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Development of Object Oriented Bare Surface Feature Extraction Algorithm for Desertification Early Warning using Nigeria Sat-2 High Resolution Imagery Data

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Abstract:- Federal Government of Nigeria in 1999 embarked on some laudable steps at pioneering the development of Space Technology in Africa which eventually led to the launching of Nigeriasat-1 on the 27th of September 2003 by National Space Research and Development Agency (NASRDA), Abuja, Nigeria. However, it is pertinent to know that since the launching of Nigeriasat-2 satellite, algorithm for the extraction of feature classes from its image has not been developed. Therefore, this study is not only exploring the techniques for the extraction of feature classes from Nigeriasat-2 VHRI but with a view to develop algorithm that will be more accessible than foreign based algorithms like eCognition to average Earth Observation Scientists. Secondly, Desertification is land degradation that occurs in arid, semi-arid and dry sub-humid areas. Over the years, desertification and drought are two related disasters largely contributing to high rate of famine, especially in the Northern part of Nigeria. This research has been conducted in order to monitor desertification extent and severity over northern Nigeria using developed algorithm from object oriented normalized Bare Surface index (nBSI). The Global Positioning System (GPS) was used specifically for picking sample points during ground sampling and reconnaissance survey. Other image processing software such as Erdas Imagine, Idrisi Selva,Ilwis and ENVI were used during various image processing procedure. Visual basics and Java software were used for algorithm and final software development. Six criteria are used to evaluate the performance of a classification method: accuracy, reproducibility, robustness, ability to fully utilize the data's information content, uniform applicability, and objectiveness.. This method proves valuable to local and regional governments, educational and research institutions, and private businesses as a result of its simplicity, low cost, and integration with a range of software products.

Keywords:- *Object Oriented Bare Surface, Feature Extraction Algorithm, Desertification, Early Warning, NigeriaSat-2 and High Resolution Imagery Data.*

I. INTRODUCTION

Federal Government of Nigeria in 1999 embarked on some laudable steps at pioneering the development of Space Technology in Africa which eventually led to the launching of Nigeriasat-1 on the 27th of September 2003 by National Space Research and Development Agency (NASRDA), Abuja, Nigeria. The success accrued from these led to the launch of NigeriaSat-2 in August 2009. Nigeria consolidated on her achievements with Nigeriasat-1 which is a Low Earth Observation (LEO) satellite with swath width of 600km with a 3-band multi-spectral imager in the green, red and near-infrared bands with wavelengths [0.52-0.62nm (Green), 0.63-0.69nm(Red), 0.76-0.9nm(NIR)] and has Ground Sampling Distance (GSD)/Spatial resolution of 32m by developing a high resolution Earth Observation satellite – NigeriaSat-2. With four spectral bands in the red, green, blue and near infrared, the satellite has a spatial resolution of 2.5m and 5m respectively.. In addition, NigeriaSat-2 carried the 32m multispectral payload of NigeriaSat-1 to ensure data continuity for a variety of applications, such as large-scale mapping and precision agriculture..

Furthermore, it is pertinent to know that since the launching of Nigeriasat-2 satellite, algorithm for the extraction of feature classes from its image has not been developed.

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Therefore, this study is not only exploring the techniques for the extraction of feature classes from Nigeriasat-2 VHRI but with a view to develop algorithm that will be more accessible than foreign based algorithms like eCognition to average Earth Observation Scientists.

Secondly, Desertification is land degradation that occurs in arid, semi-arid and dry sub-humid areas. Famine has been largely attributed to desertification and drought in Nigeria over the years, especially in the northern part of the country. This research has been conducted in order to monitor desertification extent and severity over northern Nigeria using developed algorithm from object oriented normalized Bare Surface index (nBSI)

Finally, the processes of developing indigenous customized OO scripts provides a novel platform for technology and knowledge development/patency for the Nigeria space programme and image products management.

- *Aim and Objectives*

The project aims to develop a customized Object-Oriented Feature Extraction Algorithm for Desertification early warning using the NigeriaSat-2 image. The objectives are to;

- Identify/Develop indices/codes suitable for extraction of bare surface feature class from NigeriaSat-2 image.
- Carry out feature extraction for Bare Surface using the developed indices/codes on the study area
- Produce a bare surface map based on the ground sampled data from fieldwork covering the study area
- Validate the developed indices/codes used in extracting the feature class using in order to assess the accuracy of the resultant map.
- Develop customized program for the feature class extraction from the very high resolution imagery (VHRI) of Nigeria-Sat-2 (5m Multispectral) based on the validated indices/codes.

- *The Study Area*

The satellite image used for this study cover part of Dutse LGA of Jigawa state (ranged from lower left longitude 9°12′30.04′E and latitude 11°47′11.63′N, upper right longitude 9°51′20.05′E and latitude 11°53′34.27′N, of WGS84 coordinate system, zone 32) in Nigeria as shown in Figure 1 below.

Land cover in most of the selected sites includes a heterogeneous mixture of commercial, residential, open space, bare soil, agriculture, open grass, trees, roads and open water with average area coverage of about 10 km2. In all locations, roads and buildings outline are clearly visible. The Jigawa image is sparsely vegetated because the place is Sahel. Finally, the terrain nature is slightly undulation and the image has zero percent cloud cover.

