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Comparative Assessment of Some Vegetation Indices in Mapping Vegetation Biomass

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Abstract

Changes in vegetation patterns are inevitable in our dynamic environment. The detection and analysis of these changes are necessary to the assessment and monitoring of natural resources for the purpose of environmental resource management and decision making. This study has to do with the comparative performance of some vegetation indices in mapping vegetation biomass. Landsat image 1986TM was sub mapped and processed using the combined technologies of Remote Sensing (RS) and Geographic Information System (GIS). Four vegetation indices NDVI, NRVI, RVI and EVI were calculated and used to perform a vegetation biomass mapping. ILWIS Academic 3.2 and Microsoft Excel were used for the image processing and preparation of charts for analysis respectively. The result given in a brief summary showed that NDVI performed better in vegetation extent biomass mapping while EVI performed better in vegetation vigour biomass mapping. RVI presented a rather 'deviant' performance. The optimisation of these indices in their peculiarities as found in this study, a further research into their behaviour and inclusively the use of other imageries and software were recommended.

Keywords: *Vegetation indices, Remote Sensing, Geographical Information System, Biomass, Mapping*

Introduction

The environment is dynamic. Divers changes take place on a regular basis. The vegetation which is a major component of the environment is no exception.

The detection and quantitative assessment of green vegetation for environmental resource management and decision making is one of the major applications of remote sensing (Eastman 2012). Remote sensing is basically the acquisition of physical data of an object without touch or contact. It depends on observed spectral differences in the energy reflected or emitted from features of interest.Remote sensing is used to gather information at a distance by detecting and recording electromagnetic radiation from the target areas in the field of view of the sensor instrument. This is applied in the detection and quantitative assessment of green vegetation.Features are observed at varied wavelengths in an effort to derive information about these features and their distributions. This has helped in observing the spectral response of features over a range of wavelengths. This is called spectral signature (Randall, 2012, Parker and Wolff, 1965 quoted in Campbell and Wynne, 2011).

Vegetation indices (VI) are set of models designed to provide a quantitative assessment of green vegetation biomass. The underlying basis of the application of the vegetation indices are inferences from studies on the spectral behaviour of the healthy leave. A vegetation index is an indicator that describes the greenness — the relative density and health of vegetation — for each picture element, or pixel, in a satellite image (Jesslyn,2015). Vegetation indices are the combination of different bands of a multispectral image to accentuate the vegetated areas. Vegetated areas have high reflectance in the near-infrared portion of the electromagnetic spectrum and low reflectance in the visible portion. This contrast has been the basis of a large variety of attempts to develop quantitative indices of vegetation condition using remotely sensed imagery. (Campbell and Wynne, 2011; Amadou and Eastman, 2012)

Vegetation Indices (VI) designed to provide a quantitative assessment of green vegetation biomass are applicable to both low and high spatial resolution satellite images and any other that sense in the red and near infrared regions. They have been used in a variety of contexts to assess green biomass (Kogan, 1990; Tripathy *et al.*, 1996; Liu and Kogan, 1996 quoted in Eastman 2012). The detection and quantitative assessment of green vegetation is one of the major applications of remote sensing for environmental resource management and decision making (Eastman 2012).

Vegetation is one of the most important components of the ecosystems. Knowledge about variations in vegetation species and community distribution patterns, alternations in vegetation phonological (growth) cycles, and modifications in plant physiology and morphology provide a valuable insight in to the climate, geologic and physiographic, characteristics of an area, so mapping vegetation cover is important to understand various ecological processes occurring in nature, their relationship and the various geomorphological changes occurring over the period of time.(Joshi, 2011)

Maps are visual expressions of portions of the Earth's surface. Index values are converted into visual expressions in either soft or hardcopy for various uses. Features are depicted using various combinations of points, lines, and standard symbols. Softcopy maps are stored within a computer, can be analysed, modified, enlarged or reduced in scale, while being viewed on the monitors, and printed if desired. Different types or "layers" of information can also be extracted from digital maps to be represented and analysed separately, and softcopy maps can be transferred instantaneously to other offices or remote locations electronically. Softcopy maps are indispensable in the development and operation of Geographic Information Systems. (Wolf and Ghillani, 2013)

Vegetation biomass mapping involves using the various classification algorithms to view the amount of the vegetation and level of the health of the vegetation as quantified in the indices. Vegetation biomass mapping is simply the Vegetation index mapping. Vegetation biomass are categorised in type, extent and vigour using Vegetation biomass mapping. (Seto *et al.* 2004). Vegetation indices have been used in a variety of contexts to assess green biomass (Kogan, 1990; Tripathy et al., 1996; Liu and Kogan, 1996 quoted in Eastman 2012). The study aims at performing a comparative analysis and application of selected NDVI, NRVI, RVI and EVI in mapping vegetation biomass. A study area on a Landsat TM image was chosen on which the results of the calculation of the indices was used to perform a vegetation biomass mapping and compared.

The study area

The study area is Akure and its environ which is a portion Landsat 7 TM imagery of 1986 (path 191 row 55) covering Osun, Ekiti and Ondo states of Nigeria. It is covers an area of 917590.68 Hectares and bounded by top Min X,Y (674894.25,785987.25) and Max X,Y (803172.75,857978.25) coordinates.

