Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.7, 2019
www.iiste.org

Mapping and Analysis of Vegetation Spectral Reflectance in Oil and Gas Seepage Polluted Zones Using Six Vegetation Indices

Chukwudi Andy Okereke* Princecharles C. Anyadiegwu
Department of Surveying and Geoinformatics, Imo State University, PMB 2000 Owerri, Imo State Nigeria

Abstract
The growth and health of vegetation may be adversely influenced by oil and gas pollution or leakage. Thus, when an environment is contaminated with oil and gas pollution, growing vegetation often exhibit signs of stress. Satellite remote sensing has proven to be an effective tool and approach to detect and monitor vegetation health and status in oil and gas polluted zones. Previous studies have adopted vegetation indices which are obtained from remotely sensed satellite data to monitor vegetation health. This study is aimed at demonstrating the potential of vegetation spectral techniques for detecting and monitoring of oil and gas pollution from Landsat 8 OLI/TIRS remotely sensed data. To determine the influence of oil and gas pollution on vegetation reflectance, few polluted sites were analyzed and their reflectance were compared in all the TM bands against the non – polluted sites. The mean and standard deviation reflectance of each of the bands in two groups of sites and t – test are calculated to determine if there are any significant differences between the reflectance from the polluted and non – polluted sites. Thus, the study shows that in all the spectral bands, the vegetation reflectance from polluted and non – polluted areas exhibit small significant difference with a *p-value* >0.005. To further analyze the impacts of oil and gas on vegetation, six spectral indices including NDVI, SRI, MSAVI2, SAVI, ARVI2 and EVI2 were utilized. SRI, SAVI and EVI2 showed no significant relationship between polluted and non-polluted areas with a *p-value* >0.05 higher than the alpha level of 0.05 and the calculated *t - test value* is lower than the *t-critical value of* 2.09 while NDVI, MSAVI2 and ARVI2 showed a significant relationship between the polluted and non-polluted areas.
Keywords: oil and gas pollution, Ground Truthing, Vegetation Indices, Landsat 8 OLI/TIRS, Remote Sensing and Vegetation Cover.
DOI: 10.7176/JEES/9-7-05
Publication date:July 31st 2019

1. Introduction

Underground hydrocarbon reservoir often leak as a result of abundance of oil and gas at the earth's subsurface and as the pass through impermeable seals, along faults zones, and fractures in rocks and planes of weakness between geological layers at high pressure. They form seepages at the earth's surface. The negative impact of hydrocarbon seepages in our environment includes destruction of wild life, loss of fertile soil, pollution of air and water and damage to the ecosystem (Aghalino, 2000). Hydrocarbon seepage is one of the world's environmental problems, which comes with negative impact on soil and vegetation. Hydrocarbon seepage in an area often gives rise to brownish and stressed vegetation and make fertile soil to become barren (Roberts, 1997). Vegetation is very important in our daily lives and we depend upon it to satisfy our basic needs which include food, clothing, shelter and health care . On a daily basis, our basic needs increase, and this is attributed to increase in world population, income and urbanization. Unfortunately, under field conditions, vegetation is continuously vulnerable to a wide range of biotic, abiotic and anthropogenic changes owing to hydrocarbon seepage. Hydrocarbon seepage often influences the soil chemistry, spectral reflectance, soil air composition and makes growing vegetation deficient in water and minerals intake, thus affecting their optimum growth (Schumacher, 2001). Hydrocarbon seepage also affects the health status of vegetation and make them to be stressed.

Remote sensing has the ability to detect the health status of vegetation, thus detecting if the vegetation is healthy or stressed. It is considered as a valuable tool for the determination, analysis and monitoring of vegetation status over time (Pinter et. al. 2003). Remote sensing has the ability to detect if a plant is healthy or is stressed, because vegetation spectral reflectance is dependent on the chlorophyll and water absorption in the leaves, which get affected by oil and gas impact. A vegetation which is healthy has high spectral reflectance pattern at wavelengths near infrared (800 – 1100nm) and are characterized by high absorption of blue (450nm) and red (670nm) wavelengths. The reflectance of stressed plants often shows a higher reflectance in the visible region, lower reflectance in the near infrared and a shift of the red edge position towards shorter wavelengths. The near infrared spectral shows a decrease in value due to decreasing chlorophyll in the leaves. In studying the response of vegetation to any change in the environment, their spectral reflectance characteristics are important. When radiation interacts with vegetation, it may be reflected, absorbed or transmitted, depending on its chemical constituents and the physical structure of the leaf (Miller et al., 1990; Carter, 1991; Gitelson et al., 1996; Male et al., 2010). Some features responsible for absorption and reflectance in vegetation spectra are shown in table 1.

