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Spatio Temporal Assessment of Vegetational Health in Ede South Local Government Osun State, Nigeria

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Abstract

Plant health is a major concern of any Agricultural concern as they determine directly or indirectly the level of Agricultural production and by extension, the food security of any country. The assessment was carried out using integrated remote sensing and GIS techniques in Ede South local government of Osun State, Nigeria. Temperature, Relative humidity, Soil Type and Moisture content were the environmental factors considered. Vegetational Indices (NDVI, SAVI, NDWI, SIPI) were assessed in tandem with LST and environmental factors such as Temperature and Precipitation on a multi temporal basis. NDVI values decreased within a range of (-0.56 to -0.02) from 2017 to 2019, with a subsequent increase from 2019 to 2021 by (0.02 to 0.47). Moisture content measured through NDWI decreased within a range of (-1 to -0.08) from 2017-2019, then increased from 2019 to 2021 by (0.01 to 0.46)The vegetation of the area was very unhealthy around April, 2019 as a result of very low levels of moisture content, hence moisture content is an important environmental factor of plant health as a decrease in the moisture content of the vegetation in the study area led to a corresponding decrease in the vegetation health of the study area. Variance in moisture content was found to be the principal factor in the variation of the vegetational health condition over space and time. Spatio-temporal assessment of vegetational indices should be encouraged for assessing the contributory factors influencing vegetational health conditions as integrated GIS techniques have proven beyond doubt the capabilities of spatial analysis.

Keywords: Vegetational Health, Plant Stress, GIS, Vegetation Indices, LST.

How to Cite:

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INTRODUCTION

Plant stress has been defined by Lichtenthaler as any unfavorable condition or substance that affects or inhibits a plant's metabolism, growth (Lichtenthaler H.K. 1996), or development (Ilse K. *et a*l, 2010). Since the turn of the 20th century, anthropogenic impacts have significantly altered the natural environment. (U.S. Climate Change Science Program, 2005). These alterations result in deviations from the regular environmental balance of the plants consequently introducing stress factors and causing stress conditions (Thenkabail P. S., *et al* 2004). Recently, studies have focused on the use of remotely sensed data as an alternative to traditional field measurements of plant stress parameters, as this provides information about the spatial and temporal variability of crops (Leroux et al., 2016). Remote sensing and GIS technique have proven to be very effective and has been employed in assessing the health status and degree of stress present in plants (Oladejo S.O. *et al*, 2018). Remotely sensed information on vegetation growth, vigor etc., can provide extremely useful insights for applications in agriculture, forestry, biodiversity conservation and other related fields. These types of information when applied to agriculture provide an objective basis for the macro and micro management of agricultural production (Mulla D.J. 2013, Oladejo *et al*,2018). Consequently, the use of high-resolution satellite imagery has proven its ability for comprehensive and detailed mapping and classification of tree structure and species over a long period of time (Karlson *et al*, 2016). Furthermore, anthropogenic management can lead to a change in the spectrum of species and, thus we assume that these alterations are reflected in changes of the spectral response of remote sensing signals (Kuenzer, C. et al, 2014).

STUDY AREA

Geographically, Ede is located south of Osogbo on Lat 7º43" and 7º33' North of the Equator and Long 4 º25' and 4º35' East of Greenwich Meridian. The town is on the bank of Osun river that flows north-south direction from Igede in Ekiti state. The dominant vegetation is tropical forest which favors the cultivation of cash crops such as cocoa, oil palm etc. and farming is a major occupation of the local people.

CLIMATE OF THE STUDY AREA

Ede falls within the tropical climatic region, the average temperature is 26.1ºC with the warmest month of the year being January with a recorded temperature of 28.3ºC while the coldest month is August with a recorded temperature of 23.7ºC and an average annual rainfall is 1241mm. The high annual rainfall makes the relative humidity to be high throughout the year, and it ranges between 48% and 90%. In the morning times, during the raining season, 80% is commonly observed. In times of high temperature with high temperature with high relative humidity, the atmosphere could be pretty uncomfortable. However pleasant atmosphere is generally experienced at the raining season when the relative humidity generally falls.

