atmospheric conditions (cloud and haze) and ground conditions: hence filtering. In order to filter, there are two basic steps: the first is to smoothen the NDVI value that was deployed provided it is within a certain range and in this case, a threshold of 20 percent was used as suggested by Viovy et al., (1992). But, if the subsequent value is beyond the threshold value then it is replaced by average of previous and next NDVI value. The idea is that sudden rises and falls in NDVI are not compatible with the gradual process of growth, but may be due to departure in environmental conditions or viewing geometry. This eliminated a high frequency 'noise' related changes and allows genuine changes in NDVI to be represented. This was followed by 13-point Gaussian filtering and most importantly, it is a weighted low- pass filter in time domain. Thus, the two-steps of filtering NDVI series adopted eliminated unrealistic changes and output of a smooth NDVI series and smoothened series was used subsequently jn the analysis.

Furthermore, refining the study land use and land cover (LULC) mask provided from the smoothened NDVI data in the database was used and it is expedient. These LULC was made by image classification and agricultural layers were created for making agriculture mask for the five selected LFAs. In using this agriculture mask non-agriculture pixels were omitted for further analysis. Bht, MODIS Color Composite for the five study areas was carried-out; the band Composite of Red band, the Nearest Infra Red(NIR) band andblue bandwere assigned to RGB Color Composing respectively. The Color composite tool under raster processing in ArcGIs 10.1 data mangement was used to operate the composite image. This was achieved by DODGING, i.e. change each pixel's value towards a target color. With this technique, it is also a must to choose the type of target color surface, which affects the target color. Dodging tends to give the best result in most cases. Figure 6 below is the resultant effect of MODIS color composite for the study area

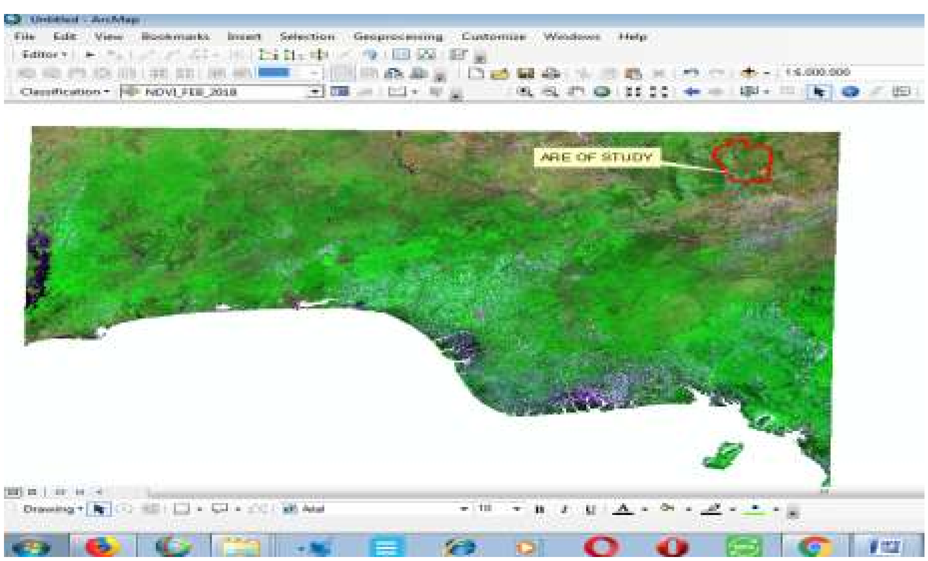


Figure 6.MODIS color composite of the study area by Dodging.

Source: Author's Labwork (2025)

Although, the available NDVI data sets were corrected for gaseous and aerosol scattering, the thick clouds still remain as noise says, Los et al., (1994); hence the need to compute the required NDVI and its generation. This was done to remove the data affected by thick cloud information on quality control flags, the MODIS file was used credited to Xiao et al., (2005). Crops exhibits distinctive seasonal patterns and the NDVI time series data was used to dynamically reflect crop growth and track crop phenological metrics change, because of the positive correlation between NDVI and Leaf Area Index (LAI) asserted by, Jakubauskas et al, (2001). The map algebra , raster calculation was accomplished in ArcGIS 10.1 and it was used to calibrate the NDVI in the normal value .The MODIS and NDVI wasmultiplied by 0.0001 to compute the normal value of the NDVI as revealed in figure 7 below;

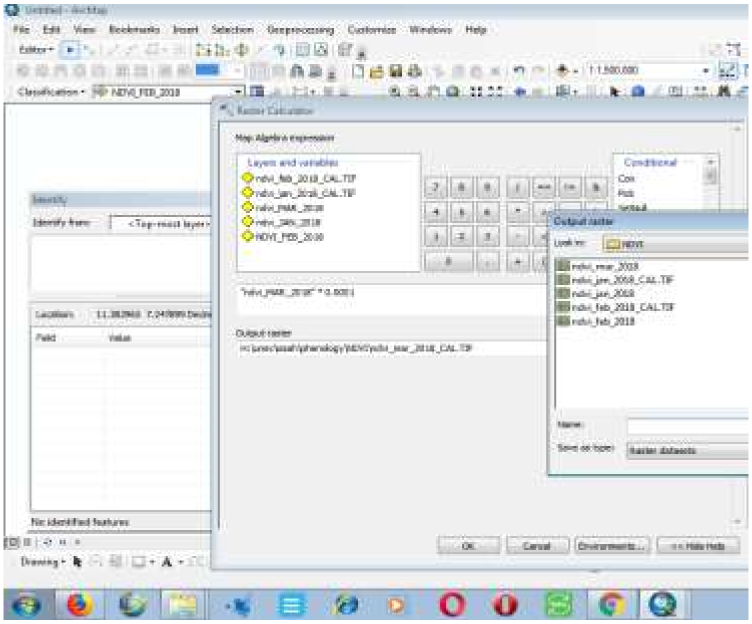


Figure 7.Calculating required NDVI and generation in ArcGIS.
Source: Author's Labwork (2025)

The next was the computation of statistical table for the NDVI images carried-out by reclassification using reclassify option of ArcGIS 10.1 spatial analyst tool. A unique ID were assigned to the NDVI value for proper reclassification of the value 1, which was given to the range of Very Low (VL), 2 to Low, 3 to Medium and 4 for High Value (HV) of NDVI. The LGAs boundaries were used for the zonal analysis since their NDVI vary by local government areas. The zonal statistical table option in Zonal tool of ArcGIS 10.1 Spatial analyst was used to compute the zonal statistics. The count is the quantity of crop in the study, area per LGA which was computed, for both minimum and maximum: and the mean value of the NDVI value within each LGA were also calculated, then the sum total of the NDVI value within each LGA were calculated using zonal statistical tool. It was exported to Microsoft Excel in order to compute the statistical table and graph, as revealed in figure 8 below and figure 9 respectively;

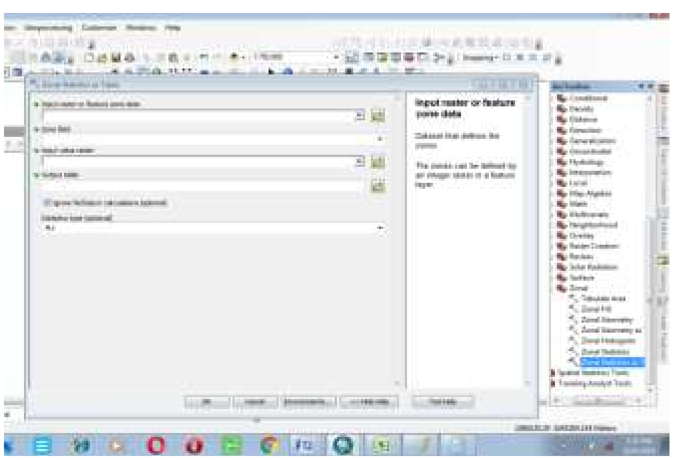


Figure 8.Computation of Zonal Statistics in ArcGIS. .
Source: Author's Labwork (2024)