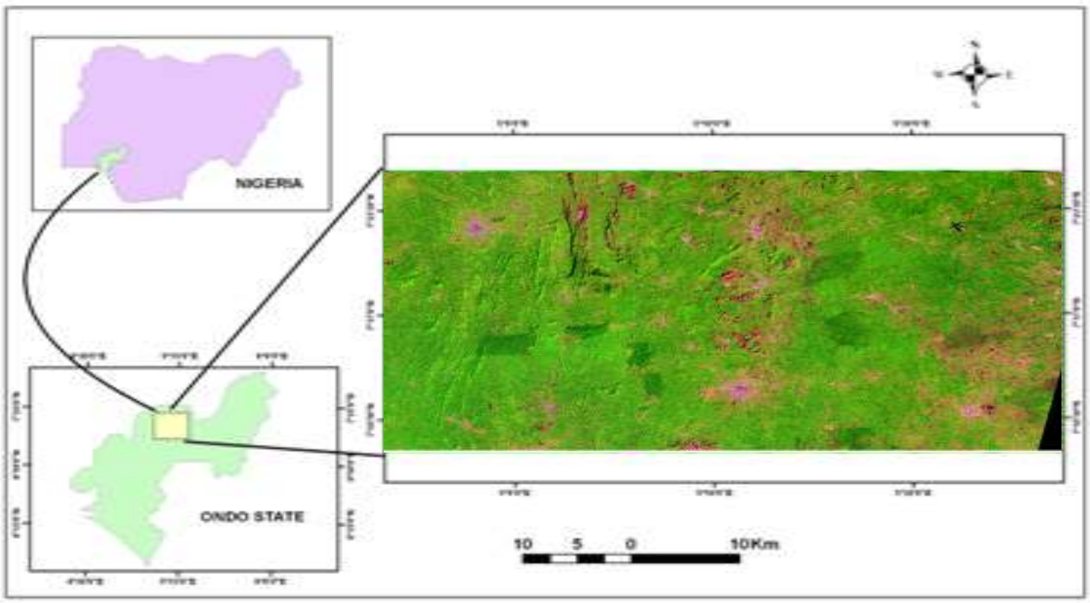


Figure 1: Map of the Study Area

MATERIALS AND METHOD

The data sets used for the study was the Landsat imageries Thematic Mapper 7 of 1986 and ILWIS 3.2 Academic software.

Image Processing

Before information was extracted from the imagery it was taken through some processing. The following steps were taken in the processing of the Landsat 7 TM image of 1986 using the ILWIS software:

i. The software [ILWIS 3.2 Academic]was launched and the image was loaded into the software, the desired bands one after another, via gateway and in the .tif format
ii. The colour composite was performed in the image processing menu and the area of interest (AOI) identified.
iii. A sub-map of the AOI was created.

The coordinate system of the sub-mapped AOI was set-(Projection-UTM, Ellipsoid-WGS1984 and Datum-Minna Zone 31N)

iv. The sub-mapped AOI was subjected to colour separation to allows retrieval for each pixel either the Red, Green or Blue value and stored these in a separate map.

v. Each of the band/colour was filtered to remove noise or perturbation on the image. Each pixel value in the raster map will be replaced with a new value obtained by applying a certain function on each input pixel and its direct neighbours. Linear filter (AVG 3x3) was adopted.

Calculation of the Vegetation Indices:

Using the map calculator in the software each of the index was calculated through their formula (see Table 1), using the filtered bands: NIR which was band 4 (B4), Red which was band 3 (B3). Table 1 shows the formular and the band representation to calculate the indices.

Table 1: Indices Formular and the band representation

INDEX	NAME	FORMULA	BANDS
NDVI	Normalised Differential Vegetation Index	NIR-RED/NIR+RED	B4-B3/B4-B3
RVI	Ration Vegetation Index	NIR/RED	B4/B3
NRVI	Normalised Ratio Vegetation Index	RVI-1/RVI +1	((B4/B3)-1)/((B4/B3)+1)
EVI	Enhanced Vegetation Index	2.4 [(NIR-RED)/ (NIR+RED + 1)]	2.4 [(B4-B3)/(B4+B3+ 1)]

Source: IDB 2015

Visualisation

The results of the calculations came primarily as maps displayed in grey colour for better assessment of the radiance (Figure 2). The radiance measures between 0(min) and 1(max). Brightness of value less than one (dark areas) indicates no vegetation while values greater than 1 (bright areas) indicates different vegetation. The level of radiance is shown in the legend. The histogram (Figure 2) shows the graphs and the statistics of the pixel usage.