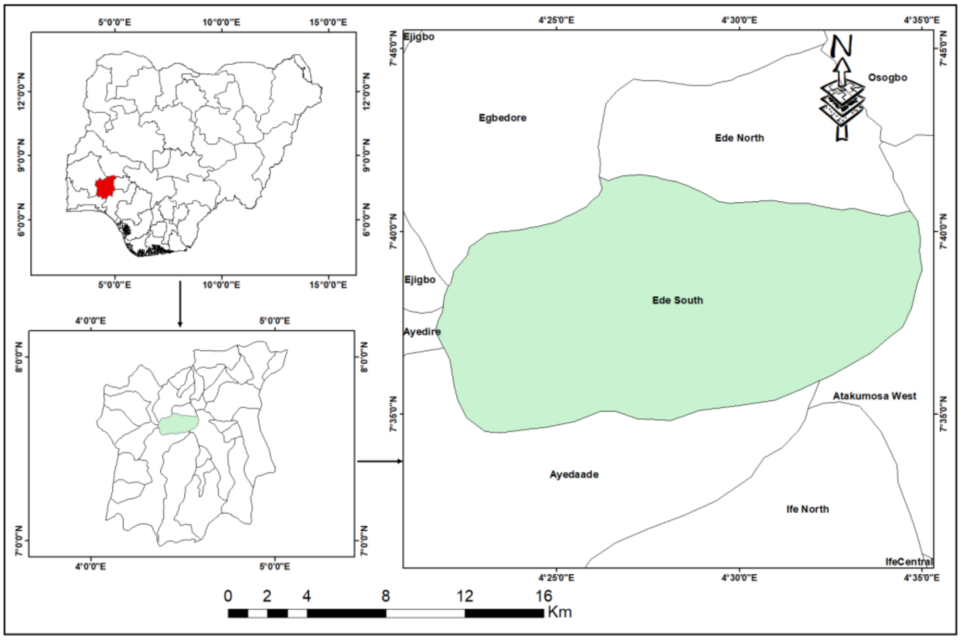

Fig 1 Study Area Map

MATERIALS AND METHOD

This chapter presents the relevant data and materials used for the project, their source, relevance, the processing operations carried out and the overall methods used in order to achieve the desired aim and objectives.

Software Used

- Arcgis 10.3
- Erdas Imagine 2015
- Microsoft Word 2013
- Google Earth Pro
- Microsoft Excel 2019

S/N	DATA	SOURCE	YEAR	RELEVANCE
1	Administrative Map	OSGOF		To extract the boundary of the local government (Lga) making up the study area
2	Sentinel 2A	ESA	2017,2019,2021	To extract the vegetation indices used in the research
3	Soil Map	FAO		To determine the soil type present in the study area
4	Meteorological data	NASA Power	2017,2019,2021	To derive rainfall data for the study area.
5	Geologic Map			To determine the geology of the area.
6	Landsat 8	USGS Earth Explorer	2017,2019,2021	To extract the Land Surface Temperature of the area

METHODS USED IN THE STUDY

Clipping or Image sub-setting

This refers to clipping out an area of interest from available data set. It is also referred to as creating a sub-map. This is necessary because it limits the analysis to only the area of interest and avoids unnecessarily working on very large data extent.

Vegetation index analysis using Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is an index of plant "greenness" or photosynthetic activity, and is one of the most commonly used vegetation indices. NDVI is correlated with many ecosystem attributes e.g. canopy cover, net primary productivity, bare ground cover etc. The index is calculated from the visible and near infrared electromagnetic spectrum reflected by vegetation. It takes advantage of the strong reflectance of vegetation in the NIR region of the EM spectrum. NDVI calculates the ratio between measured reflectance in the red and near infrared (NIR) portions of the electromagnetic spectrum. The general formula for NDVI is;

NDVI = (NIR - RED) / (NIR + RED)

Soil Adjusted Vegetation Index (SAVI)

Soil Adjusted Vegetation Index (SAVI) is a type of vegetation index that account for the variation in soil type and soil properties. NDVI results have shown variation with soil colour, and saturation effects from high density vegetation. In an attempt to improve NDVI, the SAVI is a transformation technique that minimizes soil brightness influences from spectral vegetation indices involving red and near infrared (NIR) wavelengths.