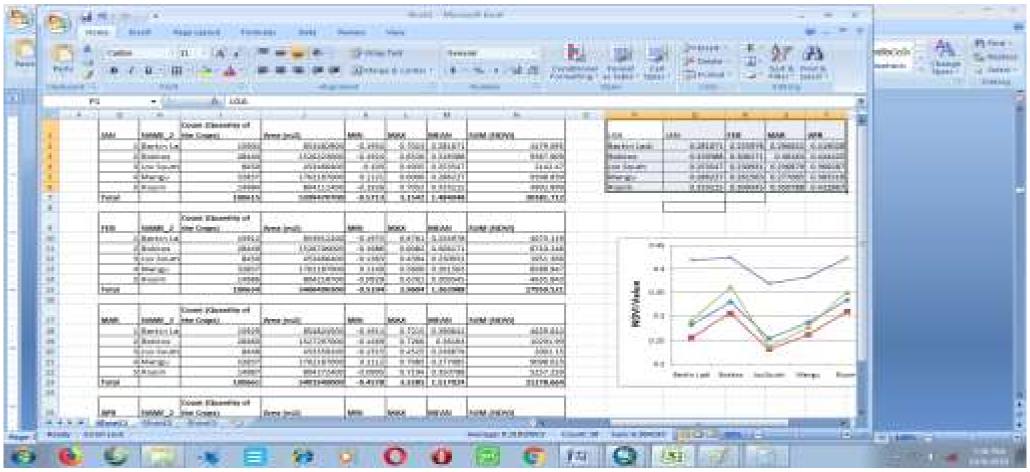


Figure 9.NDVI Value Computation per LGA in MS-Excel.
Source Author's Labwork (2025)

4. Result and Discussion:-

The NDVI for potato yield prediction was collected for five different fields from the pre-allocated points at each LGA of the study area analyzed to assess the spatial variability of the yield and the productivity at different zones within one field then compared with the remaining four fields. Each prediction must be handled as sensor and location specific in order to reveal the variability in the spatial yield. But, in general the low-growth stage (0–30 days after planting) was found to be the best time for it.

Output 1NDVI in January, 2024

Table 1 below presents some statistics of the collected potato NDVI for January, 2018 which served as benchmark for the study: Please note that, each count (quantity), is equivalent to 30 x 30 pixel.

Table 1. Greeness benchmark prediction of the study area.

JAN	Greenness	Count/Quantity	Area	PCT(%)
1	Very Low	27065	1452434249	26.85
2	Low	41169	2209320731	40.84
3	Medium	21180	1136617675	21.01
4	High	11392	611347901.7	11.30
TOTAL		100806	5409720557	100.00

Source: Author's Labwork (2025)

The greenness of crop refers to the leaf greenness (i.e., how deep the greeness) and it is basically determined by the sum total of NDVIs zoned in a particular local government area. The higher the sum total of the NDVI, the greener the leaf and vis-versa; and the greener the higher the potato yield per zone. Figure 10 below showed that, Mangu is having the highest NDVI (9398.839) in a total land area of1762187000 m^2, with a total potato yield of 32,837. This was followed by Bokkos LGA, with a sum NDVI total of 9367.809, expected potato yield in all the pixel was 28440 in a land area of 1526223000 m^2 . While Barkin Ladi, Jos South and RiyomLGAs have sum NDVI of 4479.695, 2142.47 and 4992.899 respectively. This means Mango and Bokkos LGAs shall plant potato much earlier than Barkin Ladi, Jos South and Riyom LGAs and also have the propensity of high yield and planting at least four times in a year than the rest LGAs as revealed in Table 2 below;

Table 2. Statistical table of NDVI f January 2018 of the study area.

JAN	NAME_2	Count (Quantity of the Crops)	Area (m2)	MIN	MAX	MEAN	SUM (NDVI)
1	Barkin Ladi	15904	853482900	-0.1954	0.7023	0.281671	4479.695
2	Bokkos	28440	1526223000	-0.1924	0.6526	0.329388	9367.809
3	Jos South	8450	453466400	-0.103	0.4935	0.253547	2142.47
4	Mangu	32837	1762187000	0.1121	0.6006	0.286227	9398.839
5	Riyom	14984	804111400	-0.1926	0.7052	0.333215	4992.899
Total		100615	5399470700	-0.5713	3.1542	1.484048	30381.712

Source: Ahor's Labwork (2025)

Output 2

Determination of Range (Mean) of NDVI value for Potato in Jan, 2018

The map in figure 10 below revealed how the NDVI values were categorized and ranked in all the five LGAs of the study area for the month of January, 2018. The essence of this map is to guide potato farmers on how, when and where of the crop in order to have maximum yield with minimum loss incurred. There are four categories which include Very-Low that ranges between -0.195 -0.253, then Low is 0.253-0.218, medium or mean is between 0.318-0.405, while those with high NDVI value is ranges between 0.405-0.705 respectively. The implications of these are that, any part of the LGAs of study with the mean

NDVI value of between 0.318-0.405 in the month of January 2018 has the propensity of having a high potato yield and such field or area may also grow and harvest potato 3-4 times in a year. Therefore, from Table 2 above, only Bokkos and Riyom LGAs are most likely to grow potato early and have the possibility of high yield, apart from Barkin Ladi, Jos South and Mangu LGAs that may plant in the later date based on the NDVI report. Figure 10 also revealed the geographical location of the five selected LGAs of study (their greeness nature) and their administrative boundaries, thereby given the total land areas covered for the research study and Land Use and Land Cover (LULC).

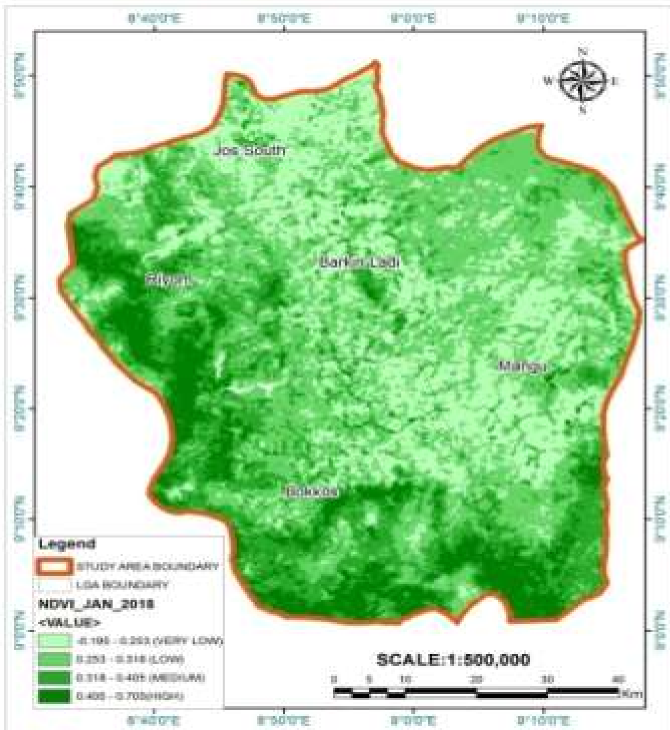


Figure 10.Shows the NDVI Grading of the study area for January 2018.
Source: Author's Labwork, (2025)

Figure 11 below is the graphical representation of the mean Normalized Differential Vegatation (Value) Index of the five selected areas for the prediction of potato yield in Plateau State

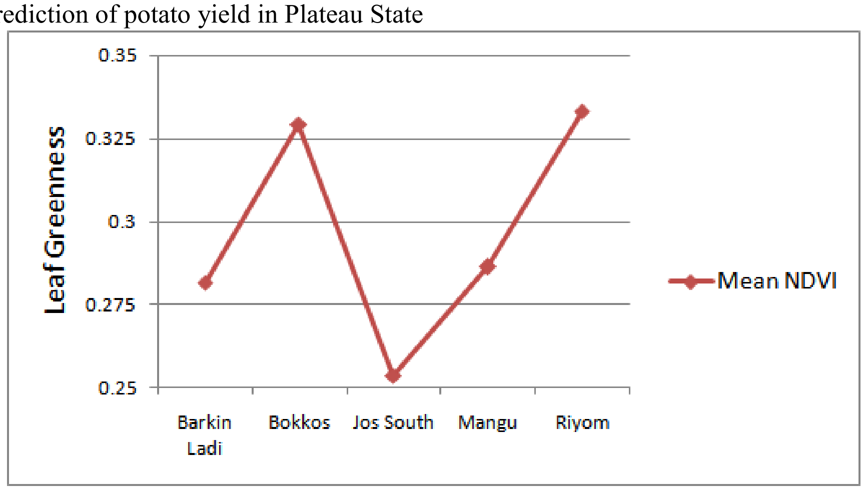


Figure 11. Graph of Potato Crop Greenness of the study areain January 2018.
Source: Author's Labwork, (2025)

