GIS-based characterization of land use, land cover patterns and microclimate of agricultural and agroforestry landscapes in a rainforest zone of Nigeria

Abstract

There is increasing need to develop sustainable land use and landscape management practices to avert accelerating trends of land, water and ecosystem degradation and for climate mitigation. This study characterized land use and land cover patterns and microclimate of permanent (forest, agroforestry, fallow, cocoa, oil palm, citrus and ornamental plant field) and annual crop land use systems in a rainforest zone of Nigeria using space-based remote sensing technology. The goal is to evaluate land use and land cover patterns and microclimate along agricultural and agroforestry landscapes in a rainforest zone of Nigeria. Land use types were: permanent (forest, agroforestry, fallow, cocoa, oil palm, citrus and ornamental plant field) and annual cropland. Vegetation indices (Normalized Difference Vegetation Index: NDVI, Normalized Difference Water Index: NDWI and Soil Adjusted Vegetation Index: SAVI) were deployed for characterizing land use vegetation cover patterns in relation to vigour and health in addition to responses to weather variables (temperature and rainfall). The NDVI intensities of vegetation cover from the land use types showed differences in vigour and health of vegetation during the rainy and dry seasons of 2017 to 2019. The NDWI of vegetation cover intensity indicates differences in moisture conditions of vegetation cover, the vegetation of the land use systems had more water content (received more rainfall) in 2017 compared to 2018 and 2019 during the rainy season while during the dry season of 2019, NDWI intensity was highest compare to 2018 and 2017. NDVI and NDWI also showed that vegetation cover of permanent land uses had better vigour and health compared to annual (maize) field. SAVI was applied to correct NDVI of vegetation cover patterns of land use types with reference to canopy gaps (soil brightness within canopy especially in spots where vegetation cover is sparse). High SAVI intensities were obtained during rainy compared to the low values during dry season (sparse vegetation cover). Decreasing order of SAVI intensities were agroforestry, oil palm, ornamental plant field, citrus, cocoa, fallow land and maize crop field. Result from the correlations among vegetation indices (NDVI, NDWI and DSAVI) were strong association ($R^2 = 1$) among the years and seasons. The strong R^2 values imply that less than 10 % of changes in NDWI (the explanatory variables) can be explained by changes in NDVI and SAVI (the dependent variable). Temperature and rainfall differed within months and years of study. Temperatures were highest for March, April and May while rainfall was highest for September of 2017 and 2018 and in October, 2019. Significantly lower rainfall amounts were received for January, February, November and December. The vegetation indices (NDVI, NDWI and SAVI) indicated vigour and water contents of the land use types within seasons and years as well as responses to weather variables (rainfall and temperature in particular). The biophysical findings from this study may advance capacities to cope with climate change challenges and ecosystem conservation. Information generated will find use as strategies for ecologically sound and sustainable land use systems and policy for mainstreaming climate mitigation in in the study area

Keywords: Rainforest, land use, vegetation, weather, landscape, ecology, services, geospatial.

INTRODUCTION

The West African rainforest belt is characterized by large biomes of the tropical and subtropical, savannah and grassland (Wilson and Primack, 2019). This region is rich in biodiversity (Gorenflo et al., 2012, FAO Stat, 2020) where agriculture is major source of livelihood, food and raw materials for industries, and foreign exchange earner. Agriculture contributes about 30 percent of the GDP to Nigeria economy, employs about 70 percent of the labour force and accounts for over 70 percent of non-oil exports, and provides over 80 percent of the food requirement of the country (Enisan & Adeyemi 2013; FAO, 2014). Nigeria has about 98.3 million hectares of land of which about 74 million hectares is useful for agriculture (Opara, 2011). Cultivated lands in Nigeria occupied 44.7 percent of land area with 37.3 and 7.4 percent consisting of arable land and permanent crops respectively while permanent meadows pastures constitute 33.3 percent, forest cover 9.5 percent, forest area covering 9.5 percent and other land use take 12.6 percent (FAO, 2015). Nigeria, lies within Sub-Saharan Africa (SSA) region, characterized by large biomes of the tropical and subtropical, savannah and grassland (Wilson and Primack, 2019). The SSA is rich in biodiversity (Gorenflo et al., 2012, FAO Stat, 2020). Agriculture is major source of livelihood in SSA. Agriculture contributes about 30 percent of the GDP to Nigeria economy, employs about 70 percent of the labour force and accounts for over 70 percent of non-oil exports, and provides over 80 percent of the food requirement of the country (Mabogunje, 2003); Enisan & Adeyemi 2013; FAO, 2014). Nigeria has about 98.3 million hectares of land of which about 74 million hectares is useful for agriculture (Opara, 2011). Cultivated lands in Nigeria occupied 44.7 percent of land area with 37.3 and 7.4 percent consisting of arable land and permanent crops respectively while permanent meadows pastures constitute 33.3 percent, forest cover 9.5 percent, forest area covering 9.5 percent and other land use take 12.6 percent (FAO, 2015).