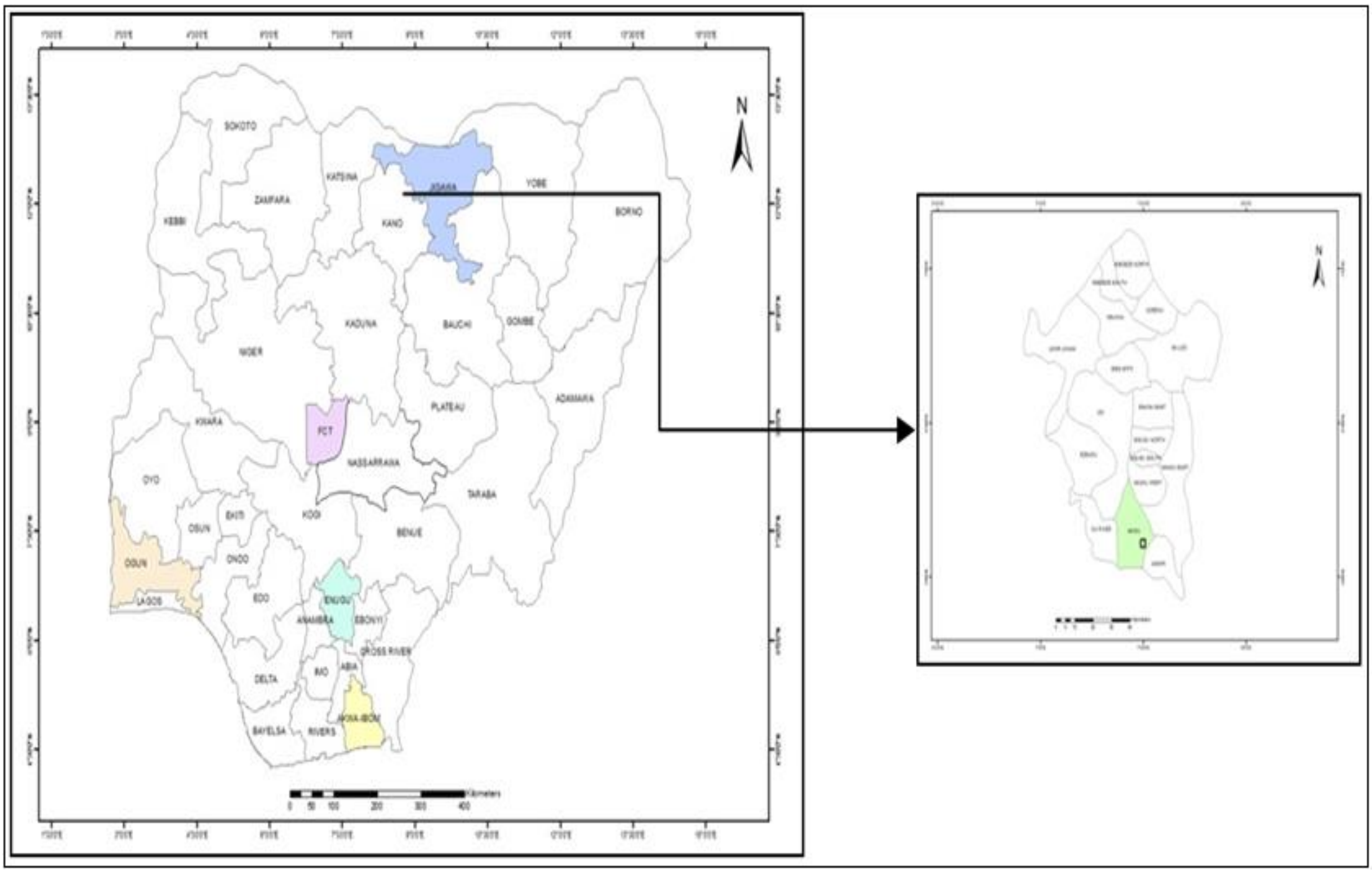

Fig 1 Figure Showing Map of Nigeria and -the Study Area

II. RELATED WORKS

In 2012, Bahram Salehi et al, used a small subset of QuickBird (QB) imagery coupled with a layer of height points called Spot Height (SH) to classify a complex urban environment. The rule-set employed different spectral, morphological, contextual, class-related, and thematic layer features based on slightly different thresholds resulting from the segmentation step.

Using the Cognition Network Language available in the eCognition software package from the segmentation step for classifying VHR imagery of small urban areas, a 92% accuracy result was achieved despite the spectral and spatial complexity of land cover types.. The high level of accuracy shows the great potential of combining vector data, VHR imagery, and object-based image analysis for the classification of small urban areas.

Li S. and X. Chen (2014) developed a new bareness index (BI) which used to map a developing region in Pearl River Delta, China using Landsat OLI/TIRS data of 2013

The BI was developed based on the logical combination of the Tasseled Cap transformation (TCB) and Normalized Difference Bareness Index (NDBaI). The results are very promising following extensive empirical, ground measurements and statistical comparisons.

Gupta & Bhadauria, 2014 proposed Object based Information Extraction from High Resolution Satellite Imagery using eCognition. In the third lab of the ES 5053 Remote Sensing class, researchers used the Land sat ETM+ image of San Antonio, ETMp27r40y01m7d21 (a subset of the ETM + image containing path27 row 40), and conducted experiments using eCognition software. It is evident from the experiment that the recently developed object-oriented strategy has significantly increased categorization accuracy. With an overall accuracy of 97.30%, it is a practical and effective method for extracting information. In summary, it has been demonstrated that the object-oriented information extraction method will become the standard for remotely sensed high-resolution data. Therefore, eCognition software's object-based approach is an efficient and practical method for interpreting remote sensing images and extracting information from them.