Output 3
NDVI in February, 2018
The mean NDVI value for the month of February, 2018 under investigation revealed that, it is oscilating between 0.292-0.378; the Very Low is 0.199-0.230, Low is 0.230-0.29 and high is 0.378-0.673. This means in the month of February, 2018 the mean NDVI value has a sharp departure from that of January, 2018. It also means some fields in the study area may not grow potato until February, but those areas where there was planting in January shall harvest at least a month earlier than those who planted

in the month of February, 2018. Furthermore, those who started in January and February actually involved in irrigation or dry season farming and it has been adjudged that, potatoes thrive better and more sizeable and tasty than those grown during the raining season. Those of the raining season are more prone to having pest's infection which may likely result in low yield. Figure 12 below explains further;

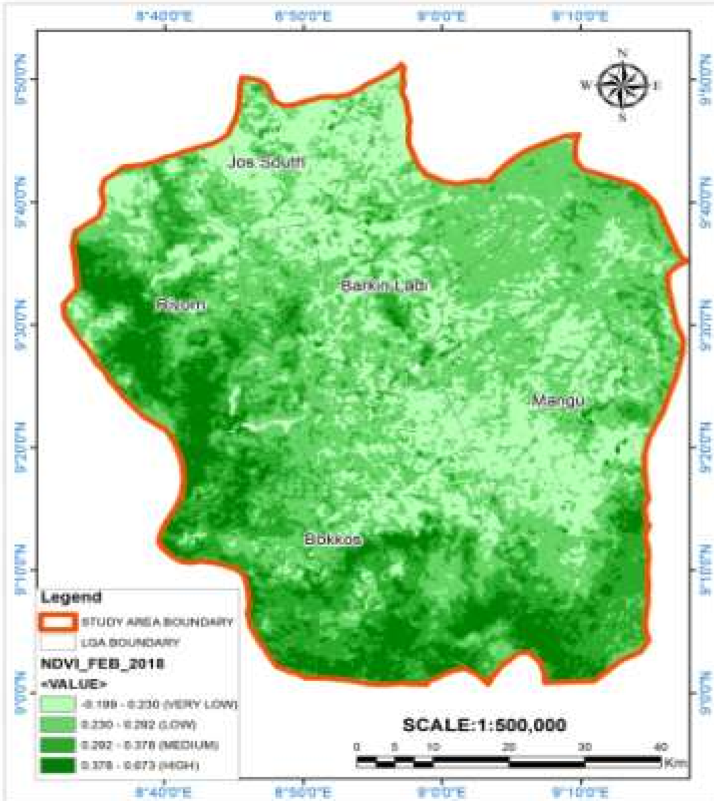


Figure 12. NDVI value of February, 2018 of the Study Area.
Source: Author's labwork (2025)

Table 3 below revealed the reflecting values for the month of February, 2018, indicating its greeness is very low (poor reflectant value), covering area of 1.391 m^2 which is representing 25.27%, followed by a low pixel reflectance of 42555 over an area of 2.284 m^2 which is equivalent to 42.21 percent, the median reflecting value stands at 21296 covering an area of 1.143 m^2 which represents 21.12%; while high reflectance value for the month of February, 2018 was recorded as 11045 in an area of .59272m^2 which is representing 10.95 percent. The implication of these reflectance values are that, potato can only be grown in February when the greeness value is at 21296; meaning also that, only 21.12 percent of the field can be cultivated for potato.

Table 3.NDVI Calendar for February, 2018.

FEB	Greeness	Count	Area m^2	PCT(%)
1	Very Low	25929	1.391	25.72
2	Low	42555	2.284	42.21
3	Medium	21296	1.143	21.12
4	High	11045	0.59272	10.95
TOTAL		100825	5.411	100

Source: Author's labwork (2025)

While Table 4 below revealed the mean, minimum and maximum NDVI values in the month of February, 2018 per LGA. The mean NDVI value per LGA vary according to their spectral signature and expected land cover area for the crop planting/yield. Riyom and Bokkos LGAs are the two LGAs with the highest mean NDVI values for February, 2018 (0.309345 and 0.306371 respectively). Although, the expected potato yield are not the same because there was a variation in the land cover by the spectral reflectance in the two LGAs (804218700 and 1526706000 m^2). This means that, Riyom LGA is expecting the highest potato yield, followed by Bokkos, Mangu, Barkin Ladi and Jos South LGAs respectively.

Table 4.NDVI for February 2018 of the Study Area.

FEB	LGA Name	Count (Quantity of the Crops)	Area (m2)	MIN	MAX	MEAN	SUM (NDVI)
1	Barkin Ladi	15912	8.54E+08	-0.1975	0.6761	0.255978	4073.119
2	Bokkos	28449	1.53E+09	-0.1986	0.6082	0.306171	8710.246
3	Jos South	8450	4.53E+08	-0.1363	0.4394	0.230931	1951.366
4	Mangu	32837	1.76E+09	0.1149	0.5606	0.261563	8588.947
5	Riyom	14986	8.04E+08	-0.0929	0.6761	0.309345	4635.843
Total		100634	5.4E+09	-0.5104	2.9604	1.363988	27959.521

Source: Author's Labwork (2025).

Figure 13 below is the graphical representation of the mean Normalized Difference Vegetation Index (NDVI) for the month of February, 2018 of the five selected areas predicting potato yield in Plateau State

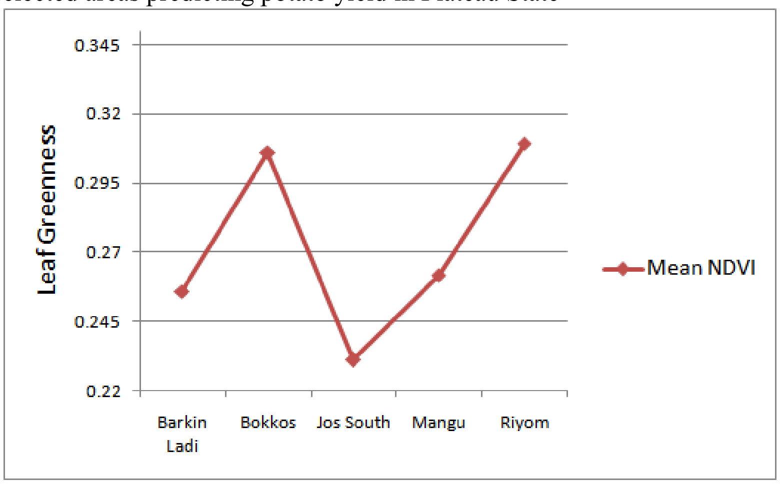


Figure 13 . Graph of crop greeness of the study area in February, 2018.