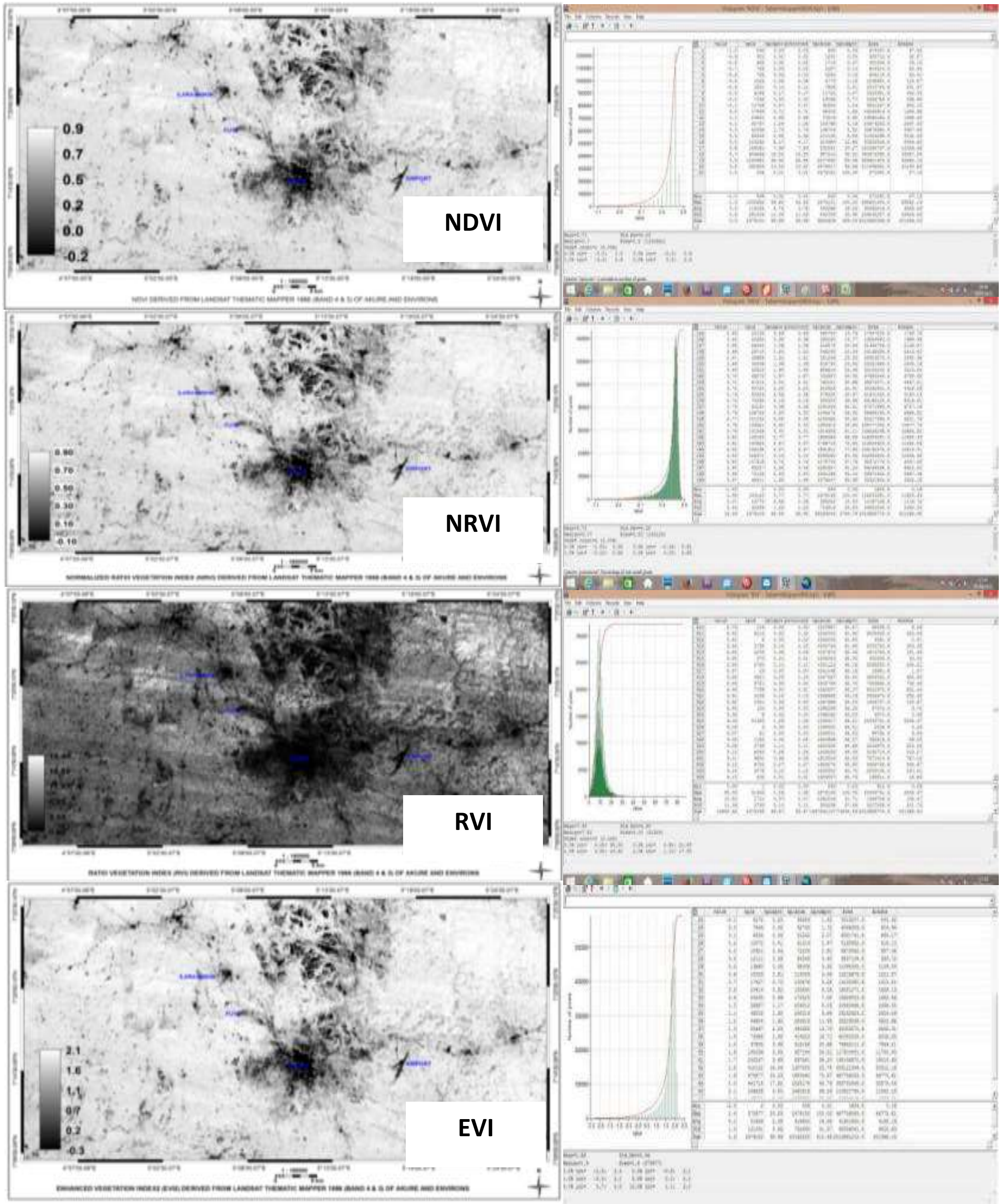


Figure 2: Derived Maps and Histograms from 1986 Landsat 7 TM Image.

Vegetation extent valuation

In order to classify the result into areas covered by vegetation and areas not covered, each of the maps were taken through slicing, with two domains (vegetated and non-vegetated) chosen.This reduced the map classes into two for evaluation (Figure 3-6) for each of the vegetation indices under consideration.

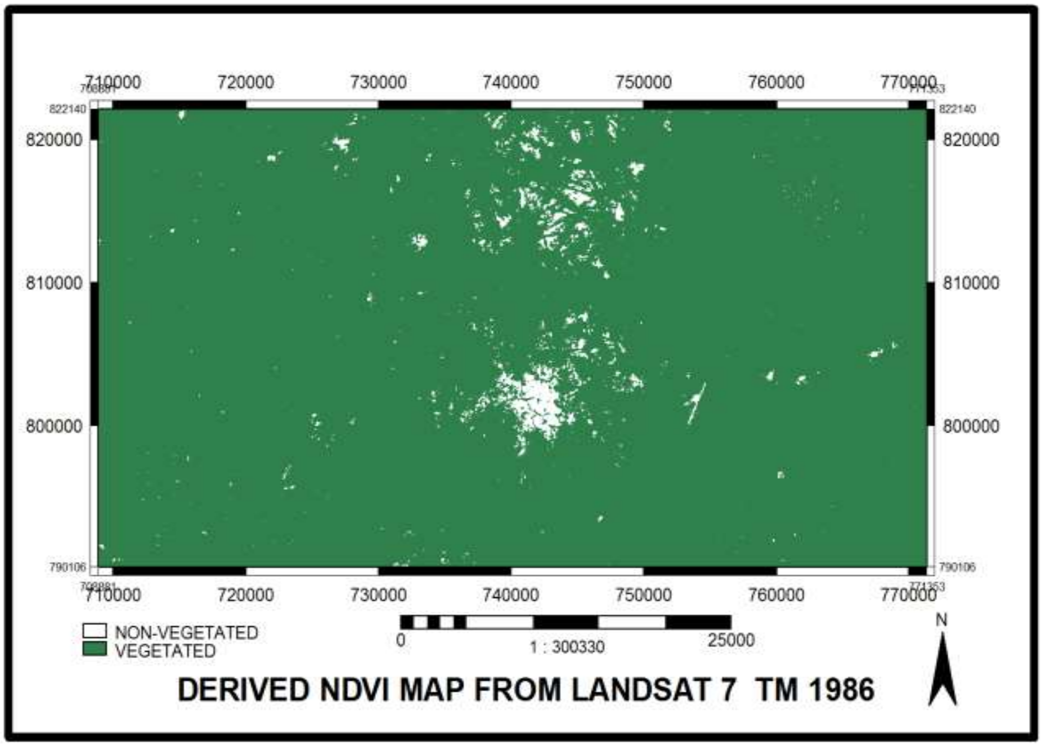


Figure 3: NDVI Map from 1986 Landsat 7 TM Image.