Kaveh Shahi et al, (2015) presented an automatic and quick approach for asphalt road extraction from WV-2 imagery. The method was based on a new spectral index which they developed using combination of red, blue and near infrared2 (NIR2) bands from a full-range spectroradiometer and WV-2 images. The new index called Road Enhanced Index (REI) can extract asphalt roads automatically with an overall accuracy 82.58%. It is worthy of note that the NIR2 spectral range is 860 – 1040nm which is more explicit than the NIR on Nigeriasat-2 images that is between 760 – 900nm.

Zhu, Cai, Liu, & Huang, 2016 proposed an information extraction of high-resolution remote sensing images based on the calculation of optimal segmentation parameters using WorldView-2 high-resolution data. The tools used for the tests included eCognition, ENVI, and MATLAB. According to the experiment results, the tightness factor should be set to 0.6, the shape parameter should be set to 0.3, and the segmentation scale should be set to 70 for the best extraction impact of plant and bare ground. The segmentation scale of 100, the shape parameter of 0.4, and the tightness factor of 0.4 yield the best results for buildings and the shadow extraction effect. Lastly, the segmentation scale of 180, the shape parameter of 0.3, and the tightness factor of 0.7 yield the best results for roads and the water extraction impact. These findings suggest that the suggested object-oriented high-resolution information extraction. based on the optimal segmentation parameters is highly effective and has practical value. However, further research is expected to realize the automaticity of the method, particularly the use of remote sensing software tools such as eCognition

Fang & Che, 2019 conducted research on object-oriented algorithms for road extraction in high- resolution using ZHEJIANG province from the World View satellite in 2018. Tests indicate that this technique may successfully extract road targets without the need for manual road seed point selection from remote sensing photos of various scenarios. Road items may be fully and clearly extracted from photos in both urban and rural settings using this technique. Future recommendations should focus on studying adaptive threshold selection based on machine learning and achieving the object's clustering segmentation by merging additional picture attributes.

Jiang, 2019 used remote sensing satellite photos to perform research on road extraction from remote sensing photographs using a convolutional neural network and conducted experiments on the Python platform. This method's accuracy is 4.7% and 3.46% greater than DMES's and AUA's, respectively. There is a good road information extraction effect using the suggested convolutional neural network-based road extraction method.

Tan, Guo, Hu, Dong, & Hu, 2021 proposed object-oriented remote sensing image information extraction method based on a multi-classifier combination and deep learning algorithm using 81 RS satellite images. The research was conducted on the OTB2013 and VOT2017 platforms. Through the comparative analysis of the OTB and VOT platforms, the algorithm works well when the requirements of the tracking standards are low (the accuracy threshold is greater than 20 pixels and the success threshold is less than 0.4 pixels). Compared with other advanced classification methods, the proposed method shows better generalization performance in accuracy, recall, f-measure, g-mean and AUC. However, to make the knowledge mined from the remote sensing image database more practical, a large amount of theoretical, technical and practical research is still needed.

Wang et al., 2021 developed a method to extract building 3D information from GaoFen-7 (GF-7) stereo-mapping satellite. The implementation tool used in the research was Python. In terms of building footprint extraction, the method can achieve intersection-over-union indicators of

89.31% and 80.27% for the WHU Dataset and GF-7 self-annotated datasets, the method could be useful for accurate and automatic 3D building information extraction from GF-7 satellite images, and have good application potential. However, future work can be on urban buildings based on GF-7 satellite images.

A multi-scale segmentation-oriented extraction technique for potentially illegal constructions was proposed by Yang in 2021. The findings indicate that the best picture segmentation effect occurs when the segmentation scale is 150, the shape scale factor is 0.7, and the compactness scale factor is 0.3.

Qiu, He, Yu, and Xie, in 2022 proposed remote sensing image information extraction and application based on an improved pixel exchange algorithm using the remote sensing image of Sentinel-2. The results show that both SPSAM and PSA can improve the shoreline extraction accuracy on the whole, but they will produce a lot of noise, especially some shoreline noise is prone to increase the difficulty of shoreline evaluation, and in some application scenarios, the accuracy will decline NDWI+PSA has good robustness. Thus, it can improve shoreline extraction accuracy to a certain extent in multiple scenes, and also remove a lot of noise. Additionally, It has certain advantages in both visual and quantitative results.

Zhang, Cui, Zhu, Jiang, & Jiang, 2022 proposed building height extraction from gf-7 satellite images based on roof contour-constrained stereo matching using Python. The MAE (Mean Absolute Error) of the estimated building heights in Yingde is 2.31 m, and the MAE of the estimated elevation of the building top and bottom is approximately 1.57 m and 1.91 m, respectively. Then the RMSE (Root Mean Square Error) of the building's top and bottom is 2.01 m and 2.57 m. As for the Xi'an dataset with 7 buildings with podiums out of 40 buildings, the MAE of the estimated building height is 1.69 m and the RMSE is 2.34 m.

The findings show that, in comparison to alternative approaches, the suggested methodology clearly increases the precision of high-rise structure height estimation.