Source: Author's labwork (2025)

Output 4

NDVI of March, 2018

The greeness of leaf in the month of March, 2018 took a different turn. This is because, as it can be observed, the very-low-yield class was mainly distributed across the field boundaries. This was attributed to the fact that pixels of these field class were located at the cross-boundary between the vegetation and the bare soil areas (field's end); where scarceness of yield existed. For instance, the NDVI for the month of March, 2018 under investigation showed that, the very lowest was between -0.181-0.252, followed by low (0.252-0.342), then the mean was 0.342-0.467, while, the highest NDVI in this month was between 0.467-0.727. It implies that, growing of potato can be done in those fields with the mean NDVI between 0.342-0.462 and expected high yield shall be in those areas of the field whose NDVI is between 0.467-0.727. Figure 14 below explains further;

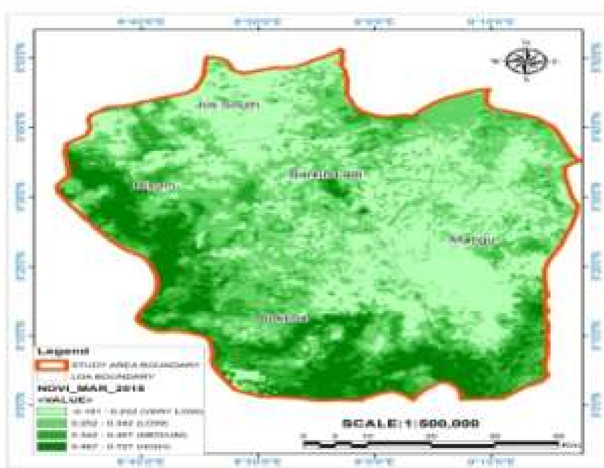


Figure 14. NDVI Value for March, 2018 of the Study Area.

Source Author's Labwork (2025)

Table 5 below shows that, the greeness coverage as the year proceeds becomes very low and covering a wider land area of 1994930381 m^2 with a 37174 total pixel which represents 36.86%, followed by 34511 pixel covering a land area of 1852021369 m^2 equivalent to 34.22 percent of the land area, then 16.57%had a medium greeness covering land area of 896736608 m^2 with 16710 total pixel or reflectance and the highest greeness value was 12458 over a land area of 68554438.2 which represents 12.35 percent. This implies that, potatoes can be grown in the month of March, 2018 when the greeness value is at 16710 and high yield is expected when the NDVI is 12458.

Table 5. Greeness Coverage in 2018

MAR	Greenness	Count	Area m^2	PCT
1	Very Low	37174	1994930381	36.86
2	Low	34511	1852021369	34.22
3	Medium	16710	896736608	16.57
4	High	12458	668554438.2	12.35
TOTAL		100853	5412242796	100.00

Source: Author's labwork (2025)

Table 6 shows the summary of NDVIs per LGA, its minimum, maximum, the mean, the total land area covered in meter square and pixel. Bokkos LGA has the highest value of NDVI (10291.99), followed by Mangu LGA with a total NDVI of 9098.623, Riyom LGA had an NDVI in the month March, 2018 of 5257.259, them Barkin Ladi LGA was 4629.642, while Jos South LGA had only 2001.15 NDVI for the month of March, 2018. What it means is that, each LGA has different mean NDVIs, therefore, there shall be variations in the quantity of potato yield, more so, the areas covered by the greeness per LGA are not the same. Time to grow also vary by local government area: meaning their spectral signature vary respectively by LGA.

Table 6 . statistical table of NDVI for March 2018 of the study area

MAR	NAME_2	Count (Quantity of the Crops)	Area (m2)	MIN	MAX	MEAN	SUM (NDVI)
1	Barkin Ladi	15929	854824500	-0.1911	0.7215	0.290642	4629.642
2	Bokkos	28460	1527297000	-0.1469	0.7266	0.36163	10291.99
3	Jos South	8448	453359100	-0.1315	0.4525	0.236879	2001.15
4	Mangu	32837	1762187000	0.1112	0.7085	0.277085	9098.623
5	Riyom	14987	804272400	-0.0995	0.7194	0.350788	5257.259
Total		100661	5401940000	-0.4578	3.3285	1.517024	31278.664

Source: author's Labwork (2025)

Figure 15 below is the graphical expression of the mean Normalized Difference Vegetation Index (NDVI) for the month of March, 2018 of the five selected areas for the prediction of potato yield in Plateau State.

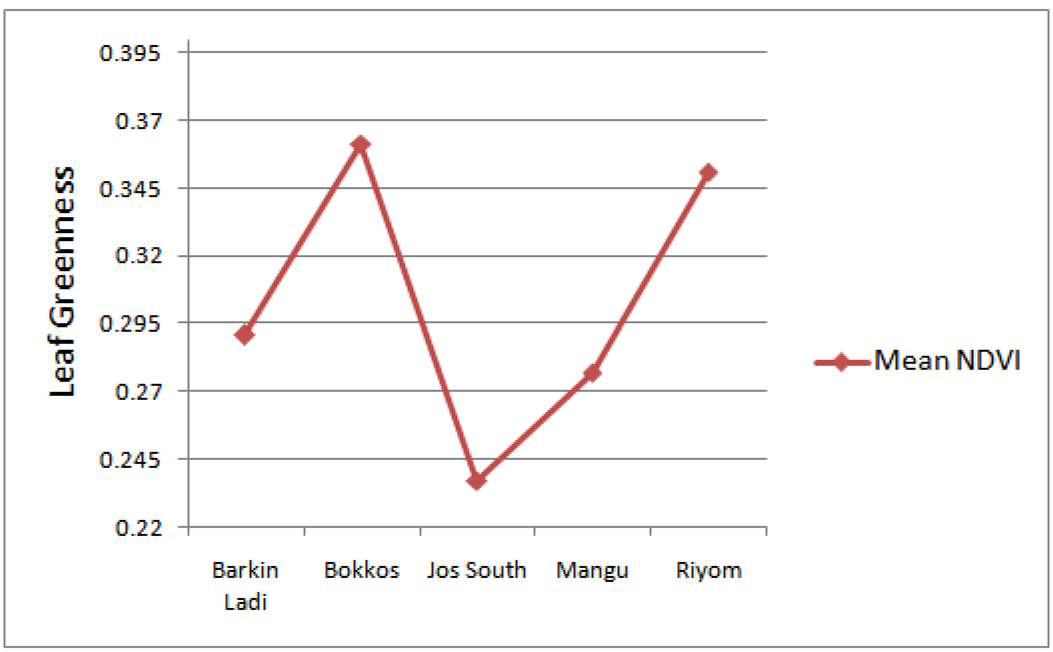


Figure 15. Graph of Crop Greeness for the study Area in March, 2018.
Source: Author's Labwork (2025)

Output 5

NDVI for the month of April, 2018

The mean NDVI in the month of April, 2018 reduced considerably, particularly when compared with the previous months from different fields. The reasons are not farfetched: the low VIs estimated values could be attributed to the reflections from the holistic surface covers (i.e. vegetation plus bare soil), especially from the coarse resolution images of Landsat-8 compared to MODIS used for the sampled LGAs. From figure 16 below, the highest VI for the month of April, 2018 was between 0.518-0.980, the mean was 0.517-0.518. low VI was 0.180-0.317 and the very low VI in the month of April, 2018 was-0.186-0.317This implies that, the mean VI value very suitable for growing potato in the study area, because some droplets of rain would have been experienced; therefore, when the rain is about reaching its peak in July, time for harvest would have come and gone. But, the question is, 'Will the yield be reasonable enough when compared with those planted between the month of January to March, 2018'. The answer is 'Yes'. However, it may not be as qualitative and costly as those grown by irrigation or during the dry season

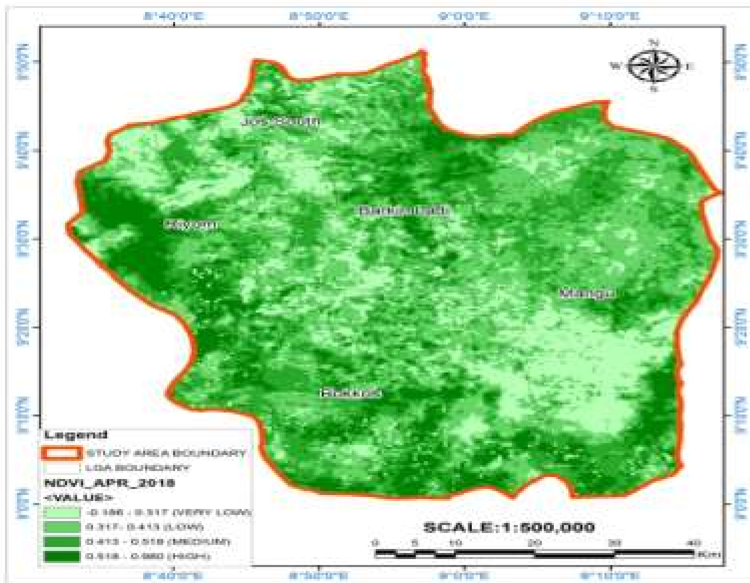


Figure 16.NDVI Value Estimate in April, 2018.