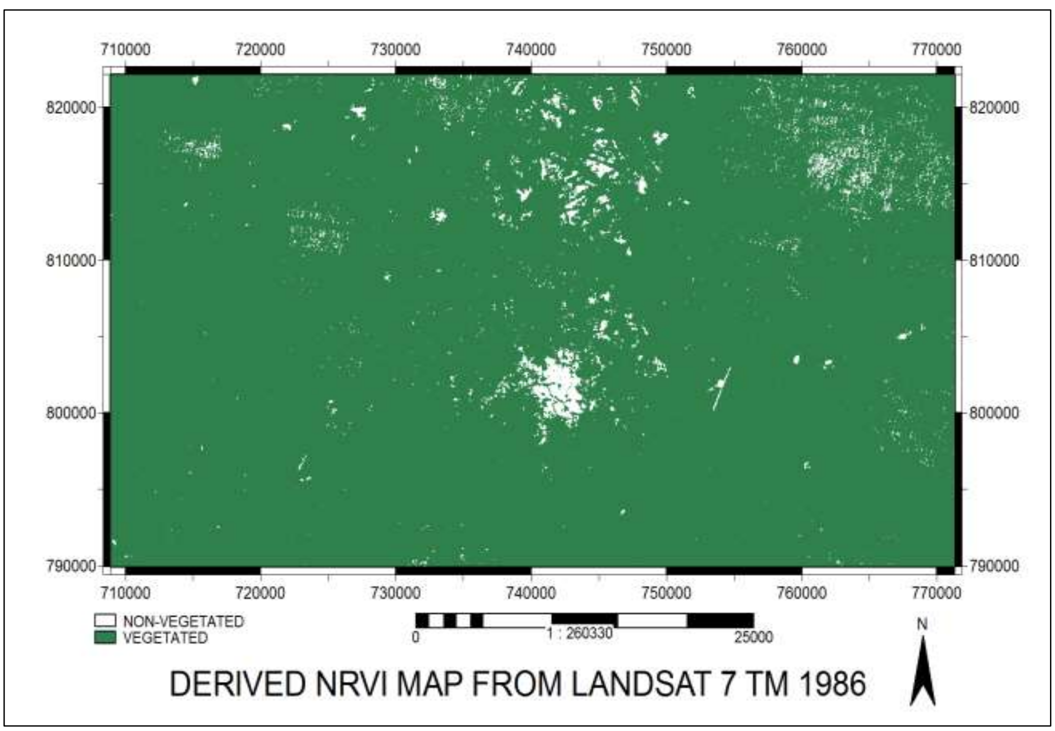


Figure 4: NRVI Map from 1986 Landsat 7 TM Image.

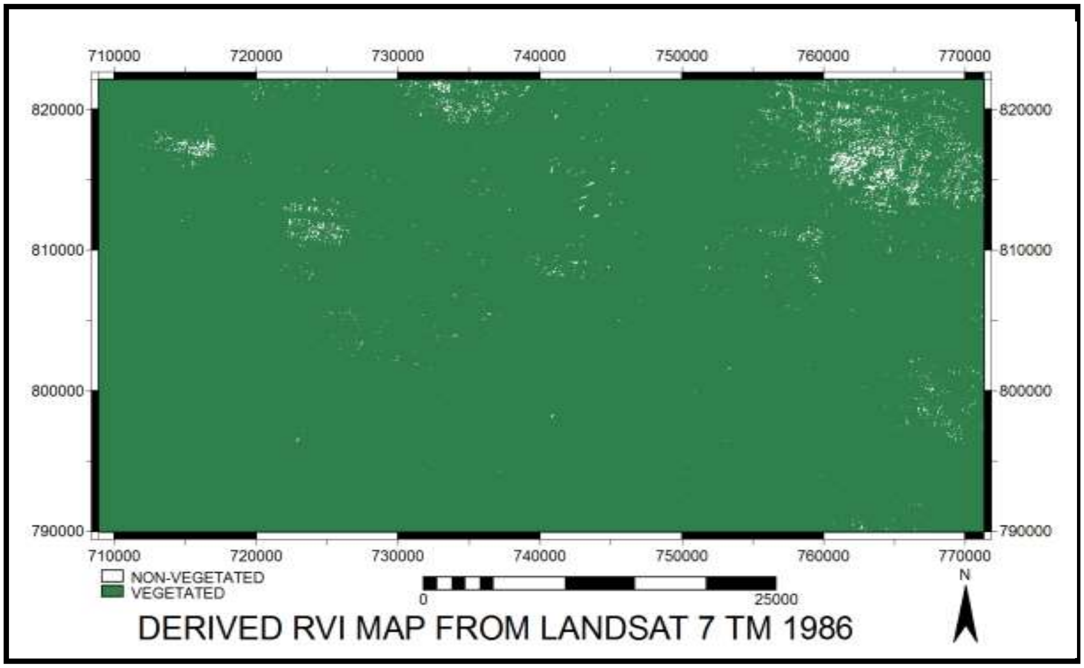


Figure 5: RVI Map from 1986 Landsat 7 TM Image.

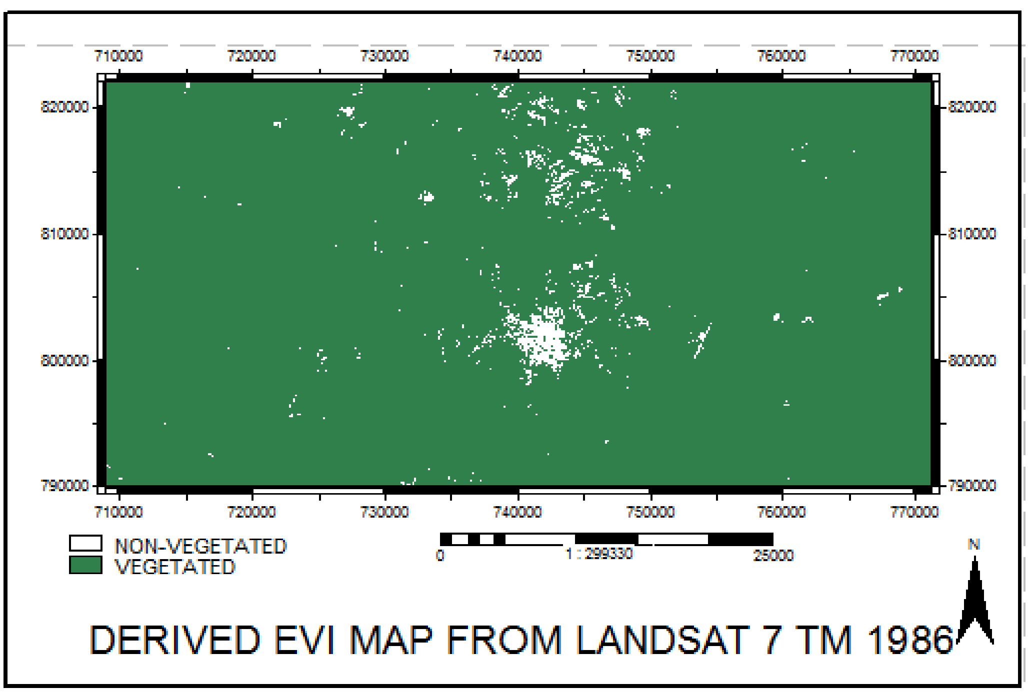


Figure 6: EVI Map from 1986 Landsat 7 TM Image.