Xu, Li, Peng, He, & Wu, 2022 proposed information extraction from high-resolution remote sensing images based on multi-scale segmentation and case-based reasoning. Two WorldView-2 satellite remote sensing images of the Qinzhou City of Guangxi Province and one Siwei Digital Camera (SWDC)-4 aerial image of the Guigang City of Guangxi Province were used. By comparing the results of extracting the surface coverage information from the SVM method and the proposed method, it is found that the results extracted by the SVM method are rich in information and have good visual effects, but there are also many incorrectly extracted surface coverage objects, which require a large amount of manual removal later.The amount of information extracted by the proposed method is relatively small, and there are relatively few erroneously extracted surface coverage objects, and the workload of later manual removal is small. Therefore, future studies on how to further optimize case feature combinations of different case libraries or case matching similarity models.

Although object-based features extraction methods have gained popularity recently and have shown impressive accuracy in previous studies, it is not clear if these methods are a highly accurate way to extract most features from all multiple high resolution images. Furthermore, given that every satellite is distinct and every location has its own set of obstacles, it is unknown if these techniques can be utilized to accurately map Nigeriasat-2 VHR photos and obtain similar findings.

With the successful launch of Nigeriasat-2 in August, 2011, theory and application researches based on the image became hotspot at home and abroad. The Nigeriasat-2 collects image data for four spectral bands (Blue Red, Breen and Near Infrared) with a 5m spatial resolution for all bands except a 2.5 m panchromatic band. It does not have the Thermal Infrared Sensor (TIRS) needed to collect image data in the thermal infrared (TIR) channel and short wave infrared (SWIR) channel. These two bands was used extensively to develop the Normalized Difference Built-Up Index (NDBI), Index-based Built-Up Index (IBI), Urban Index (UI), Normalized Difference Bareness Index (NDBaI), and Bare soil index (BI).

III. MATERIALS AND METHOD

The Global Positioning System (GPS) was used specifically for picking sample points during ground sampling and reconnaissance survey. Other image processing software such as Erdas Imagine, Idrisi Selva,Ilwis and ENVI were used during various image processing procedure. Visual basics and Java software were used for algorithm and final software development.

A. Feature Extraction

Each object was given a land cover class by means of a hierarchical rule-based classifier. Using a fuzzy membership function or strict thresholds, the object-based approach enables the analyst to combine spectral, textural, morphological (geometry and extent), contextual, and class-related features of objects to assign a class membership degree (between 0 and 1) to each object (Frauman et al., 2005; Walker et al., 2008).

The overall accuracy which will estimates how well the features on the ground are captured by the feature extraction process will be calculated.

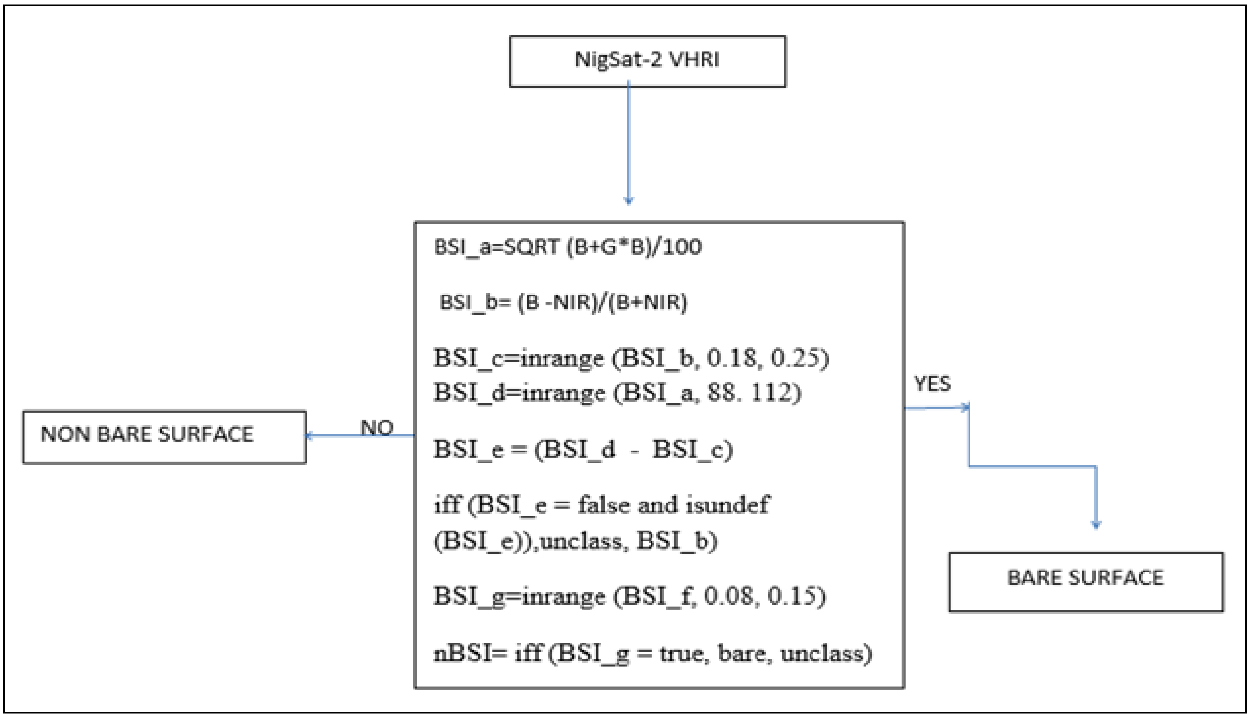

Fig 2 Flowchart for Extracting each Feature Class from Nigeriasat-2 Image

B. Dataset

The NigeriaSat-2 VHR satellite images acquired in August, 2012 with spatial resolution of 5m were used. This image covers part of Jigawa State.