Source: Author's Labwork (2025)

The estimation of greeness of leaf of crop for the month of April, 2018 in Table 7 below shows that, the very low greeness occurred in 18803 pixels over a land area of 1009056759 m^2 which represents 18.64 percent, low VI had a total pixel of 38098 that occupies 2044516534 m^2 land area which represents 37.77%, then the mean value of the spectral signature was recorded as 130063 occupying a total land area of 1613320974 m^2 which is equivalent to 29.81 percnt, while the highest pixel displayed for the month under investigation was 13892 which represents 13.77% in a land area of 745509572.6 m^2. What it implies is that, in the month of April, 2018 about 30% of the field shall grow potatoes, therefore it is expected to have a corresponding percentage yield of potatoes.

Table 7. Crop Greeness Coverage Estimation for April, 2018.

APR	Greenness	Count	Area	PCT
1	Very Low	18803	1009056759	18.64
2	Low	38098	2044516534	37.77
3	Medium	30063	1613320924	29.81
4	High	13892	745509572.6	13.77
TOTAL		100856	5412403790	100.00

Source: Author's labwork (2025)

While in table 7 below, it revealed the sum total of NDVI, the area covered in meter square and the minimum, maximum and mean quantity of crops (Potatos) yield per LGA for the month of April, 2018. The sum total of NDVI in Mangu LGA being the highest in the month of April, 2018 was 12593.51,with expected potato yield of 32837 and area covered was 1762187000 m^2 , this was followed by Bokkos LGA with a sum NDVI of 12079.14 and expected potato yield and land cover was 28460 in 855092800 m^2, Barkin Ladi had an expected potato yield of 15934 with sum NDVI of 6676.795 in 855092800 m^2 land area; Riyom LGA expected yield was 14987 on a land area of 804272400 m^2 with a sum NDVI of 6337.512; wile Jos South LGA predicted potato yield for the month of April, 2018 stood at 8447 over a land area of 453305400 m^2 and a sum NDVI of3119.365. What it means is that, Mangu and Bokkos LGAs shall have the highest potato yield in the month of April, 2018 because of suitable mean NDVIs which enables about 48% of their field for growing potato, coupled with favourable soil moisture in these fields under investigation.

Table 8. NDVI Statistics in April, 2018 of the Study Area.

APR	LGA Name	Count (Quantity of the Crops)	Area (m2)	MIN	MAX	MEAN	SUM (NDVI)
1	Barkin Ladi	15934	855092800	-0.1818	0.7429	0.419028	6676.795
2	Bokkos	28460	1527297000	-0.1682	0.9799	0.424425	12079.14
3	Jos South	8447	453305400	-0.1859	0.7183	0.369287	3119.365
4	Mangu	32837	1762187000	0.085	0.7482	0.383516	12593.51
5	Riyom	14987	804272400	0.051	0.8182	0.422867	6337.512
Total		100665	5402154600	-0.3999	4.0075	2.019123	40806.322

Source: Author's Labwork (2025)

Figure 17 below is the graphical expression of the mean Normalized Difference Vegatation Index

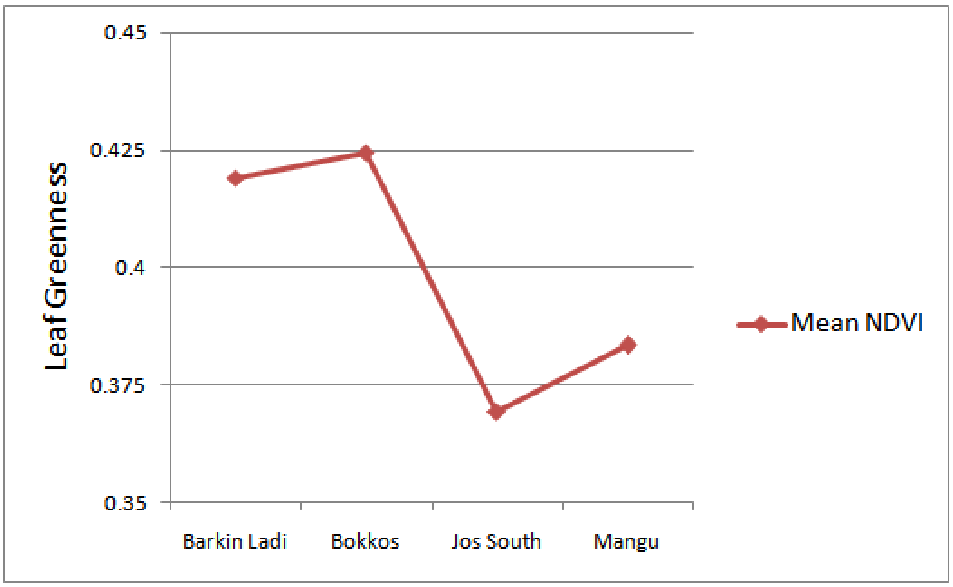


Figure 17. Graph of Crop Greeness of the Study Area in April, 2018.

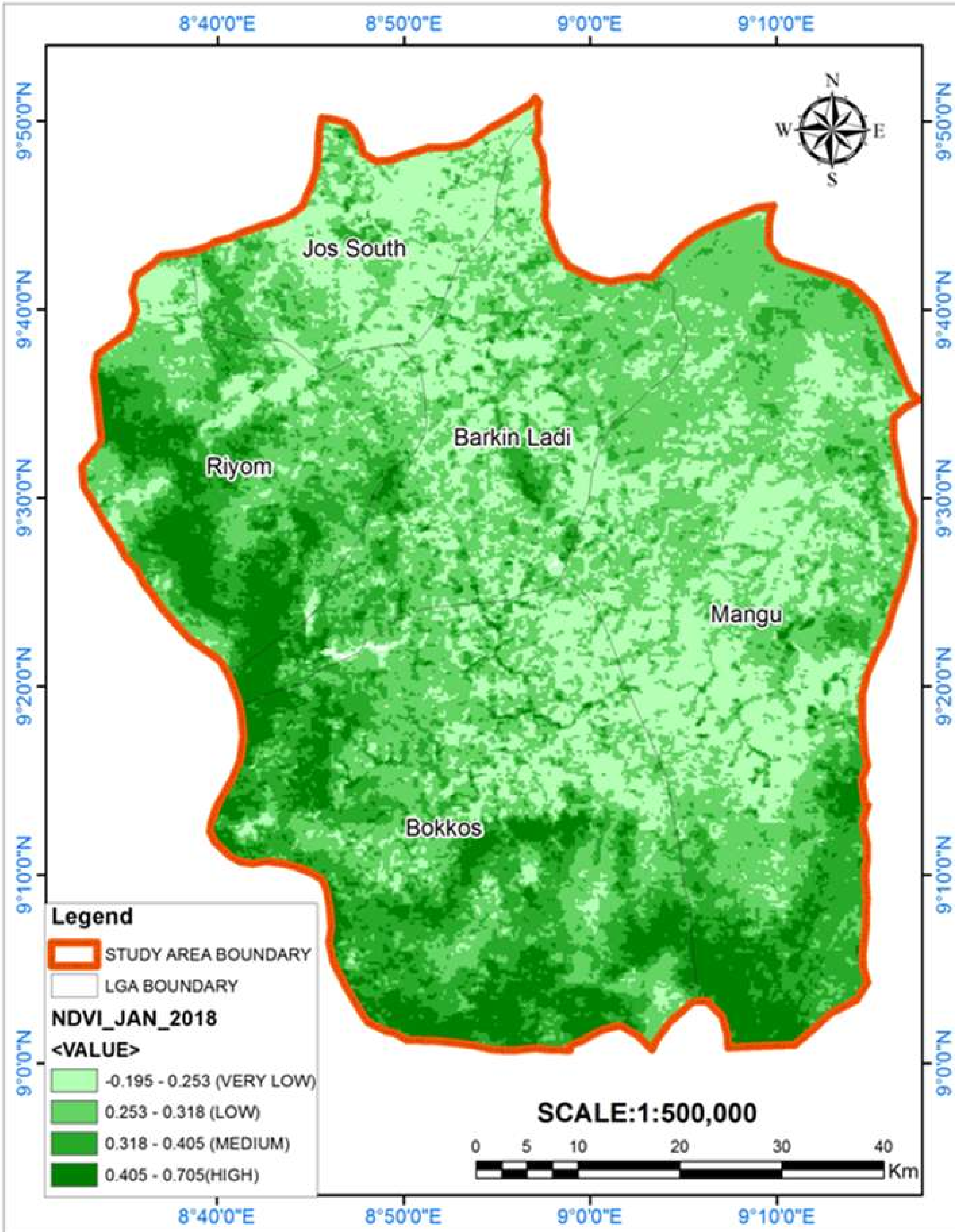
Source: Author's Labwork (2025)