The index is given as:

SAVI = (1 + L) * (NIR - RED) / (NIR + RED – L)

Where L is a canopy background adjustment factor. An L value of 0.5 in reflectance space has been found to minimize soil brightness variations and eliminate the need for additional calibration for different soils. The transformation was found to nearly eliminate soil-induced variations in vegetation indices.

Normalized Difference Moisture Index

The NDMI describes the crops water stress level as the ratio between the difference and the sum of the refracted radiations in the near infrared (NIR) and short-wave infrared (SWIR) portions of the electromagnetic spectrum.

NDMI = (NIR – SWIR) / (NIR + SWIR)

The SWIR band reflects change in both the vegetation water content and spongy mesophyll structure in vegetation canopies while the NIR reflectance is affected by leaf internal structure and leaf dry matter content but not water content. The combination of the NIR with the SWIR removes variation induced by leaf internal structure and leaf dry mater content improving the accuracy in retrieving the vegetation water content.

Extraction of land surface temperature from the images

Land surface temperature (LST) is the emissive temperature of land derived from solar radiation. It is a basic monitor of terrestrial thermal behavior. The LST for this study helps to derive the temperature data for the study between 2017, 2019 and 2021. LST values were calculated using radian reflectance values of the three Landsat images which were transformed to radiant surface temperature.

RESULTS AND DISCUSSION

Soil Map

Soil type is considered as one of the factors that influences vegetational health condition. The soil map of the area shows that the major soil type in the area is clay and sandy clay loam. It can be inferred from this that the soil in the study area will have high water retention ability and might be prone to waterlogging in the event of heavy rainfall.

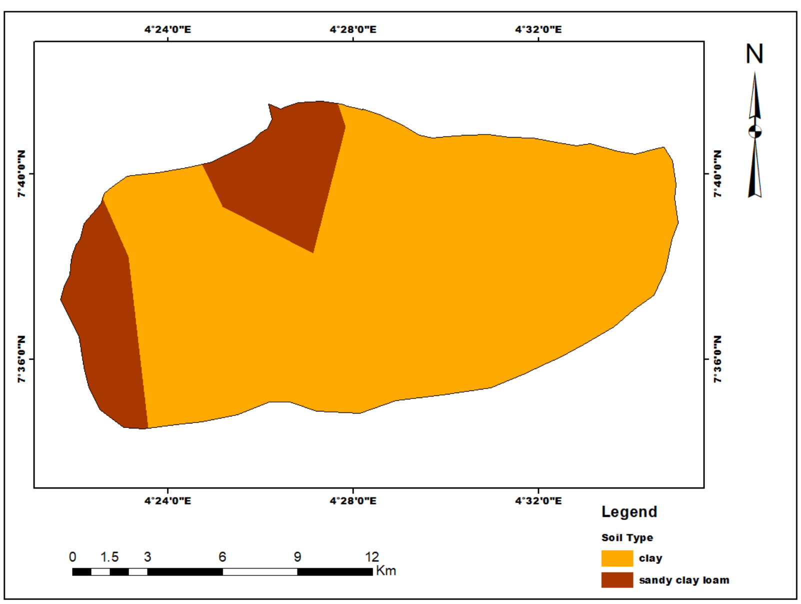

Fig 2 Soil Map of the Study Area

Normalized differential vegetation indices (NDVI)

The NDVI maps of the study area shows the variation in the vegetational health condition for the duration of study (2017, 2019 and 2021). NDVI values ranges from -1 to 1 with -1 indicating absolutely no vegetation cover and 1 indicating perfectly healthy vegetation. In year 2017, NDVI values ranged from (-0.0358037 to 0.757811) with the majority of the area having NDVI values greater than 0.5 while in 2019, NDVI values ranged from (-0.071611255 to 0.665745698) with the majority of the area between 0.3 – 0.45, and 2021 has an NDVI range of (-0.0119449 to 0.686058) with the majority of the area between 0.48 – 0.61. This indicates a reduction in the vegetational health condition from 2017 to 2019 with a recovery from 2019 to 2021.