C. Feature Class Extraction based on Fieldwork

The GPS coordinates taken during the fieldwork were entered into Excel spreadsheet and exported into and plotted in the Satellite image within the ArcGis environment. The feature of interest is the Bare Surface which includes open space, degraded land, Aeolian deposit and bare rocks within or around the study area.

D. Ground Truthing and Map Preparation

After the feature extraction, another field visit was made to the study area with a hard copy of the interpreted Satellite image. The purpose of this was to verify and validate the degree of accuracy between the features in the extracted layer and those on the ground in terms of accuracy, reliability, completeness among others. The observed and the extracted were intersected to determine the confidence level. This was carried out in ArcGis and exported excel as “dbf”. The field coordinates collected was 101 points for the study site. These points were plotted on each satellite image covering different study sites and for extracting each feature class within the study area. Useful observations were also made that serves as input for the final editing. The resultant map serves as the truth map because of the high level of accuracy achieved.

E. Development of Indices/Codes for Feature Extraction

There are established and mathematically proven indices such as vegetation indices, water indices, Base soil indices etc. This mathematical combination of satellite image channels such as Red, Blue, Green and NIR having different wavelengths ranges allows remote sensing specialists to observe how each feature class react to electromagnetic radiation from the sun.

Using the command box in Ilwis 3.2 software, each band (Red, Green, Blue and Near Infra Red) of the NigeriaSat2 VRI was subjected to different mathematical manipulations in order to derive best band combination for extraction of each feature class.

F. Validation of Indices and Accuracy Assessment of Output Map

In order to evaluate the performance of a classification method, six criteria are used which are accuracy, reproducibility, robustness, ability to fully use the information content of the data, uniform applicability, and objectiveness (Hasmadi, I. M., et al, 2009).

In reality, no classification algorithm can satisfy all these requirements nor be applicable to all studies, due to different environmental settings and datasets used. The confusion matrix approach is the one most widely used in accuracy assessment.

Accuracy of classification is the fraction of correctly classified ground truth (or test set) pixels of a certain ground truth class. For each class of test set pixels (row), the number of correctly classified pixels is divided by the total number of test pixels in that class; for example, if for the 'bare surface' class, the accuracy is 440/530 = 0.83 meaning that approximately 83% of the 'bare surface' ground truth pixels also appear as 'bare surface' pixels in the classified image.

The overall accuracy measures the probability that a classified pixel from a given category actually represents that category on the ground.

- *The Overall Accuracy can be Calculated as:*

$$\text{Overall Accuracy (\%)} = \frac{P_c}{P_t} \times 100 \qquad (1)$$

- Where P_c = number of correctly classified pixels
- Where P_t = total number of classified pixels

For this research, the overall accuracy is calculated for each extracted feature map. This is done by mathematical comparing the truth map generated from field work with the map generated from developed indices for the feature class for the study site.

IV. RESULTS AND DISCUSSION

A. *Results of Development of Indices/Codes for Features Extraction*

- *Bare Surface Class Extraction Code*

In order to extract bare surface feature class from the NigeriaSat2 HVR image, the equation below was used

$$\text{Bare Surface Index (BSI)\_a} = \frac{SQRT\,(B+G*B)}{100} \qquad (2)$$

$$\text{BSI\_b} = \frac{B-NIR}{NIR+B} \qquad (3)$$

BSI_c = inrange (BSI_b, 0.18, 0.25) (4)

BSI_d = inrange (BSI_a, 88. 112) (5)

BSI_e = (BSI_d - BSI_c) (6)

BSI_f = iff (BSI_e = false and isundef (BSI_e)),unclass, BSI_b) (7)

BSI_g = inrange (BSI_f, 0.08, 0.15) (8)

Normalized BSI= iff (BSI_g = true, bare, unclass) (9)

This means that the resultant map (nBSI), areas with values between 0.08 and 0.15 from BSI_g map is classified as bare surface while other areas will be unclassified.