Output 6

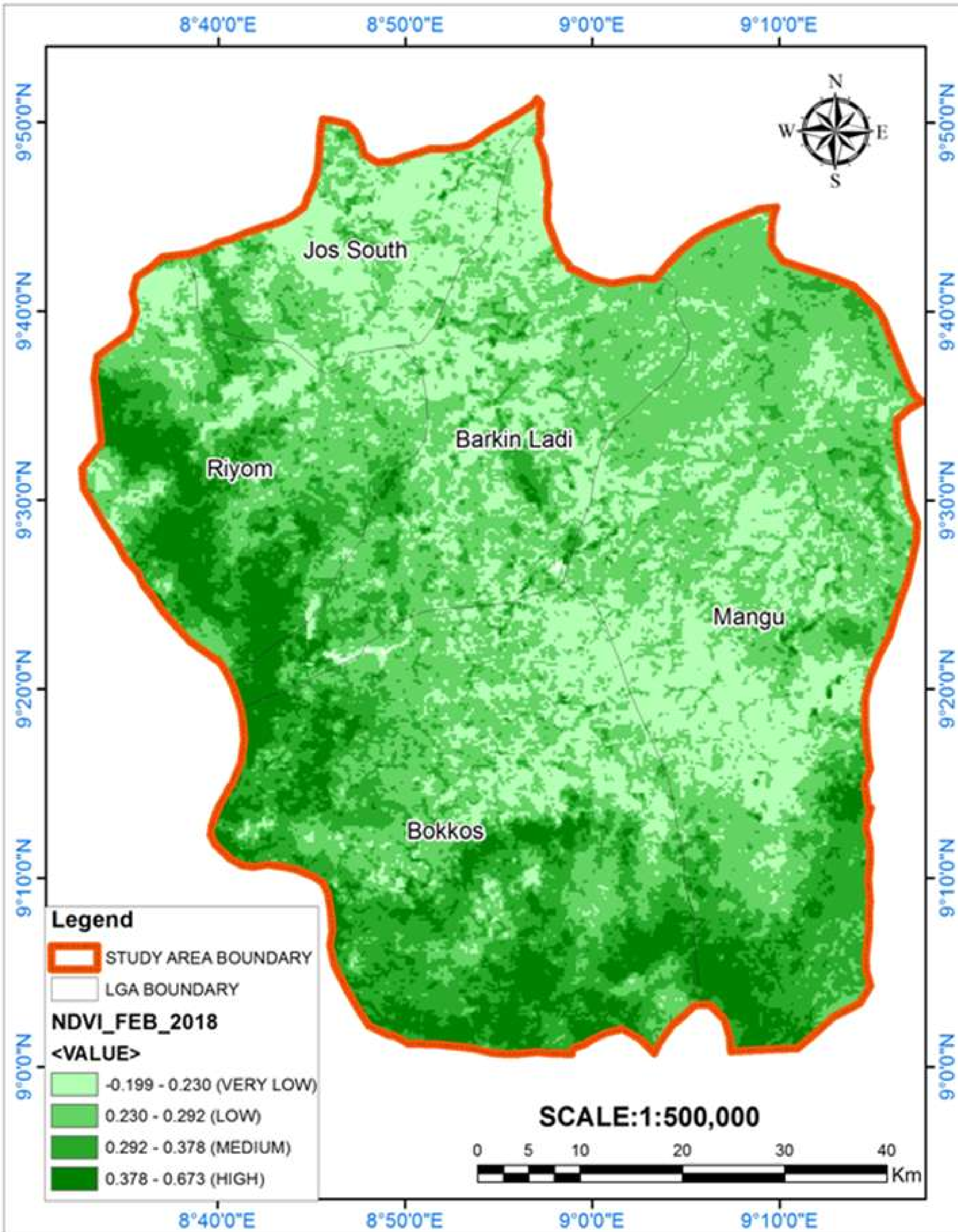
Maps of Zonal Analysis for the Classified Yield.

The predicted yield maps of the classified fields were developed from the MODIS satellite image by deploying different index as shown in Figure 18 below. These maps from top-left revealed a considerable variation in yields within each field as represented by the classes; it can be observed that the very-low-yield (VLY) class was mainly distributed across the field boundaries (i.e., the fringes). This was attributed to the fact that pixels of these yield classes were located at the cross-boundary between the vegetation and the bare soil area (field end), where scarceness of the yield existed. On the other hand, the low VIs estimated values could be attributed to the reflections from the holistic surface cover (i.e. vegetation plus bare soil), especially if the satellite images has a coarse resolution.

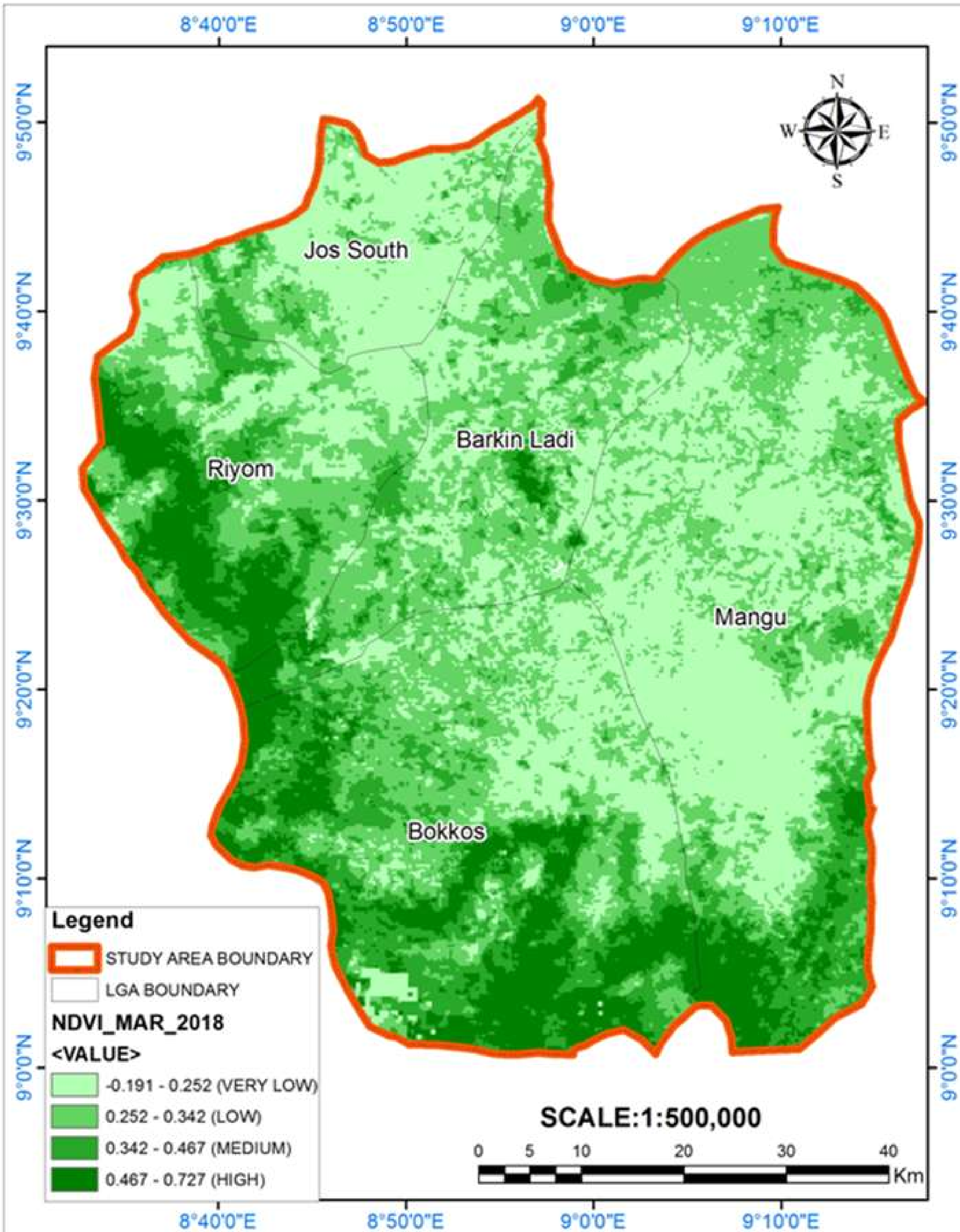
The yield classes of median and high were described based on pixel count and area occupied in meter square that is associated with class creation. This was done by comparing the yield potentials within the high-yield in figure18. Maps of the very-low-yield classes, a variation of yield ranging from 20 to 40 meter square was found to exist within each field. The least yield values (0 to 20 VI) observed along the field's boundary where the cumulative reflectance of soil and vegetation was detected at the field's end.