Expansion and intensification of agricultural has been a major driver of decline on biodiversity and ecosystem services (Foley et al 2005; Kuyah et al., 2016). This underscores the emerging value placed on sustainable management of agricultural landscape and their potential to supply ecosystem services (Sonja, 2011). Aside from the provision of food and fibre, agricultural landscapes offer habitats for insects that deliver pollination and pest control services (Morandin & Kremen, 2013). Services rendered by the ecosystem is altered through the expansion and intensification of agriculture, this in will affect livelihood of the human population mostly of which dwell in the rural areas and rely on ecosystem services for their living through smallholder fielding, pastoralism and fisheries (Egoh et al., 2012). Human influence on the land and other natural resources is accelerating because of global rapid population growth (Kanianska, 2016; BokaieZarkesh et al., 2016; Zang et al., 2013), leading to creating more need for settlements, roads, increase demand for food and shelter, basic amenities and increase in agricultural production (Nzoiwu et al., 2017). This has invariably led to the increase in the encroachment on natural vegetation, converting wild lands to agriculture and other uses (Kanianska, 2016). It is therefore known that anthropogenic activities have important impacts on ecosystem processes in landscapes (Bizuhoraho et al., 2017). However, vegetation cover within a locality ensures ecosystem sustainability and services such as prevention of soil erosion, reduction in soil and nutrient loss and the biogeochemical cycles (Hooper et al., 2005, Kuyah et al., 2016).

According to Fairhurst (2012), farming system in a broad sense encompasses all components of a field enterprise including cropland, cropping system, livestock, common grazing land and woodlots management. The farming and cropping systems in Nigeria are diverse, permanent and annual (arable) crop fields permanent land uses systems are based on the production of industrial tree-crops notably; cocoa, oil palm and rubber with food crops sometimes inter-planted between them (Akano et al., 2018). This type of fielding system is also called Agroforestry. Agroforestry is recognized as a land use option in which trees provide both product and environmental services (Alao and Shuaibu, 2013, Kuyah et al., 2016). It is well known that smallholder farmers in Sub-Sahara Africa raise and manage a mix of exotic and indigenous trees in different ways to provide a variety of ecosystem services and improve their field produce (Nyaga et al., 2015). Research has however shown that land uses that incorporate forest such as agroforestry and forest-grass fallowing have great potentials for carbon sequestration (Resende, 2022). It is a carbon fielding strategy, involving carbon trapping and long-term storage of atmospheric carbon dioxide (Stephanie, 2018). This process has been described critical to mitigating or deferring global warming (Jacobson, 2019).

Agricultural management and land use practices, have potential to resolve adaptation challenges to climate change and variability of weather events and provision of ecosystem services. Such understanding would promote sustainability of ecosystems and improve performance of agriculture as strategy for climate change mitigation (adaptation and resilience building).

Human influence on the land and other natural resources is accelerating because of global rapid population growth (Zang et al., 2013, Kanianska, 2016; BokaieZarkesh et al., 2016), leading to increases in agricultural production (Nzoiwu et al., 2017). Agricultural land use activities in relation with land cover changes and effects on terrestrial ecosystem functions and fitness have been recognized as a global problem (OECD, 2016). This has invariably led to the increase in the encroachment on natural vegetation, converting wild lands to agriculture and other uses (Kanianska, 2016). It is therefore known that anthropogenic activities have important impacts on ecosystem processes in landscapes (Bizuhoraho et al., 2017). However, vegetation cover within a locality ensures ecosystem sustainability and services such as prevention of soil erosion, reduction in soil and nutrient loss and the biogeochemical cycles (Hooper et al., 2005, Resende, 2022).