Table 1: Absorption features of vegetation spectra (Smith (2002) and Blackburn (2007).

Contributing factor	Wave lengths (nm)	Interaction/Process
Chlorophyll a	435, 670-680, 740	Strong absorption
Chlorophyll b	480, 600-650	Strong absorption
g-carotenoid	420, 440, 470	Strong absorption
ß-carotenoid	425, 450, 480	Strong absorption
Anthocyanins	400-550	Absorption
Lutein	425, 445, 475	Absorption
Violaxanthin	425, 450, 475	Absorption
Chlorophyll a & b	550	Strong reflectance
Water, oxygen	760	Strong reflectance
Water	970	Weak absorption
Water, CO2	1450, 1944	Strong absorption

Vegetation indices are the most common and frequently used indices which indicate the relative density and health of vegetation. Vegetation indices such as NDVI, SRI, SAVI and MSAVI2 etc. compare the reflectance in the red and near – infrared bands. Healthy vegetation reflects a significant amount in the near – infrared portion of spectrum and reflects minimal in the visible, because chlorophyll present in plant leaves strongly absorb visible light, which is used in photosynthesis and the cell structure of the leaves strongly reflect near – infrared light. NDVI is the most widely used vegetation index. This index is adopted to distinguish healthy vegetation from others and from non – vegetated areas with the aid of red and near – infrared reflectance values. Calculations of NDVI for a given pixel usually result in a number which ranges from minus one (-1) to plus one (+1). No green leaves give a value close to zero. A zero means no vegetation and close to +1 (0.8 – 0.9) indicating the highest possible density of green leaves. SRI provides a general indication of vegetation. It is simply the reflectance in the NIR band divided by the reflectance in the red band. A larger SR value indicates healthy vegetation while lower values indicate soil, water or ice.

The aim of this study is to map and analyze the spectral reflectance of vegetation in hydrocarbon seepage polluted zones using vegetation indices. The SAVI is structured similar to the NDVI but with the addition of a soil brightness correction factor L. The "L" factor is one which is determined by the relative percentage of the vegetation, depending on its darkness or lightness (L=0 for very high vegetation cover, 1 for very low vegetation cover and 0.5 for intermediate cover) (Gibson et al., 2000). It is adopted as an exponent assigned to the red- band value in the denominator as well as a multiplier (L+1) of the first term.

Table 2: Summary of some common vegetation indices [Haindongo, (2009)]

Vegetation Index	Acronym	Author	Formula
Normalized Difference Vegetation index	NDVI	Rouse et al. 1974	(NIR-R)/(NIR+R)
Simple Vegetation Index	SVI	Pearson and Miller, 1972	Near Infrared/Red
Soil Adjusted Vegetation Index	SAVI	Huete, 1988	(NIR-R)/(NIR+R+L)*(1+L)

1.2. Study Area

Ugwueme is located in the present Awgu Local Government Area of Enugu State. The town is bound by Latitude $6^0\ 0'\ 00''N$ and $6^0\ 03'\ 00''N$ and Longitude $7^0\ 24'\ 00''E$ and $7^0\ 28'\ 00''E$ of geographical co - ordinates. The study area has mainly Ferralitic soils known as Red Earth, which is poorly drained and is particularly suitable for the cultivation of cash crops. The zone experiences heavy rainfall during the rainy season with an annual record of 1,800 mm which aid heavy flooding, soil leaching, erosion, extensive outwash and percolation during the dry season with an annual temperature of 26.6^0C. Oil and Gas seepage in the study area is categorized as Macro-Seepage. Macro-Seepage is oil and gas seepage that can be seen with the eye directly on the surface as asphalt, oil pond or gas bubbles when associated with water or mud – volcano.