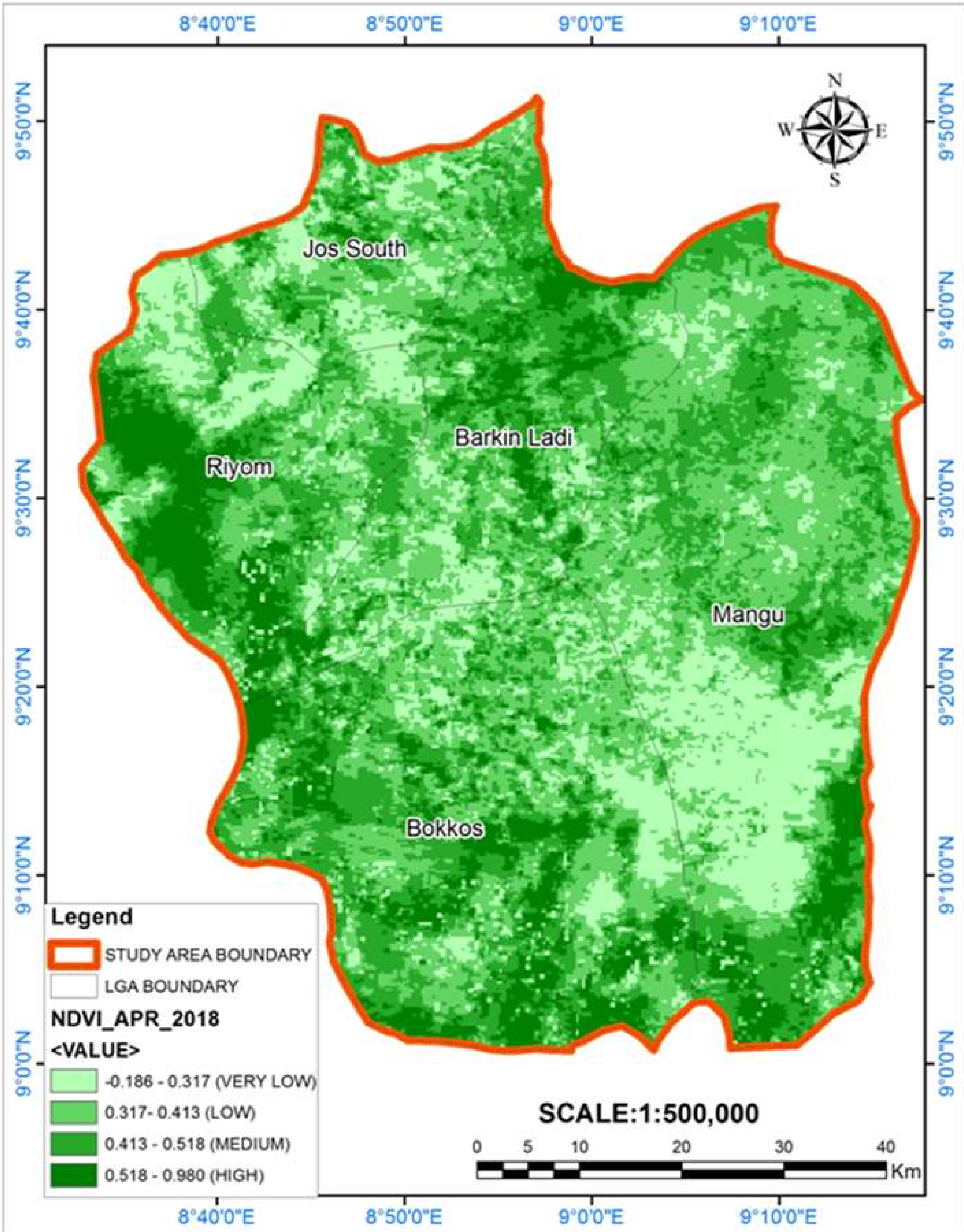
(a): Crop Greenness of study area in January



(b): CropGreenness of study area in February



(c): Crop Greeness of study area in March



(d): CropGreeness of study area in April

Figure 18.Composite Map of Greeness from Jan-April 2018 of the Study Area.

Source: Author's labwork (2025)

From figure19 below, it revealed that, the preponderance of productivity was achieved within the high-yield classes of fields 1.5 and 4.0, with total absence of very-high-yield class in field 0 and 1.0, which were observed to have average values of 3.000 for both fields and a yield range of1.0 to 4.0 for field 4 and 5 respectively. On the other hand, the most productive areas (high yield classes) were observed to be less frequent when compared with median-yield classes. These results highlighted the importance of improving the productivity over the three least yield classes (medium, low and very low) to increase the total field productivity through the use of potato yield monitoring techniques and suitable management. Also, it is believed that, expanding the analysis to cover environmental and soil influential factors which can enhance the yield productivity.

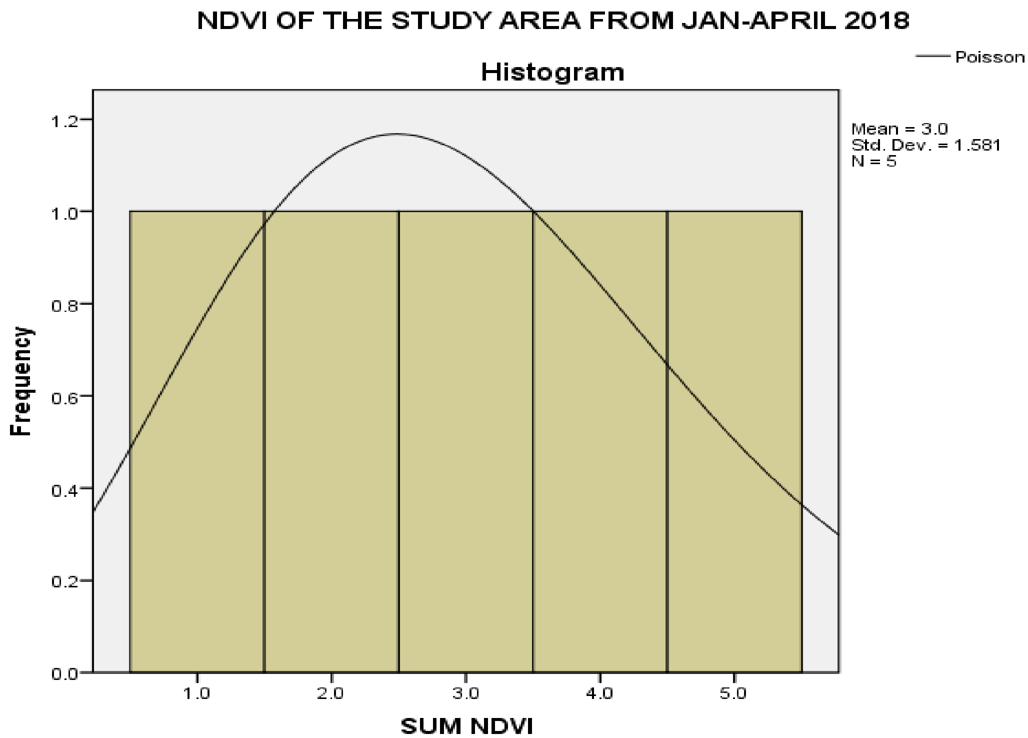


Figure 19.Sum NDVI of the Five Fields.