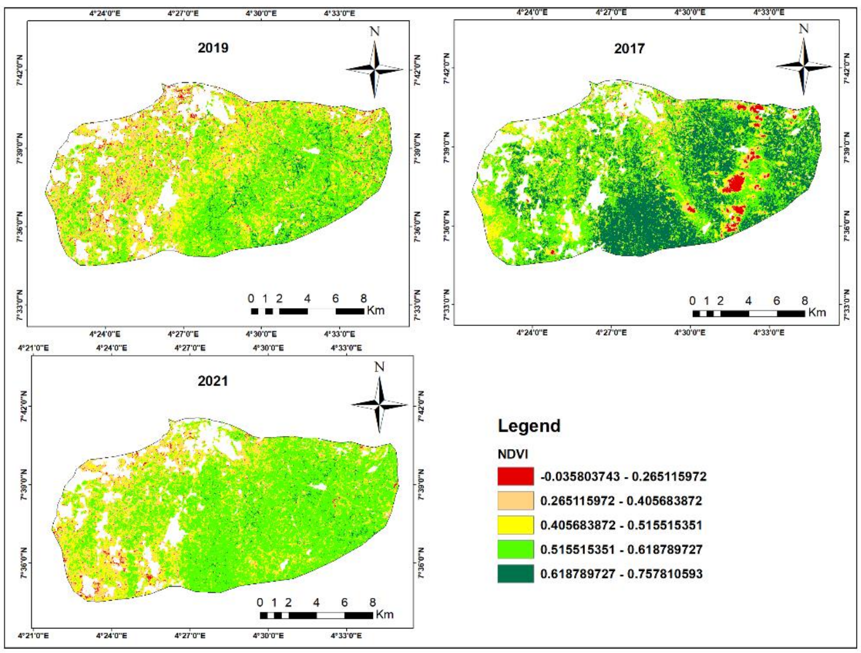

Fig 3 NDVI Map

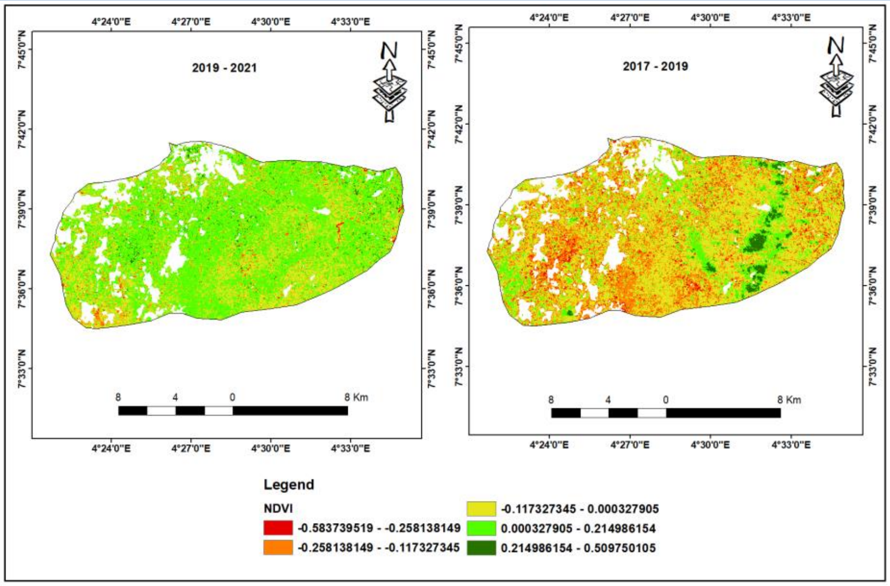

Fig 4 NDVI changes from 2017 - 2019

Land surface temperature analysis

The land surface temperature of the study area for three different years (2017, 2019 and 2021) was generated from the satellite imageries. The land surface temperature map and change analysis were used to determine the changes in the land surface temperature of the study area over the years and how it has possibly affected the vegetational health condition. The analysis shows that there is slight increase in the land surface temperature between 2017 and 2019 and a slight increase between 2019 and 2021. The correlation results shows that the LST might not be responsible for the variation in vegetation health between the years.