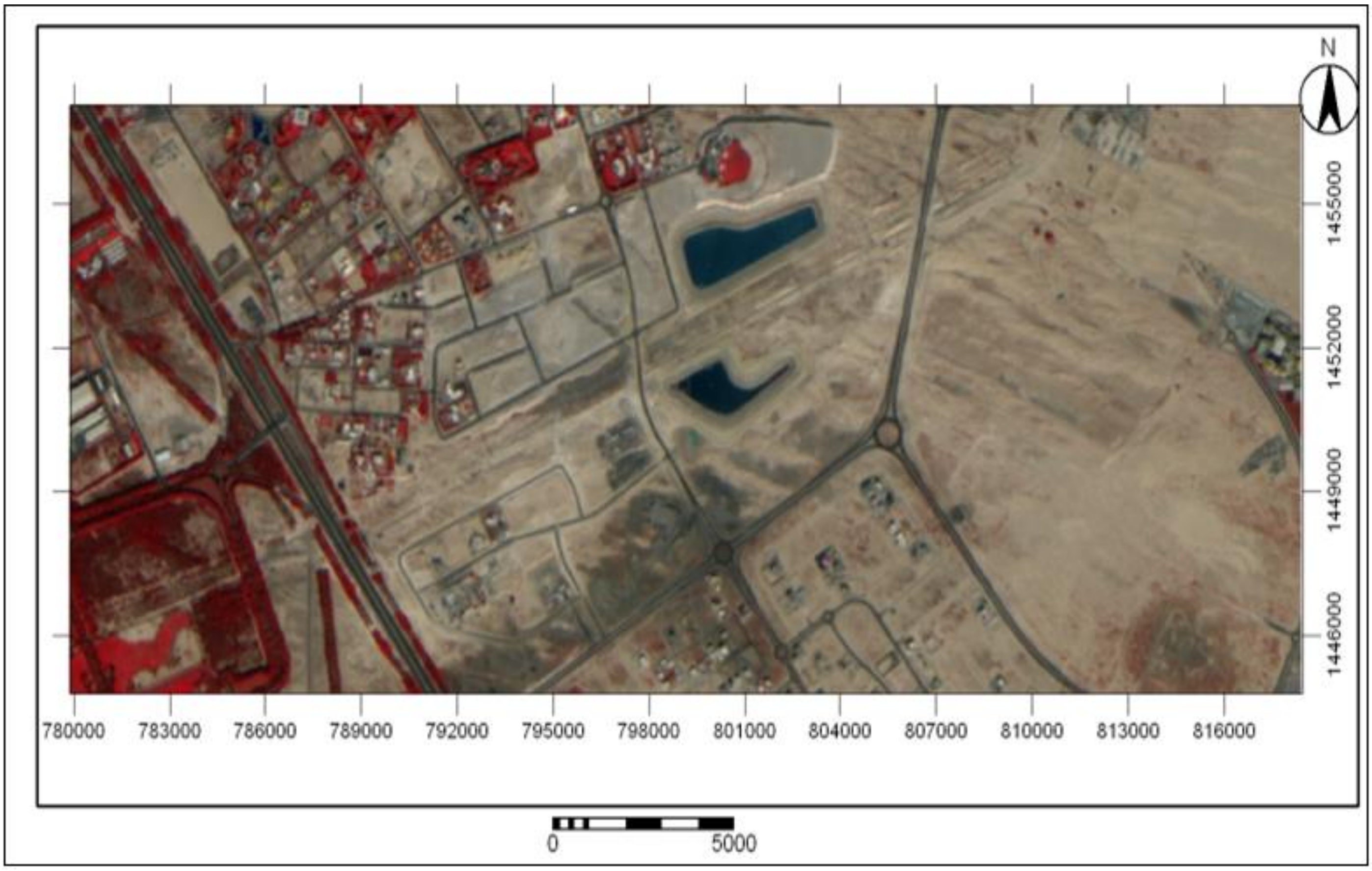

Fig 3 NigeriaSat-2 Image Covering Part of Jigawa State

- *Bare Surface Area Extraction*

NigeriaSat-2 image covering the study site was used as base map (figure 3 refers) and the area covered by bare surface was extracted based on the developed indices (equations 2 to 9 refers) is presented in figure (4).

- *Bare Surface Area Extraction based on Fieldwork*

NigeriaSat-2 image covering the study site was used as base map (figure 3 refers) and the area covered by Bare surface for the study site generated based on the fieldwork is presented in figure (5).