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.7, 2019

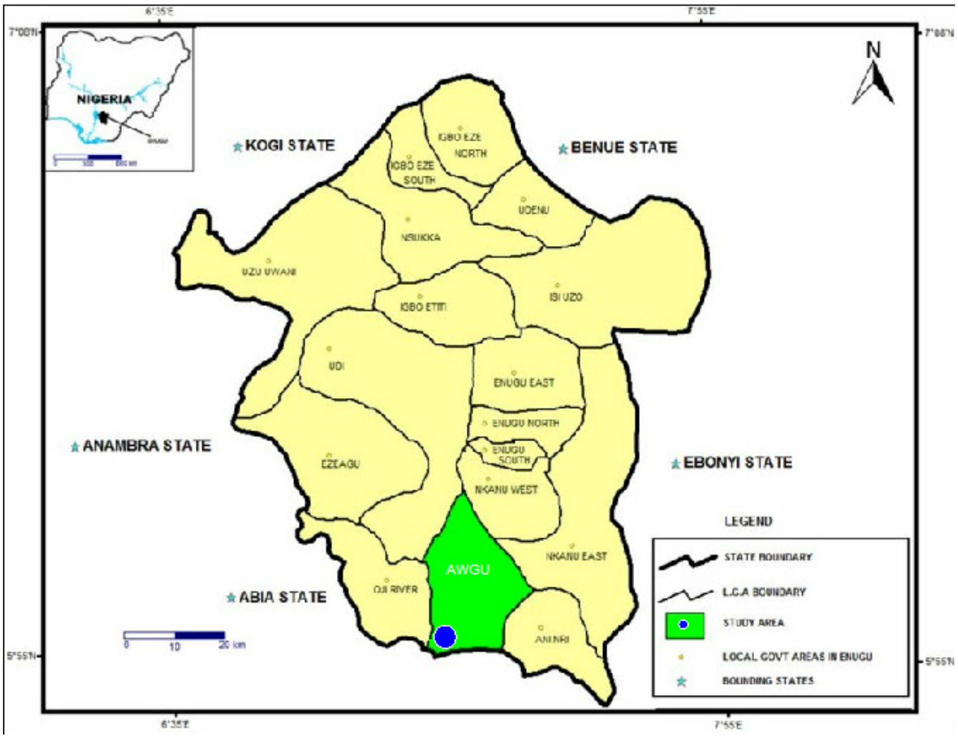


Figure 1. Location of the study area (*Source: modified from Obeta and Nwankwo, 2015*)

2. Materials and Methods

2.1. Data Collection

The study was carried out using Landsat 8 OLI/TIRS 2016 imagery which was acquired freely online from the site www.http://earthexplorer.usgs.gov. They were retrieved from path 188 and row 55, path 188 and row 56 and path 189 and row 55 at a scale resolution of 30m. ArcGIS 10.3 software was used to compliment the display and processing of the data. The global positioning system (GPS) was used during field studies to obtain ground truthing information. To determine the influence of pollution from hydrocarbon seepage on vegetation reflectance, we analyzed few polluted sites and then compare their reflectance in all the Landsat 8 OLI/TIRS bands against the non – polluted sites. We then calculated the mean as well as the standard deviation reflectance of each of the bands in two groups of sites, and t – test to determine if there are any significant differences between the reflectance from the polluted and non – polluted sites.

Table 3: Sample points of 7 polluted and non – polluted vegetation areas and Location

Sample Points	Categories	Location X	Location Y
1	Polluted	328572.962	670618.500
2	Polluted	327051.605	669130.216
3	Polluted	325519.664	663492.595
4	Polluted	326620.333	665566.933
5	Non – Polluted	328916.260	666979.811
6	Non – Polluted	333000.773	667376.687
7	Non – Polluted	328717.822	664234.753

2.2. Comparison of vegetation reflectance in polluted and non-polluted sites

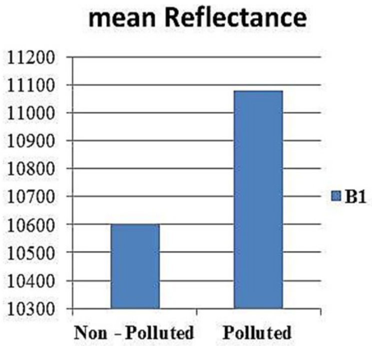
Sequel to testing the hypothesis of the study, vegetation reflectance from sample points were obtained from Landsat 8 OLI data. The statistics for mean and standard deviation of the vegetation spectral reflectance were computed using statistical tools in SPSS. To test for the statistical significance of the study, it is assumed that seepage pollution is related to the changes in vegetation reflectance in all the spectral bands from the sampled polluted and non – polluted sites. To test for hypothesis of the study, a null hypothesis assumed there is a relationship between oil pollution and changes in vegetation spectral reflectance from the polluted areas. The result of the null hypothesis is either accepted or rejected (see table 4).