Normalized Difference Water Index (NDWI)

NDWI value ranges from -1 to 1, NDWI value for 2017 ranges between (-0.329456 - 0.494968) while the values for 2019 ranges from (-0.744557 - 0.442148) and the NDWI value for 2021 ranges from (-0.482652 - 0.378333). Change detection of NDWI values shows that there is a general decrease in the NDWI distribution from 2017 to 2019 within a range of ((-1 to -0.08), the NDWI distribution values then increased with a range of (0.01 to 0.46). This indicates a reduction in the moisture content of the vegetation from 2017 to 2019 and then a subsequent increase in the moisture content from 2019 to 2021.

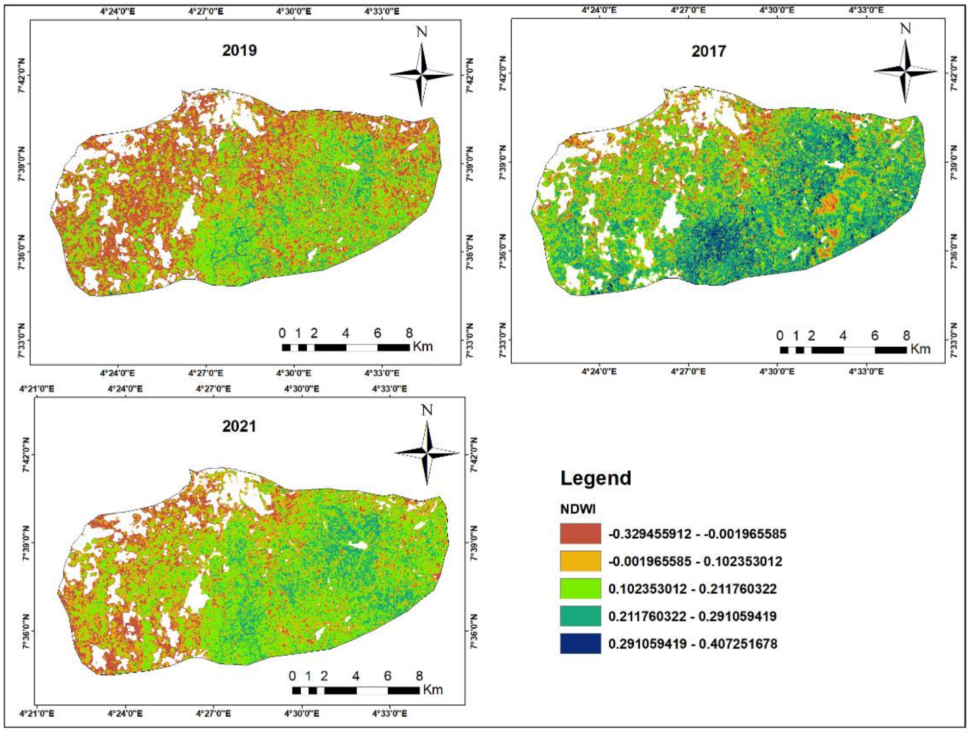

Fig 5 NDWI map

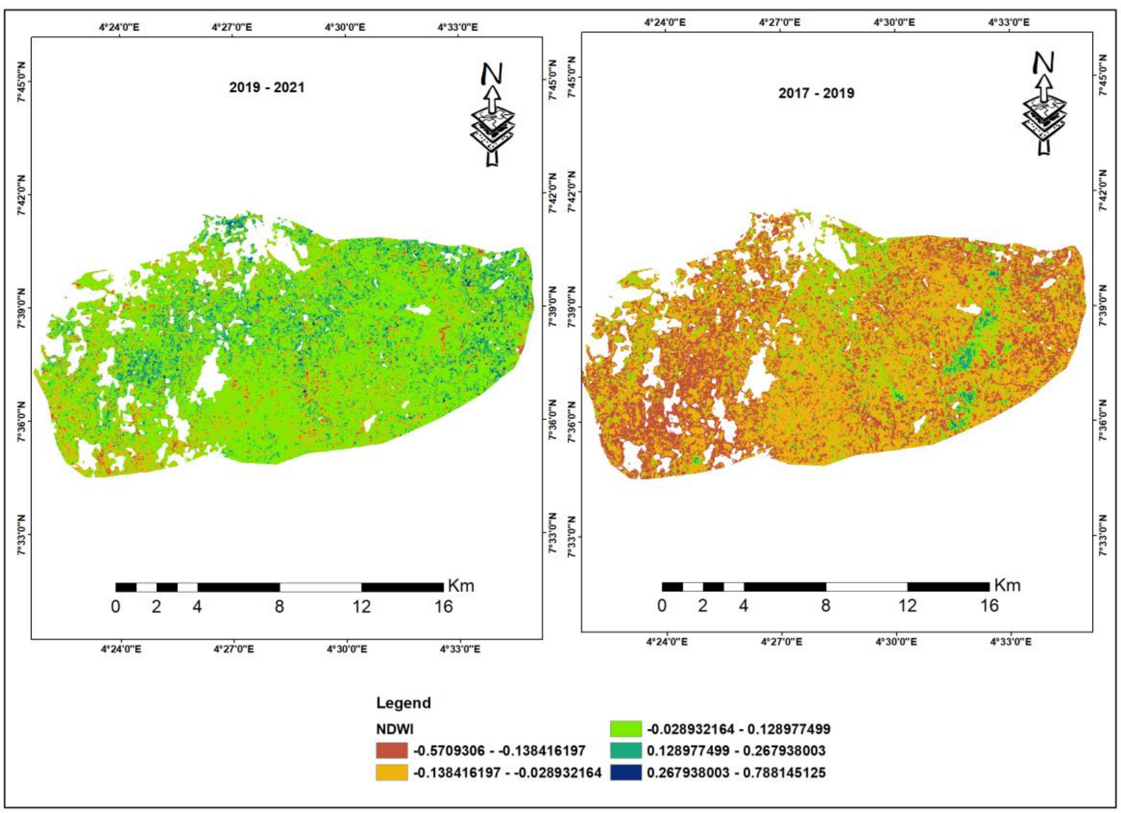

Fig 6 NDWI changes from 2017 - 2021

Relationship between Vegetational Health Condition and Environmental Factors (Temperature, Moisture content)

The analysis indicates that the variation in the surface temperature has no impact on the Vegetational health condition as the temperature variation between the years was quite insignificant and the correlation results show no significant impact on the Vegetation Health. Moisture content on the other hand was found to be very important to the vegetational health condition of the area as the correlation results shows a very high relationship between moisture and vegetation health. According to the results, a reduction in the moisture content of the vegetation in the area led to a decrease in the vegetational health condition.