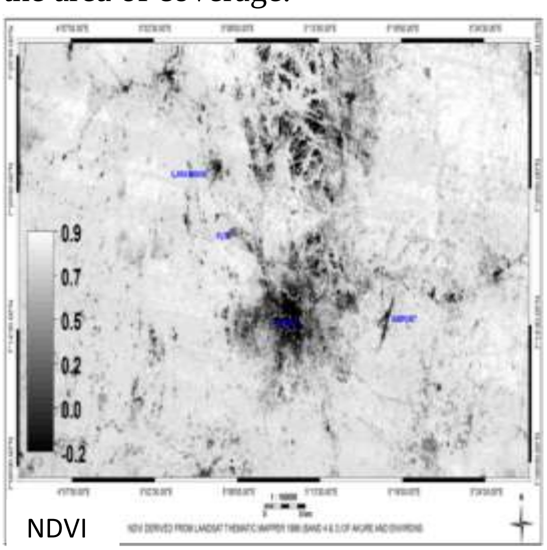
The different vegetation indices has unique characteristics that distinguish it from others. Table 2 summarized the functions of the four vegetation indices under study.

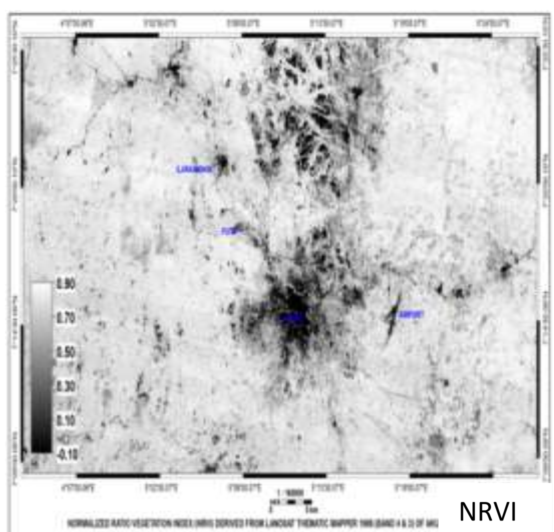
Table 2: Index Rationale

NDVI: **To produce a spectral VI that separates green vegetation from its background soil brightness**
RVI: **To separate green vegetation from soil back ground**
NRVI: **Normalization is similar in effect to that of the NDVI, reduces topographic,illumination and atmospheric effects. It creates a statistically desirable normal distribution.**
EVI: **Improves upon the quality of the NDVI product, it corrects for some distortions in the reflected light caused by the particles in the air as well as the ground cover below the vegetation. Does not become saturated as easily as the NDVI when viewing rainforests and other areas of the Earth with large amounts of chlorophyll.**
(Source: Eastman and Amadou, 2012)

DISCUSSION OF RESULTS

The results obtained in this study were in two parts as observed in the two types of maps produced: These are the vegetation vigour maps (Figure 7) from the direct calculations in grey scale; and the vegetation extent maps (Figure 8) for the area of coverage.





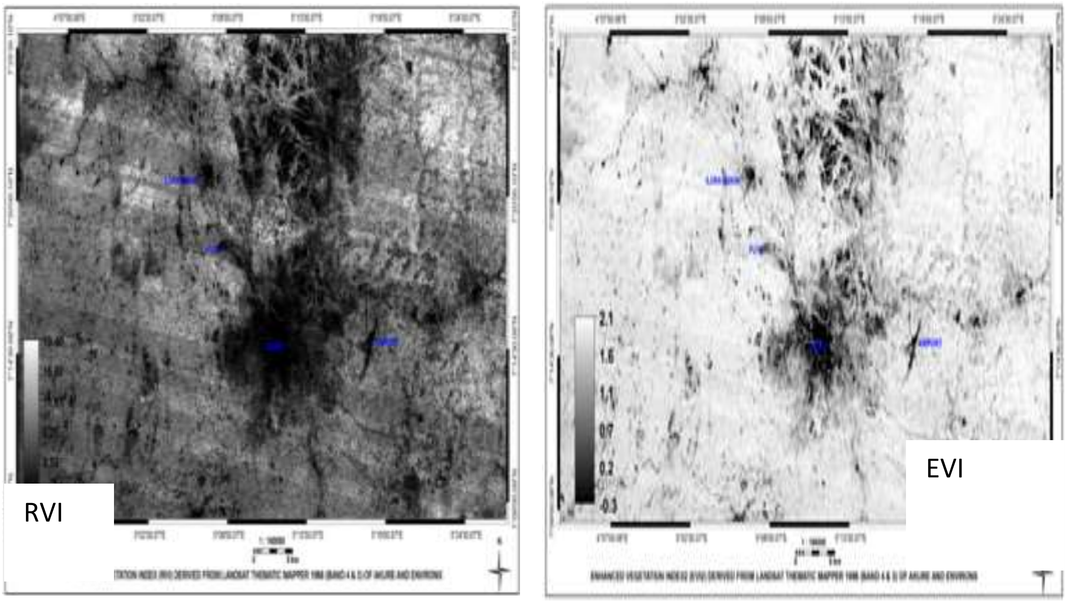
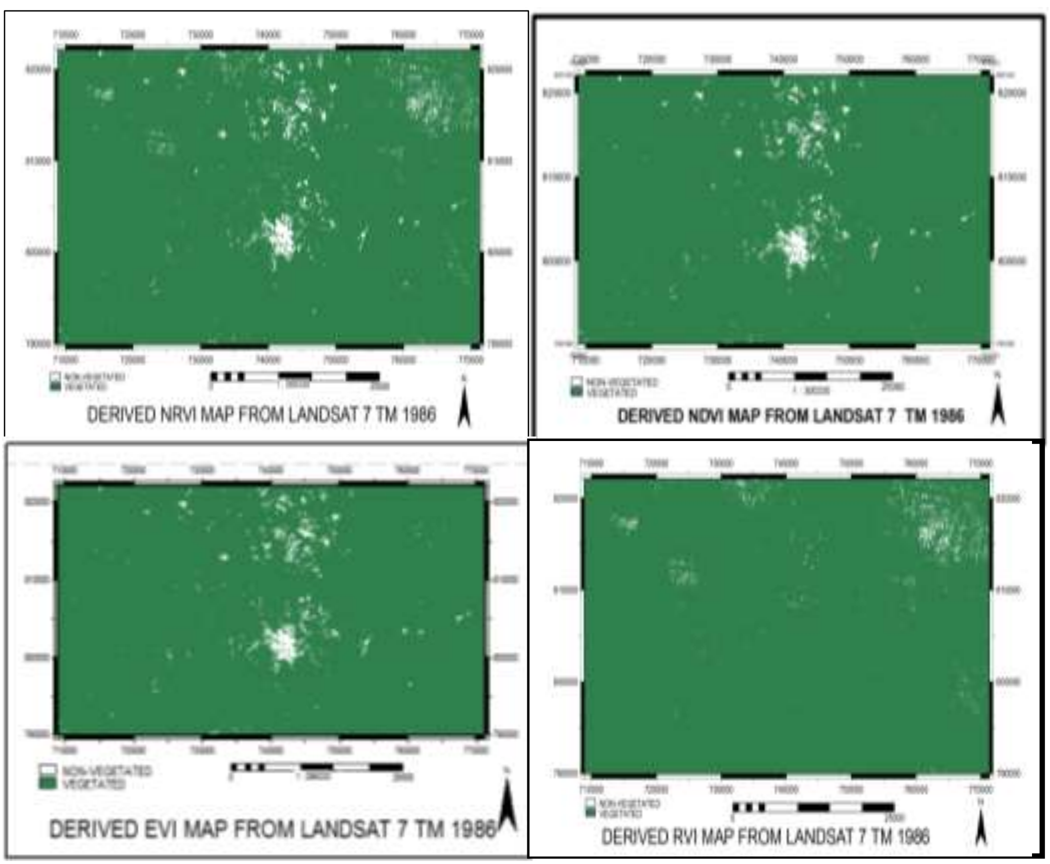