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.7, 2019

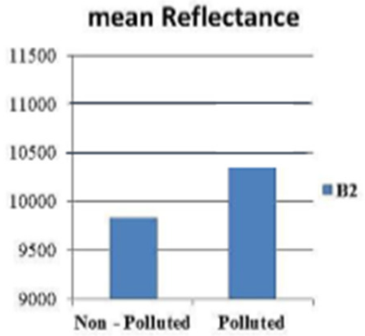
Table 4: Calculated statistics for spectral bands from polluted and non-polluted points

Reflectance	**Non - Polluted**			**Polluted**			**Calculated Statistics**
Spectral Bands	**Mean**	**Standard Deviation**	**Standard Error**	**Mean**	**Standard Deviation**	**Standard Error**	**t – Test value**
B1	10599.000	74.953	53.000	11078.000	38.891	27.500	0.420
B2	9835.500	109.602	77.500	10472.000	142.128	100.500	0.710
B3	8950.000	203.647	144.000	9771.500	292.035	206.500	1.350
B4	8290.000	384.666	272.000	9788.000	817.415	578.000	0.910
B5	14474.000	207.889	147.000	14289.000	60.811	43.000	0.520
B6	10689.000	1691.399	1196.000	13524.000	1367.545	967.000	1.180
B7	7857.000	1192.182	843.000	10286.000	1524.522	1078.000	0.420
B8	8637.000	257.387	182.000	10207.000	873.984	618.000	1.420
B9	5033.000	1.414	1.000	5045.500	12.021	8.500	0.880
B10	27762.000	1157.534	818.500	29459.000	552.958	391.000	1.050
B11	25538.000	876.105	619.500	26782.000	481.540	340.500	0.710
	Probability Error (alpha level) 0.05						
	Degree of Freedom 22.00						
	t-critical value 2.09						

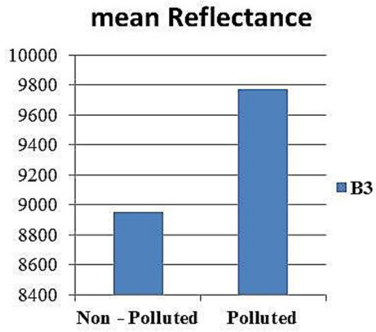
From the study, it is noted that in all the spectral bands, the vegetation reflectance from polluted and non-polluted areas showed small significant difference with a *p-value >0.005.* For the mean and standard deviation [See figure 2 (a – k)] for the various Landsat 8 bands, the statistical tests reveal significance differences between the reflectance of vegetation in the polluted and non - polluted areas. For example, in blue spectral band, green spectral band, red spectral band, and other spectral bands except spectral bands 5 and 8, the reflectance in the non - polluted areas were lower than in the polluted areas. In contrast, the NIR band showed a higher reflectance in the non – polluted areas as compared to the polluted sites. We note that these results are intriguing and need further studies.



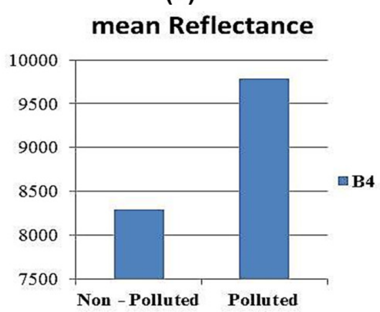
(a)



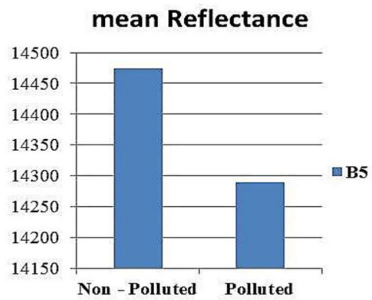
(b)



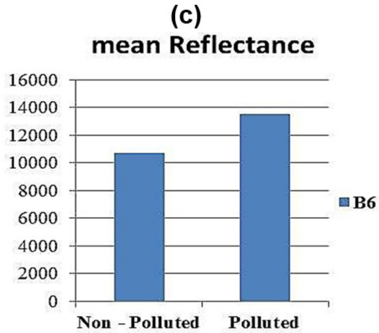
(c)



(d)



(e)



(f)