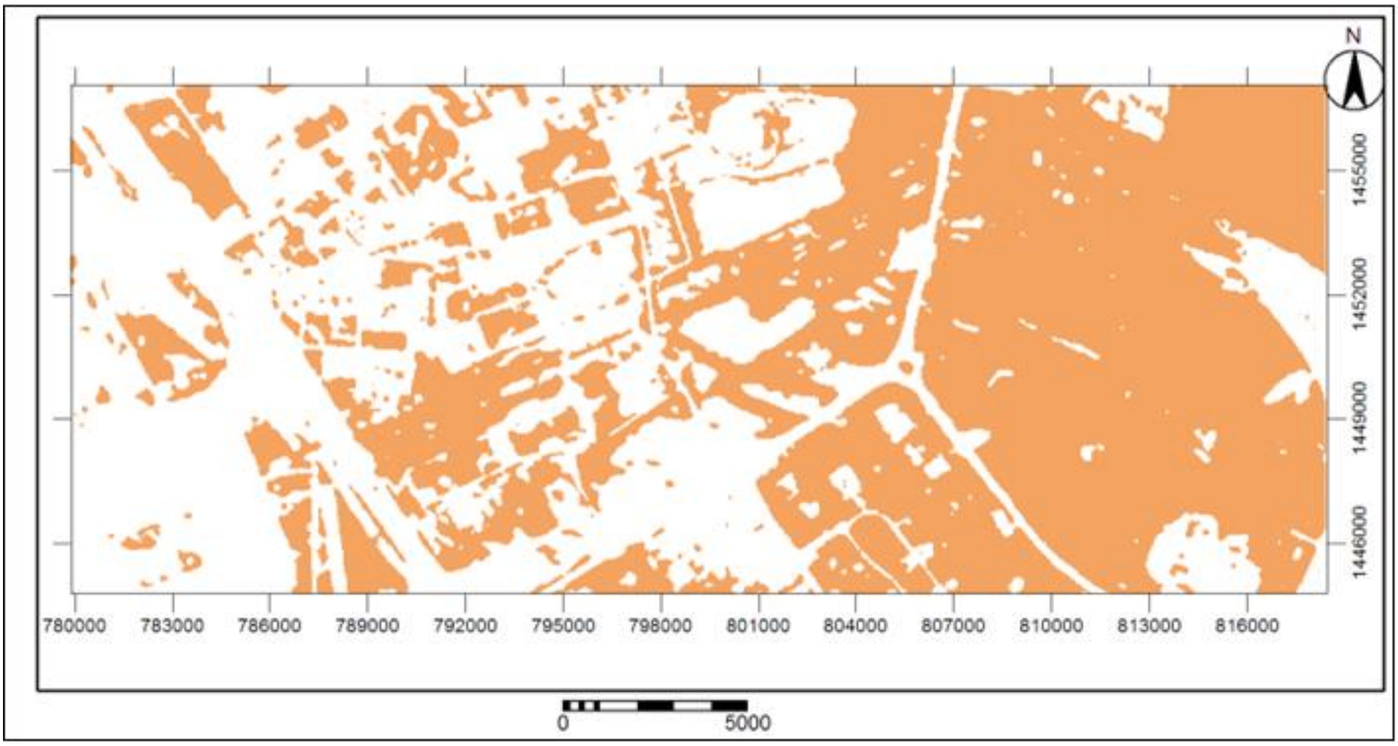

Fig 4 Map showing Extracted Bare Surface Areas within Part of Jigawa based on Developed Index

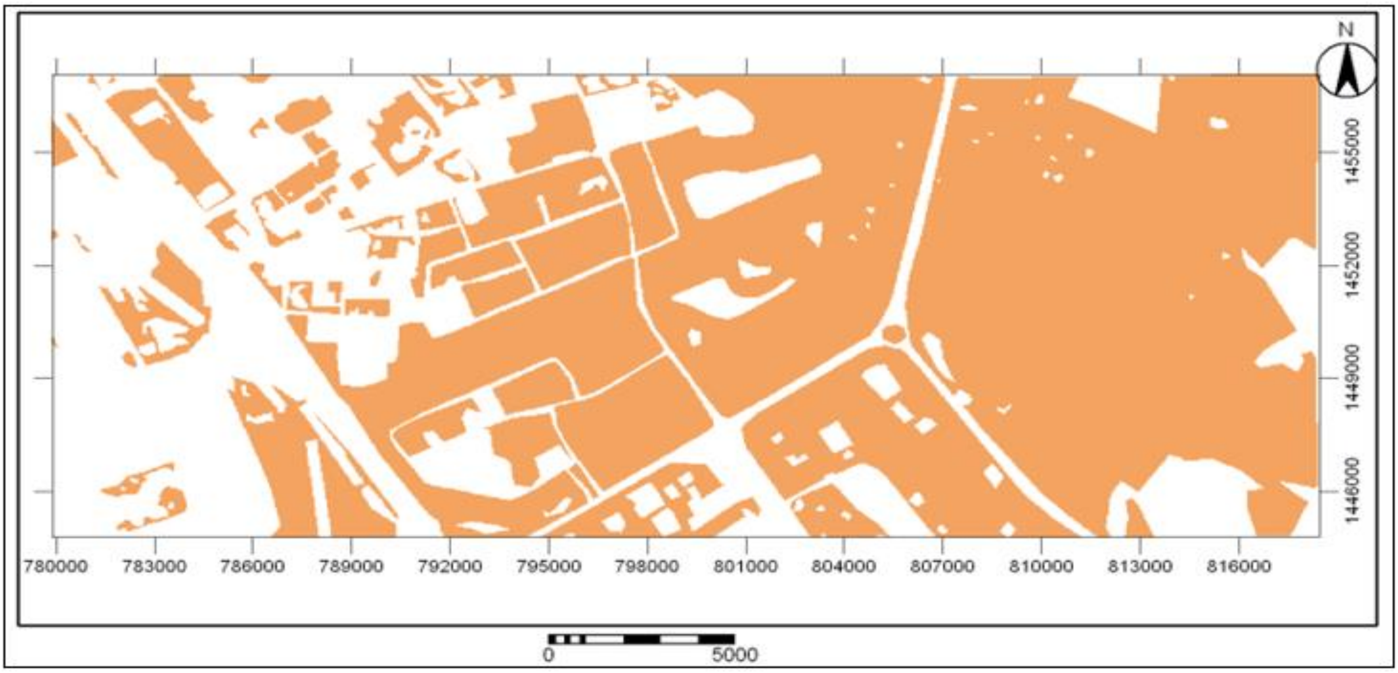

Figure 5 Map Showing Bare Surface Areas Covering Part of Jigawa Generated based on Ground Truth

➢ *Results from Developed Bare Surface Indices Accuracy Assessment*

The bare surface area cover map for the study site generated based on the fieldwork is presented in figure (5) while the bare surface area cover map for the study sites extracted based on the developed indices is presented in figure (4).

Comparison between the bare surface area cover maps for part of Jigawa extracted based on the developed indices with bare surface area cover based on the fieldwork (truth map) shows that 271,766 pixels matched out of a total number of 338,148pixels. Therefore the overall accuracy is 80.35% (equation 1 refers).

B. Algorithm Development and Design

➢ *Algorithm Development*

It should be noted and very importantly that what the developed program does is basically use the validated developed indices with respective threshold to run the process and thereby makes it automatic.