Figure 7: The Combined Vegetation Vigour Maps



`Figure 8: The Combined Vegetation Extent Maps

From the histogram menu, the command line was used to calculate the area of coverage of vegetated and non-vegetated. The maps were produced in pseudo colour for easy visualisation.

Table 3: Index Measure in Pixel Ranges and generalization								
RANGES							**AREAL EXTENT**	
INDEX							**VEG(ha)**	**NVEG(ha)**
NDVI	0.9	0.70	0.5	0.2	0.0	-	**197409**	**3933**
NRVI	0.9	0.70	0.5	0.3	0.10	-	**196462**	**3254**
RVI	19.40	14.76	10.11	5.47	0.82		**199294**	**67.4**
EVI	2.1	1.6	1.1	0.7	0.2	-0.3	**196476**	**3469**

The difference between the two maps is that the first maps visualised the vegetation health in ranges shown in first section of Table 3, while in the second maps there was a generalisation into just vegetated and non-vegetated areas with the figures shown in second section of Table 3

Interpreting the Histograms

To interpret the histograms (Figure 9), the following were noted. The horizontal axis of the histogram shows the range of possible brightness levels (usually 0 to 255), and the vertical axis represents the number of image cells that have a particular brightness. The significant brightness variability in the scene is shown in the breadth of a histogram peak: Histogram with much narrower peak depicts an image with more uniform surface cover, with less brightness variation, while Histogram with multiple peaks depict extensive areas of different surface materials with distinctly different brightness.

The characteristics of the maps is best inferred from the histogram. The inferred characteristics in this study are: Skew, Shade, peak shape, pixel usage.

Skew

With the exception of RVI, all other histogram had a similar positive skew (away from the zero point).This shows an emphasis of brightness or healthy vegetated areas. Only RVI skewed negatively (towards zero point) thus depicting emphasis of non-vegetation. This is observed in the exceptional dark appearance of the RVI map compared to others. From the rationale table 2, RVI should separate green vegetation from its soil background,thus, it classified all other features as various vegetation and the remaining as soil background.

Shade

NRVI is a normalized RVI, whose normalization is supposed to be similar to that of NDVI (Table 2). This effect is evident in the histogram. The statistics of NRVI is similar to that of NDVI in many cases. NRVI also combined the characteristics of both NDVI and RVI. Rightward skew for NDVI and shade for RVI. The shade may be the effects of the reduction of topographic, illumination and atmospheric effect. Probably, thereason for lower non-vegetation coverage than that of NDVI (Table 3).