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.7, 2019

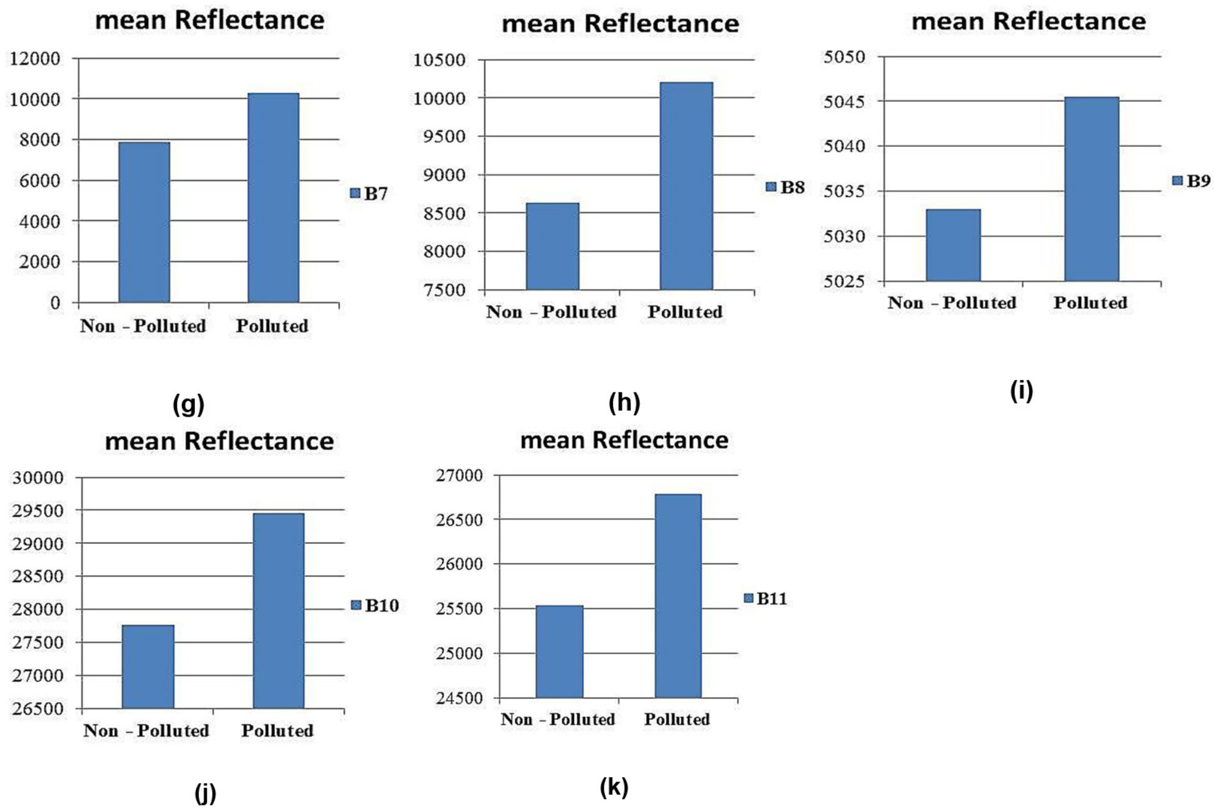


Figure 2: (a – k): Mean and standard deviation for vegetation reflectance (B1 – B11)

3. Results

Adoption of vegetation indices minimizes the noise in the data. Therefore, to further analyze the impacts of Hydrocarbon seepage on vegetation in the study, there is need to calculate the vegetation indices. Thus, we need to first analyze if there were any significant differences between the vegetation indices derived for the polluted sites and those from the non-polluted sites. Secondly, we identify which vegetation indices are best suitable for depicting the impacts of pollution on vegetation in the study area. Table 5 shows the results from a sample of vegetation indices that were calculated.

Table 5: Calculated statistics for spectral vegetation indices

	Non - Polluted			Polluted			Calculated Statistics	
Vegetation Index	Mean	Standard Deviation	Standard Error	Mean	Standard Deviation	Standard Error	t – Test value	P – Values
NDVI	0.270	0.012	0.009	0.173	0.024	0.017	2.600	0.01725
SRI	1.740	0.045	0.032	1.420	0.070	0.050	1.530	0.14141
MSAVI2	0.405	0.018	0.013	0.260	0.036	0.026	3.880	0.00093
SAVI	0.220	0.028	0.020	0.065	0.049	0.035	1.430	0.16798
ARVI2	0.647	0.029	0.020	0.415	0.058	0.041	2.600	0.18072
EVI2	0.136	0.014	0.010	0.022	0.028	0.020	1.390	0.01725
	t-critical value 2.09							
	Degree of Freedom 20.00							
	Probability Error 0.05							

In the study, for vegetation indices computed; SRI, SAVI and EVI2 showed no significant relationship between polluted and non-polluted areas with a *p-value* >0.05 higher than the alpha level of 0.05 and the calculated *t-test value* is lower than the *t-critical value of* 2.09. In contrast, other vegetation indices (NDVI, MSAVI2 and ARVI2) in comparison indicated a significant relationship between the polluted and non-polluted areas. The maps for the various vegetation indices can be seen below (see figures 3 through 8).