Source: Author's Labwork (2025)

The positively skewed distribution of NDVI across the five LGA's of the study in figure 19 above revealed that the fields produced a broad variety of yields within the four yield classes. Production with such variability could complicate the planning for the zone management in terms of following a specific type of agricultural activity. The distribution curve (Figure 19) is a symmetrical bell-shaped, hence, it further strengthen the assumption that sum NDVI is normally distributed. Therefore, the sum NDVI should be described using mean and standard deviation. If the variable 'LGA' is explored, it will be realized that LGA is not normally distributed. The mean is 3.000, the median is 3.000, the histogram obviously shows that sum NDVI is skeewed to the left (positive skeewness, 3.7). Therefore, to describe sum NDVI, the value of the median be used and IQR instead of mean and SD.

Table 8.Mean Score of Sum NDVI of the Study Area.

SUM NDVI			
		Statistic	Std. Error
Mean		3	0.7071
95% Confidence Interval for Mean	Lower Bound	1.037	
	Upper Bound	4.963	
5% Trimmed Mean		3	
Median		3	
Variance		2.5	
Std. Deviation		1.5811	
Minimum		1	
Maximum		5	
Range		4	
Interquartile Range		3	
Skewness		0	0.913
Kurtosis		-1.2	2

Source: Aothor's Labwork (2025)

In the nutshell, the bell shaped histogram of Table 8 above propose that, potato can be grown conveniently in all the five sampled fields, except that, the yields vary from one field to another, depending on the greeness value, soil type, moisture content, timely growing of potato and other related climatic conditions that are pertinent to its productivity.

Output 7

Mean Leaf Greeness (Jan-Apr, 2018).

The mean value of leaf greeness in Table 9 below showed that, there was a normal distribution of greeness from January to April, 2018: and the increase was gradual with little or no significant effect. Although, potato yield were mostly found at the edges of the study area and all across. For example, in Barkin Ladi LGA, it is only in the month of April, 2018 that, there was a significant difference in the greeness value (0.419028), when compared with Vis of January to March, 2018 (0.281671,0.255978,0.36163) of rise and fall VI values. Whereas in Bokkos LGA, there was a remarkable difference between the mean greeness value of January (0.329388) and April, 2018 (0.369287), also in February(0.306171) and April, 2018 (0.36163).2018, if compared with Bokkos and Mangu LGAs. The implication is that, Bokkos and Mangu LGAs have the propensity of producing a very high yield potatoes in the entire study area as revealed in the variability of their greeness values from Table 9 below. While Mangu and Riyom LGAs had slight variability differences in greeess values from the month of January to April, 2018, but Riyom had more VI than Mangu LGA in the month of April, 2018 as shown in the Table 9..

Table 9.Mean Greeness Values from Jan-Apr, 2018 of the study Area.

LGA	JAN	FEB	MAR	APR
Barkin Ladi	0.281671	0.255978	0.290642	0.419028
Bokkos	0.329388	0.306171	0.36163	0.424425
Jos South	0.253547	0.230931	0.236879	0.369287
Mangu	0.286227	0.261563	0.277085	0.383516
Riyom	0.333215	0.309345	0.350788	0.422867

Source: Author's Labwork (2025)

Figure 19 below is the graphical expression of the mean Normalized Difference Vegatation Index (NDVI) from the month of January to April, 2018 of the five selected areas for the prediction of potato yield in Plateau State.

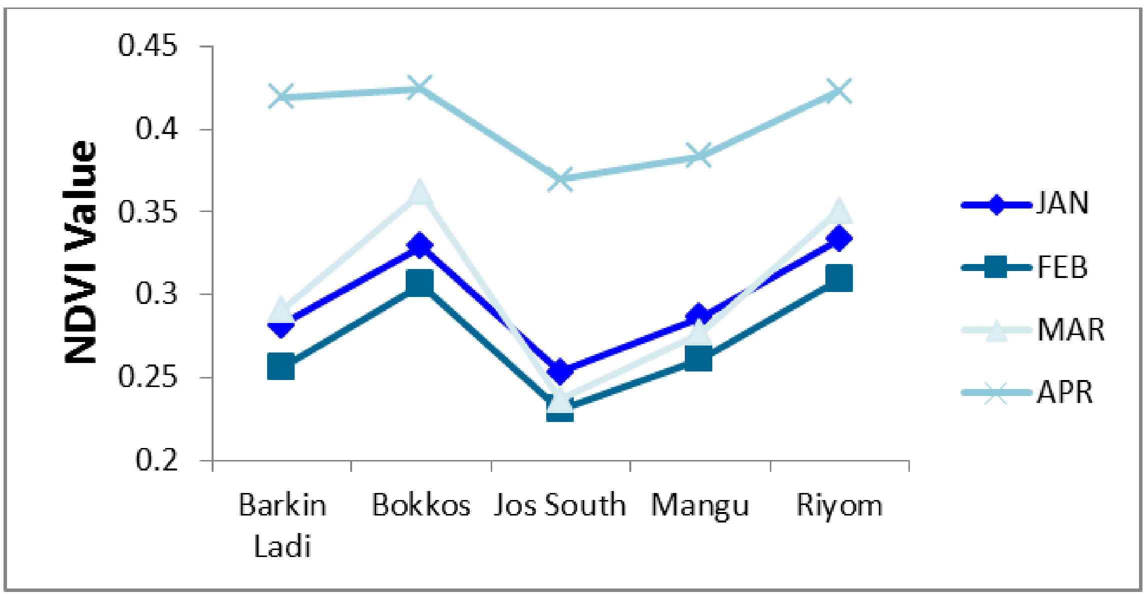


Figure 19.Mean Greeness Values from Jan-Apr, 2018 of the study Area.

Source: Author's Labwork (2025)

4. Conclusions:-

The approach ho this article was developed to extract some key elements (i.e. number of crops per field (LGA) and their planting peak harvesting dates) of crop growth cycle in the sampled LGAs. This involves smoothing followed by interpreting temporal variations. This was illustrated by taking the NDVI data over five fields in five LGAs of Plateau State between January-April, 20118. For the sampled LGAs, about 67.9% area was single crop and 33.2% was double crop.

The reduction in the greeness means as the potato is growing, the spectral signature or reflection capacity from the pixels reduces, particularly as the crop grows to maturity or harvest period. It also indicates that, it is better to grow potato in the month of January when the moisture in the soil is just moderate and relatively conducive for the crop

The results support the use of NDVI derived from MODIS image spectrometer for intensive vegetation sampling as a means to monitor pattern and predict potato yield, but only following site-specific validation. Satellite-derived NDVI shows promise for predicting seasonal timing of peak potato yield, but all the fields- and satellite-derived measures of NDVI were estimators of potato growing changes, demonstrating the need for alternative techniques to track timing or yield. This study highlights the overall importance of matching the scale of NDVI measurements to the potato phenology properties being studied, and the scales at which those properties are regulated.

Abbreviations

I.	**MODIS**	**-**	**Moderate Resolution Imaging Spectroradiometer**
II.	**NDVI**	**-**	**Normalized Differential Value Index**

Conflicts of Interest

Not applicable in this article

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