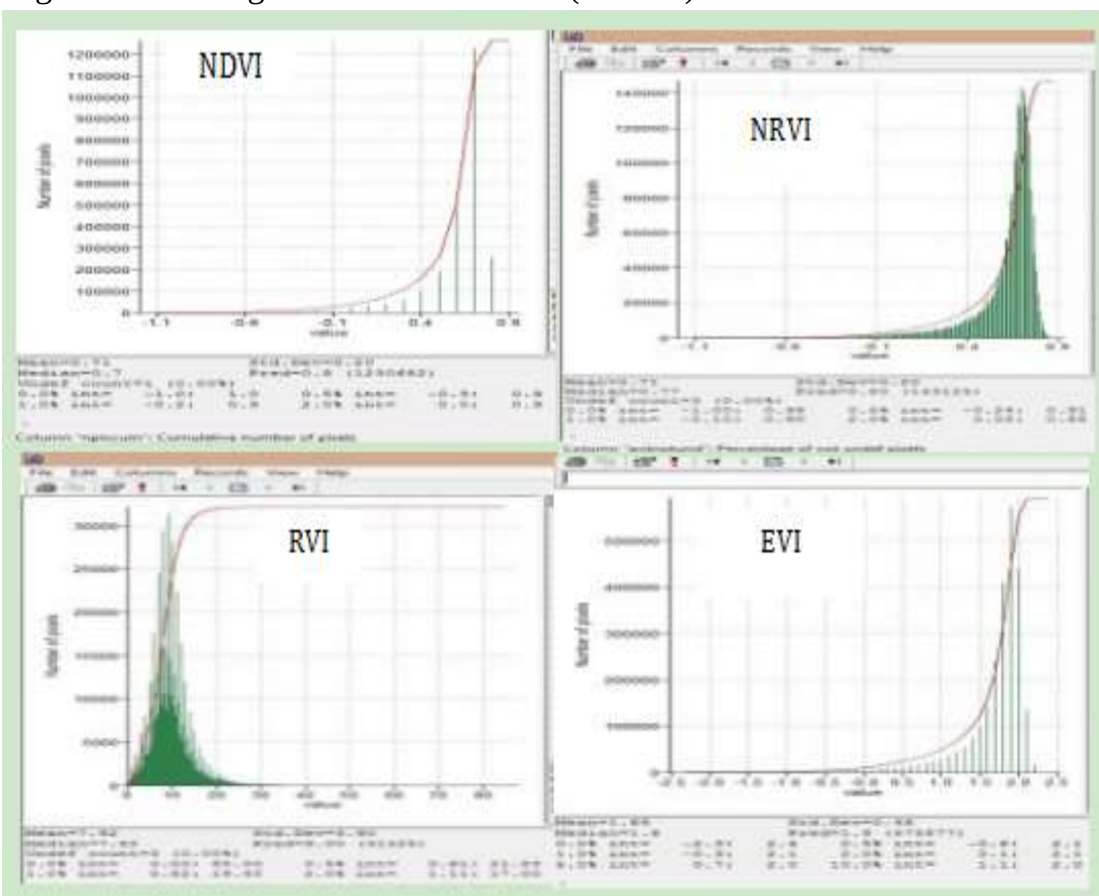


Figure 9: The Combined Vegetation Vigour Histograms

Peak shape

All the histogram have narrow peak which shows that the study area had more uniform surface cover, with less brightness variation. None of the histogram had multiple peaks which shows that the study area did not include extensive areas of different surface materials with distinctly different brightness.

Pixel Usage

The range of pixel in Table 3 show that EVI has more pixel usage in covering the vegetation vigour (2.1 max, -0.3 min).

Vegetation Aerial Extent

The extent of vegetation covered by each of the index was shown in Figure 3-6 and Figure 8. The measure of the extent of vegetation and non-vegetation covered by each index is shown in Table 4.

Table 4: Vegetation Aerial Extent

INDEX	VEG(ha)	NVEG(ha)	Total (ha)
NDVI	**197409**	**3933**	**201342**
NRVI	**196462**	**3254**	**199716**
RVI	**199294**	**67.4**	**199361.4**
EVI	**196476**	**3469**	**199945**

The sum total of extent coverage, vegetation and non-vegetation extents covered by each of the vegetation index is represented in charts as shown in figure 7, 8, and 9 respectively.

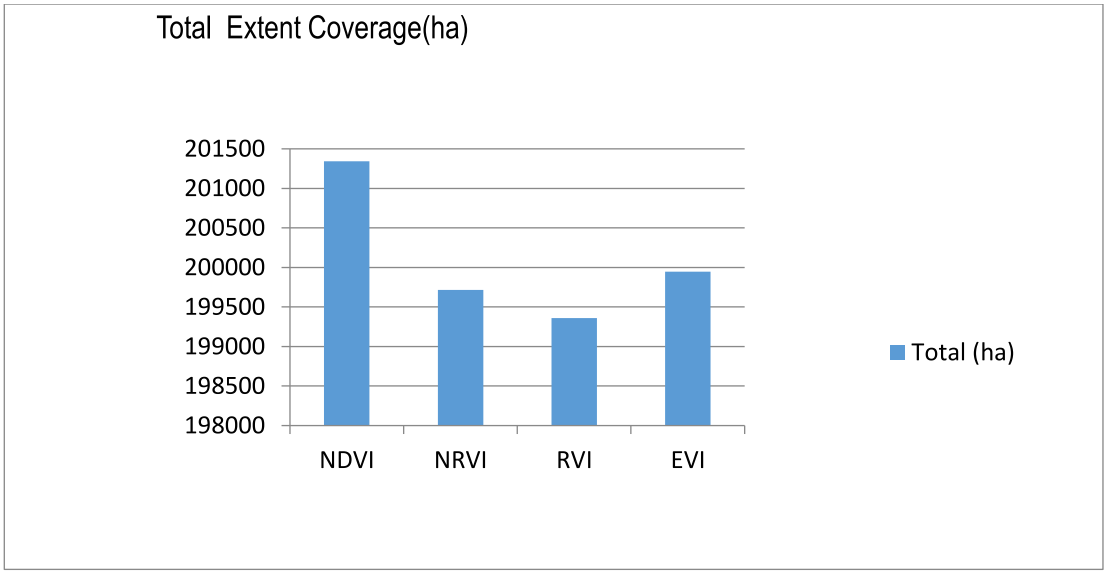


Figure 7: Total Extent Coverage (ha)

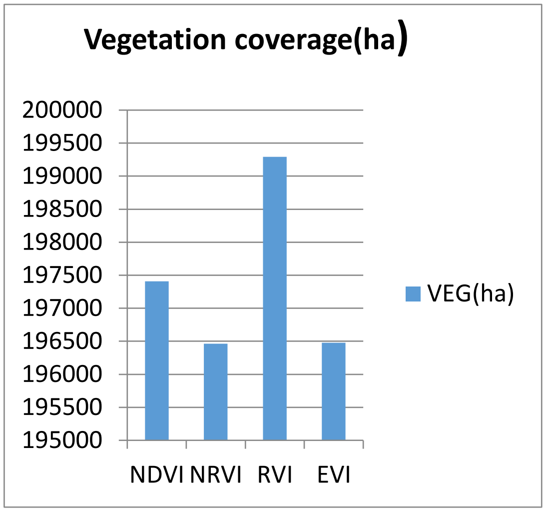


Figure 8: Total Vegetation Coverage (ha)