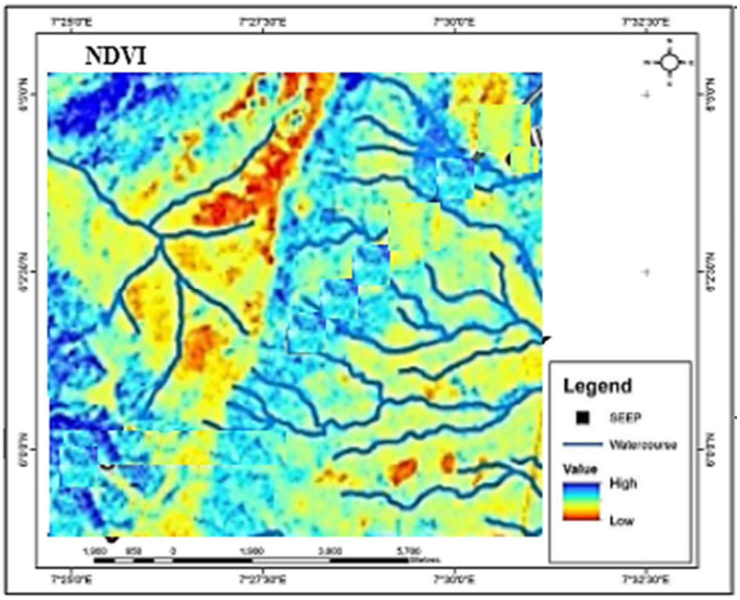


Figure 3 : NDVI map of the study area (source: author, 2019)

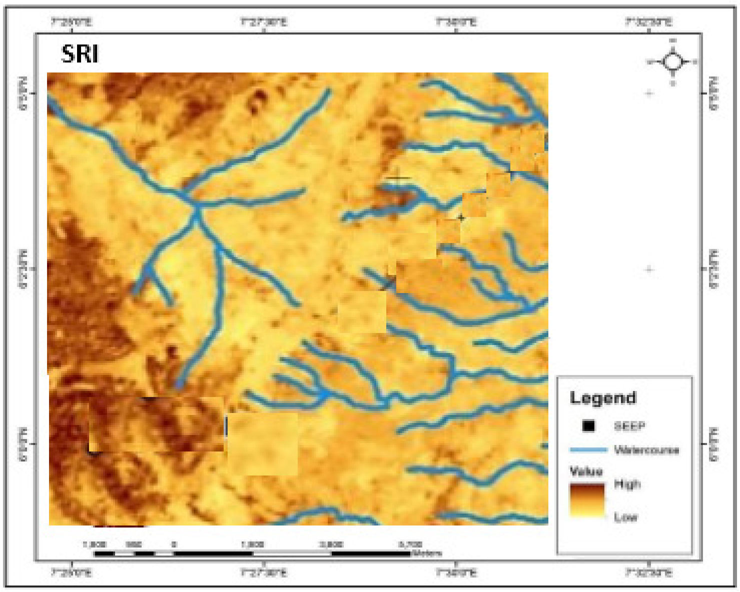


Figure 4: SRI map of the study area (source: author, 2019)

ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) DOI: 10.7176/JEES
Vol.9, No.7, 2019

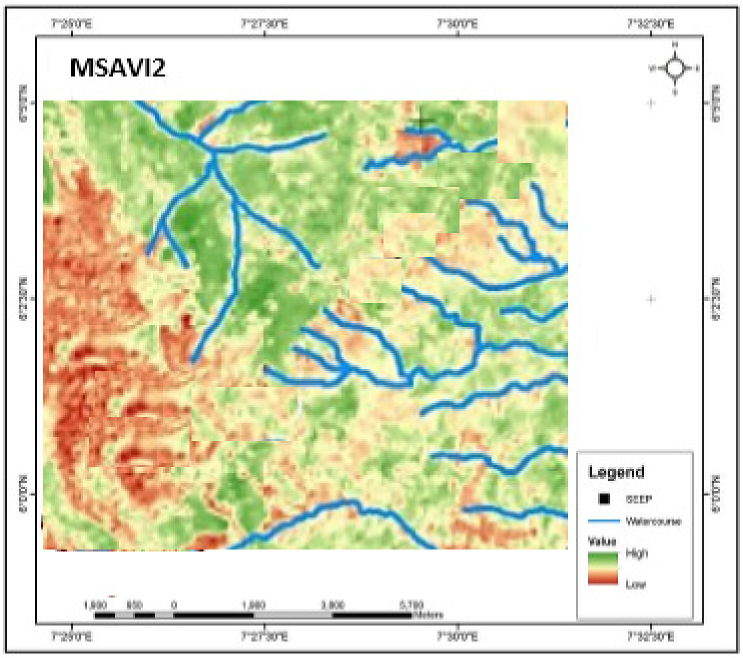


Figure 5: MSAVI2 map of the study area (source: Author, 2019)