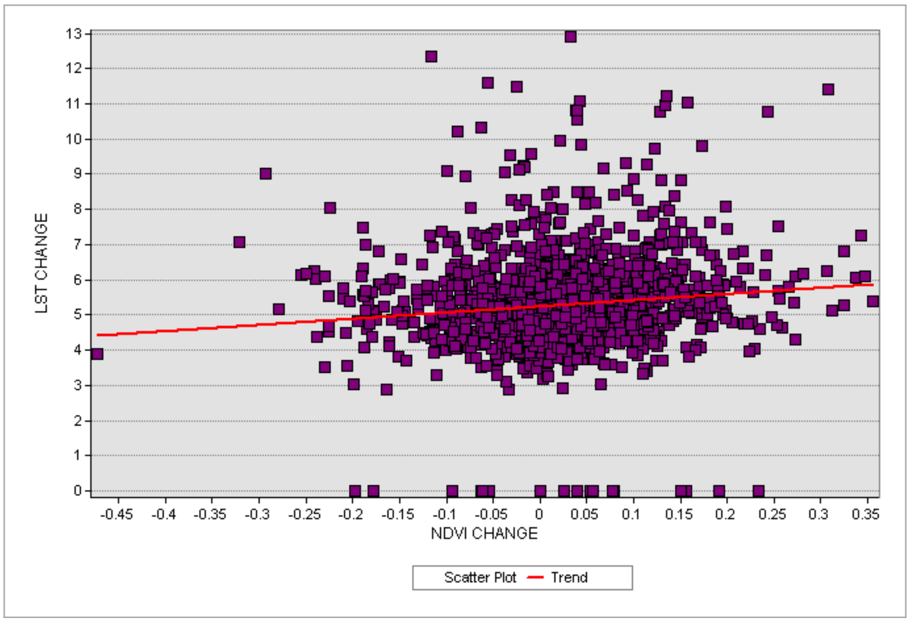

Fig 7 Trend of LST to NDVI

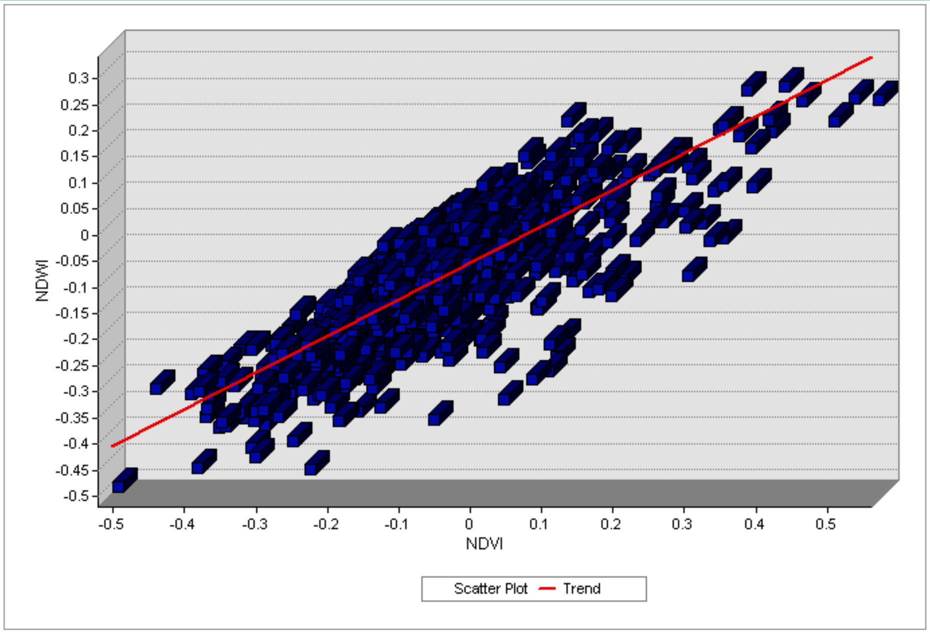

Fig 8 Trend of NDWI to NDVI

CONCLUSION AND RECOMMENDATION

Integrated GIS techniques have proven beyond doubt the capabilities of spatial analysis. In this study, Sentinel images were used satisfactorily to determine the health status of vegetations in the study area. This study has shown the versatility and usefulness of remote sensing data and GIS approaches in assessing plant health using vegetational indices such as NDVI, SAVI, LST, NDWI, SIPI. It can be deduced from this study that the temperature and relative humidity had no impact on the vegetational health status of the study area, while the rainfall and soil moisture content had a very significant impact on the vegetational health status of the area. The assessment of the multi-temporal data allows for comparison for multiple years and determine the relationship between the environmental parameters and vegetation health. Knowledge of the correlation between them could be used later in to estimate vegetation health from prevailing environmental conditions.

Based on this study, we can conclude that:

- Remote sensing and GIS techniques is very effective and can be used to assess vegetation health status.
- The vegetation of the area was very unhealthy around April, 2019 as a result of very low levels of moisture content

- Moisture content is a very important environmental factor of plant health as a drop in the moisture content of the vegetation in the study area led to a corresponding drop in the vegetation health of the study area.

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