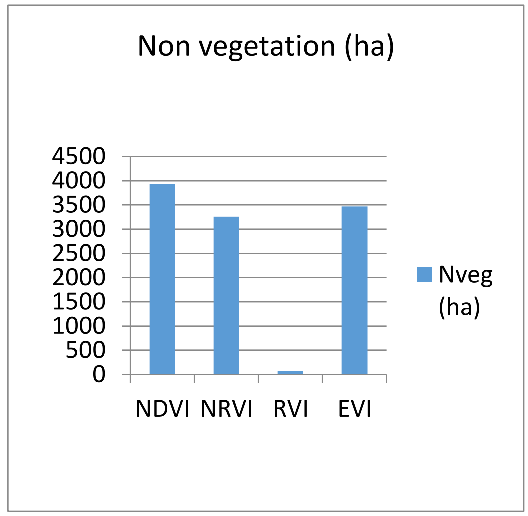


Figure 9 : Non-vegetation Coverage (ha)

From table 4 and figure 8, NDVI has the highest total area covered followed by EVI, then NRVI and amazingly RVI. In mapping Vegetation, RVI was highest followed by NDVI while NBVI and EVI had close performance. In mapping non-vegetaion NDVI was highest followed by EVI, then NRVI while RVI showed very poor performance. Thus it is safe to infer that when it comes to general all inclusive mapping, NDVI performed better than the rest while RVI has the least performance. But when it comes to exclusive vegetation mapping RVI performed better than them all and for exclusive non-vegetation mapping NDVI performed better but closely followed by EVI which is also closely followed by NRVI.

APPLICATIONS

From the results and the observations, it can thus be inferred that for general all inclusive vegetation extent biomass mapping, NDVI performed better than the rest and thus adjudged as most preferable when such mapping is needed. NRVI which is designed to reduce topographic, illumination and atmospheric effects can used instead of NDVI in situations where topographic illumination and atmospheric effect is a problem. When vegetation vigour was considered, EVI performed better as seen by its wider pixel range coverage (Table 3). This could be because of its design as spelt out in table 2. When soil background coverage is desired separate from the vegetation, RVI is suggested as seen in the exceptional dark appearance of its map (Figure 2 and Figure 5). It is suggested for use to geologists, hydrologists etc. prospecting for rocks, minerals and water bodies.

CONCLUSION

NDVI performed better in mapping vegetation extent and was good in vegetation vigour. But for mapping vegetation vigour EVI performed better. NRVI stood in between and RVI had a rather different behaviour, which could be an advantage to non-vegetation mapping. All the vegetation indices can be optimised for mapping as observed from the results of this study in their peculiarities either combined or individually.

The limitation of this study is majorly from the background of the author as a prospective major in the application of Remote Sensing to Surveying and Geoinformatics otherwise known as Geomatics or geospatial technology; and secondly that the study was part of the author's preliminary involvement in his PhD studies in the field of Remote Sensing applications. In addition, Landsat 7 TM used could affect the behaviour of the indices when compared to recent sensors like the Enhanced Thematic Mapper, Operation Land Imager (OLI)/ Thermal Infrared Sensor (TIR) found in Landsat 8 and 9. The use of other non-landsat sensors like sentinel could reveal different information. The software used could have affected the result. The use of many more Remote Sensing software can help ascertain the findings and encourage the optimization of the result. Thus the findings in the study are opened to further research and authentication.

RECOMMENDATIONS

The efficiency of remote sensing techniques to carry out assessment and monitoring of vegetation extent and vigour has been further confirmed in this study. It has helped in comparing chosen vegetation indices' performance in an area of applications. The optimisation of these indices in their peculiarities from the findings in this study is highly recommended. More research into the behaviour of the indices and their unique advantage in mapping vegetation and non-vegetation biomass is also recommended. It is recommended that the study should be carried out using other imageries like Spot 5 and other Remote sensing software for a more confirmation and authentication of the findings in this study.

REFERENCES

Amadou T, & EastmanJ. R (2012). IDRISI Selva Manual: Vegetation Indices. IDRISI Productions.

Burrows C.J (1990). Processes of vegetation change. London: Unwin Hyman.

Campbell, J.B & Wynne, R.H (2011). *Introduction to remote sensing.*5th ed. The Guilford

EastmanJ. R, 2012. IDRISI SelvaManual. IDRISI Productions.

Andrés Viña., Anatoly A. Gitelson., Anthony L.,Nguy-Robertson., Yi Peng., 2011.Comparison of different vegetation indices for the remote assessment of green leaf area index of crops. *Remote Sensing of Environment, 115*, 3468–3478.

Jesslyn, F.B (2013). NDVI, the Foundation for Remote Sensing Phenology. Earth Resources Observation and Science (EROS) Center. Sioux Falls, SD 57198

Karen, K & Kemp (2008). Encyclopedia of geographic information science, SAGE Publications, Inc

Joshi, P.C, 2011. Performance evaluation of vegetation indices using remotely sensed data. *International Journal of Geomatics and Geosciences, 2,* (1), 234

Marek Mróz, Anna Sobieraj (2004). Comparison Of Several Vegetation Indices Calculated On The Basis Of A Seasonal Spot Xs Time Series, And Their Suitability For Land Cover And Agricultural Crop Identification.

Randall B.S (2012). An Introduction to Remote Sensing of Environment (RSE).

Robert O, Phyllis M.F & Todd K (2003). Introduction to California Plant Life; p. 112

Robert, S (n.d). Introduction to Remote Sensing. New Mexico State University

Seto K.C., Fleishman E. & Fay J.P (2004). Linking spatial patterns of birds and butterfly species richness with Landsat TM derived NDVI. *International Journal of Remote Sensing, 25*, 4309-4324

Dutta, R (2014). Review of Vegetation Indices for Vegetation Monitoring.

IDB 2015 - List of available Indices: Available at http://www.indexdatabase.de/db/i.php

Bruno, B., Davide, C., Pasquale, D.V (2004). Remotely Sensed Vegetation Indices: Theory and Applications for Crop Management. *RivistaItaliana di Agrometeorologia, (1)* 36-53.