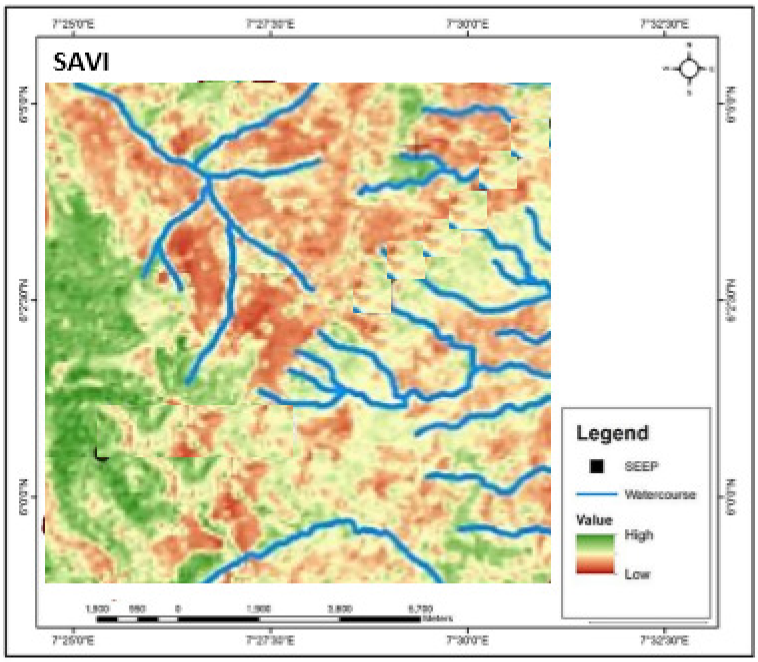


Figure 6: SAVI map of the study area (source: Author, 2019).

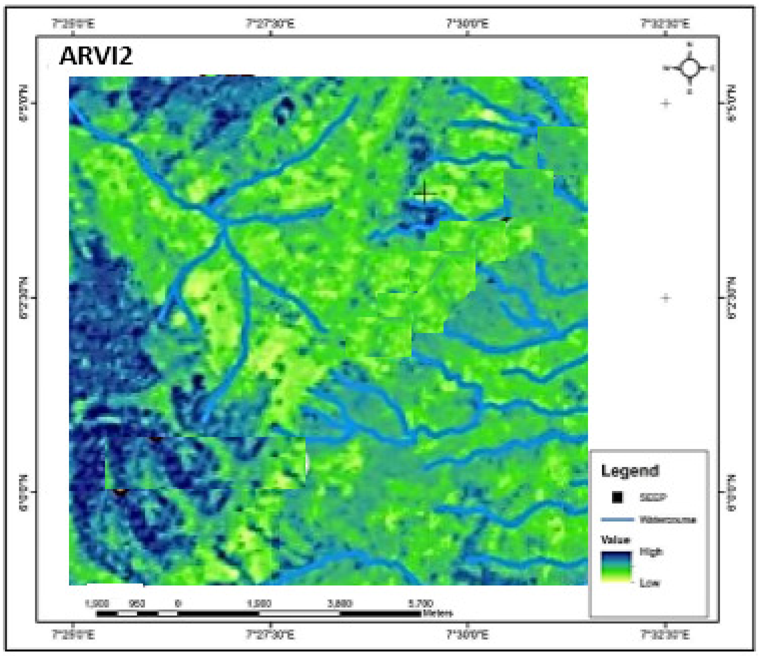


Figure 7: ARVI2 map of the study area (source: Author, 2019)