Below is the algorithm for the extraction of bare surface feature class from Nigeriasat-2 image covering parts of Jigawa State based on the developed and validated indices/codes using visual basic programming language;

- Dim BSI_a As Double
- Dim BSI_b As Double
- Dim BSI_c As Boolean
- Dim BSI_d As Boolean
- Dim BSI_e As Boolean
- Dim BSI_f As Boolean
- Dim BSI_g As Boolean
- Dim BAI_a As Boolean
- Dim BAI_b As Double

- BSI_a = 0.3 * Sqr(CDbl(mbBlueData(lngPixelIndex)) + CDbl(mbGreenData(lngPixelIndex)) * CDbl(mbBlueData (lngPixelIndex)))
- BSI_b = calcBandIndex(CInt(mbRedData (lngPixelIndex)), CInt(mbNIRData(lngPixelIndex)))
- If (BSI_b >= 0.11) And (BSI_b <= 0.15) Then
- BSI_c = True
- End If
- If (BSI_a >= 88) And (BSI_a <= 102) Then
- BSI_d = True
- End If
- BSI_e = BSI_d - BSI_c
- BSI_f = IIf(((BSI_e = False) And (BSI_e = False)), False, True) 'unclass and value assignment respectively
- If BSI_f = False Then
- Exit Function
- End If
- If (BSI_b >= 0.58) And (BSI_b <= 0.85) Then
- BSI_g = True
- End If
- BAI_a = IIf(((BSI_d = True) And (BSI_g = True)), False, BSI_d)
- BAI_b = IIf(BAI_a = True, BSI_a, False)
- If BAI_b = False Then
- Exit Function
- End If
- 'to make provided algorithm traceable in this code
- IsPixelSettlement = IIf(BAI_b > -0.85, True, False)
- End Function
- Private Function IsPixelBareSurface(lngPixelIndex As Long) As Boolean
- Dim BSI_a As Double
- Dim BSI_b As Double
- Dim BSI_c As Boolean
- Dim BSI_d As Boolean
- Dim BSI_e As Boolean
- Dim BSI_f As Boolean
- Dim BSI_g As Boolean
- BSI_a = 0.3 * Sqr(CDbl(mbBlueData(lngPixelIndex)) + CDbl(mbGreenData(lngPixelIndex)) * CDbl(mbBlueData(lngPixelIndex)))
- BSI_b = calcBandIndex(CInt(mbRedData (lngPixelIndex)), CInt(mbNIRData(lngPixelIndex)))
- If (BSI_b >= 0.11) And (BSI_b <= 0.15) Then
- BSI_c = True
- End If
- If (BSI_a >= 88) And (BSI_a <= 102) Then
- BSI_d = True
- End If
- BSI_e = BSI_d - BSI_c
- BSI_f = IIf(((BSI_e = False) And (BSI_e = False)), False, True) 'unclass and value assignment respectively
- If BSI_f = False Then
- Exit Function
- End If
- If (BSI_b >= 0.58) And (BSI_b <= 0.85) Then
- BSI_g = True
- End If
- IsPixelBareSurface = BSI_g 'to make provided algorithm traceable in this code
- End Function

➢ *Front End Interface (FEI) Design*

In order to design the Front End Interface (FEI) of the program, visual basic (VB) software was used. VB has both design mode and code modes. Both modes and codes can be used to design the FEI. In this research, the design mode used since the concept of design is already been visualized the way it should be.

The FEI was designed in such a way that it is user friendly and required no previous expertise in the field of Remote Sensing and GIS.

In addition, the designed FEI allows the end users to be able to (a) Select input data which is NigeriaSat-2 image in tagged Image File Format (TIFF) band by band from choice directory/folder (b) Display image in red, blue, green combination (RGB) (c) Select choice feature class that they want to extract (d) Calculate area coverage of resultant map and also (e) Select output choice directory.

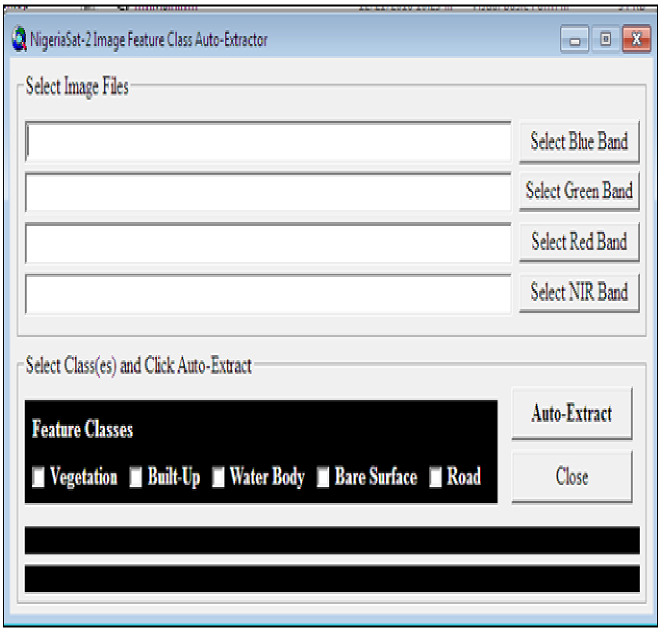

Fig 6 Figure Showing the Designed Front End Interface (FEI)

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V. CONCLUSION AND RECOMMNDATIONS

The study focused on the automation of the algorithm developed with the used of the object-oriented techniques for desertification early warning.

In addition, the global searching for indices suitable for satellite data with limited radiometric and spectral characteristics was solved.

However, because of its ease of use, low expense, and integration within a range of software products, this method prove to be valuable to local and regional governments, educational and research institutions, private industry.

Daily monitoring of bare surface areas with the states is an indicator for monitoring desertification encroachment. Monthly data analysis is statistically correlated to monitor the trend and give acquired information to relevant Government ministries and agencies saddled with the responsibilities of environmental disaster monitoring and management.

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