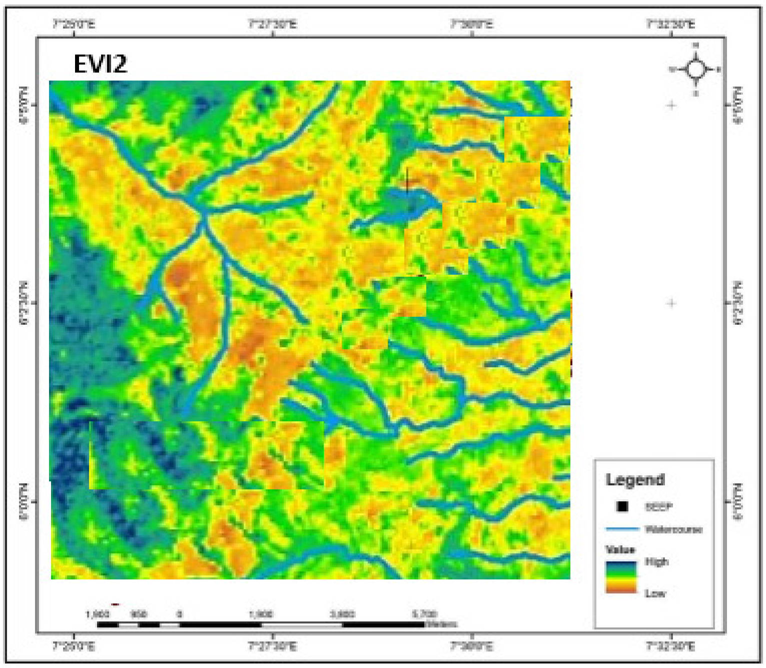


Figure 8: EVI2 map of the study area (source: Author, 2019)

4. Conclusion

The study shows that Remote Sensing and GIS is a valuable tool to detect and monitor the health of vegetation in hydrocarbon seepage zones. Thus in all the spectral bands, the vegetation reflectance from polluted and non – polluted areas exhibit small significant difference with a *p-value >0.005.* To further analyze the impacts of oil and gas on vegetation, six spectral indices including NDVI, SRI, MSAVI2, SAVI, ARVI2 and EVI2 were utilized. SRI, SAVI and EVI2 showed no significant relationship between polluted and non-polluted areas with a *p-value* >0.05 higher than the alpha level of 0.05 and the calculated *t - test value* is lower than the *t-critical value of* 2.09 while NDVI, MSAVI2 and ARVI2 showed a significant relationship between the polluted and non-polluted areas.

References

Aghalino, S.O., (2000). Petroluem exploration and the agitation for compensation by oil mineral producing communities in Nigeria. Journal of Environment Policy Issues, Vol. 1: II.

Blackburn, G. A., (2007). Hyper-spectral remote sensing of plant pigments. *Journal of experimental botany*, 58: pp 855–867.

Carter, G. A. (1991). Primary and secondary effects of water content on the spectral reflectance of leaves. *American Journal of Botany* pp 78.

Gibson, P.J., Power, C.H., Goldin S.E. and Rudahl, K.T. (2000). *Introductory to Remote Sensing: Digital Image process and applications*, pp 111-113

Gitelson, A. A. and Merzlyak, N. (1996). Signature analysis of leaf reflectance spectra: Algorithm development for remote sensing of chlorophyll. *Journal of Plant Physiology*, 148: pp 494-500

Haindongo P. (2009). Investigating the factors influencing vegetation stress in a part of the Keiskamma catchment, Eastern Cape, a remote sensing and GIS approach: Unpublished M.Sc Dissertion, Nelson Mandela Metropolitian University, South Africa.

Male, E., Pickles, W., Silver E., Hoffmann G., Lewicki, J. and Apple M. (2010). Using hyperspectral plant signatures for CO_2 leak detection during the 2008 ZERT CO2 sequestration field experiment in Bozeman, Montana. *Environmental Earth Sciences*, 60: pp 251-261.

Miller, J. R., Hare, E. W. and Wu, J., (1990). Quantitative characterization of the red edge reflectance. An inverted-Gaussian model. *International Journal of Remote Sensing*, 11 (10), pp 1755– 1773.

Obeta, M. and Nwankwo, C. (2015). Factors Responsible for Rural Residential Water Supply Shortage in Southeastern Nigeria. *Journal of Environmental Geography*. 8. 21-32. 10.1515/jengeo-2015-0009.

Pinter, P. J. and J. L. Hatfield (2003). Remote Sensing for Crop management. *Photogrammetric Engineering and Remote Sensing*, pp 647-664.

Roberts, H.J.,(1997). Oil contaminated soil and some reclamation. *Journal of Soil Science*, 24: 231-245

Schumacher, D., (2001). Petroleum exploration in environmentally sensitive areas: Opportunities for non-invasive geochemical and remote sensing methods, pp. 012-1 – 012-5. *Annual Convention of the ASPG.*

Smith, K. L., (2002). Remote sensing of leaf responses to leaking underground natural gas. Unpublished PhD, University of Nottingham, Nottingham, UK.