Agricultural land use activities in relation with land cover changes and effects on terrestrial ecosystem functions and fitness have been recognized as a global problem (OECD, 2016, *IPCC 2013*, Bufebo, 2021*)*. Land use systems have both drivers and regulators of ecosystem energy and water balance and other ecosystem services. Land use, land cover changes are the major determinants of environmental services rendered by ecosystem (Bufebo, 2021). The scenarios of neighbourhood and ecosystem responses of land use and land cover elements (vegetation pattern) in tropical agroecologies is inadequately researched (Nair et al., 2010; Agele et al., 2017). In particular, land surface pattern-processes notably from tropical land use types such as intercropping, land rotation fallow and agroforestry and the correlates with ecosystem processes and microclimate has not been adequately evaluated.

Land use-enhanced land cover patterns in landscape depend on factors such as vegetation type, soil type, and land use intensity (IPCC 2013, Bufebo, 2021). Agricultural land use activities and associated land cover patterns has consequences on terrestrial ecosystem functions and fitness (OECD, 2016). Land use and land management practices designed to increase soil C storage, restoration of degraded lands, improved livestock and manure management to reduce CH_4 and N_2O emissions (Bufebo, 2021). Sustainable land use practice have environmental benefits of carbon sequestration for GHG mitigation and biodiversity conservation. While the carbon sequestration potential of forest-based land use system may offer added income stream for smallholder farmers. In order to sustainably manage the potential risks and challenges of global environmental change and climate extremes, sustainable resources management practices are required to improve environment performance of land use especially of the humid tropics

Sustainable land use practice have environmental benefits of carbon sequestration for GHG mitigation and biodiversity conservation.

Patel et al. (2002) reiterated that space-based technologies have played a very important role in the improvement of system of acquiring and generating agricultural information. The premier way of generating this information is through the use of satellite remote sensing, Geographic Information System (GIS) and other related methodologies (Uchua, 2011). Atzberger (2013) listed some applications of remote sensing in agriculture. The author concluded that biomass and yield estimation; vegetation vigor and drought stress monitoring; assessment of crop phenological development; crop acreage estimation and cropland mapping; and mapping of distribution and land use/land cover changes. Aerial images have been widely used for vegetation performance prediction, water stress on vegetation, soil availability/brightness (Batta, 2011). These images provide high spatial cloud free information of vegetation and detection of changes in vegetation spectra characteristics. Analysis of vegetation and detection of changes in vegetation patterns are very important for natural resources management and monitoring (Panda et al., 2010).

Agricultural practices are known to have environmental effects that affect a wide range of land use and land use cover scenarios (Gbenga and Adeyemi, 2013), Literature reports that ecosystem processes of carbon, water balance and energy fluxes in landscapes are affected by land use, land cover, and vegetation dynamics. Such effects have been attributed to the feedback of landscape processes on the climate (Agele et al., 2018, Awoonor et al., 2022).

This study incorporated space-based remote sensing technology (GIS) to evaluate land use and land cover patterns along agricultural and agroforestry landscapes in a rainforest zone of southern Nigeria. The objective of the study is to characterize land use effects on land cover patterns of permanent (forest, agroforestry, fallow, cocoa, oil palm, citrus and ornamental plant field) and annual crop land use systems in a rainforest zone of Nigeria using geospatial techniques.

Materials and Methods

Land use systems along the chronosequence of the Teaching and Research Farm, the Federal University of Technology, Akure, Nigeria. The land uses were delineated using their coordinates (aid of GPS) (Plate 1.). Each land-use and their coordinates were shown in Table (1) below while Table (2) showed their description respectively. The study site geographically geo-referenced on coordinate lines of 734393E, 808614N; on the western flank of meridians. Climate of the study site is characterized by humid tropical climate of the West African Monsoonal type with distinct wet and dry seasons. Annual rainfall reaches mean value of about 1450 mm coupled with high temperature reaching a peak of about 32 ^{0}C around February and a threshold of about 21 ^{0}C around August. Relative humidity ranges from about 70% around January to about 90% in July (Agele et al., 2017). Vegetation is regrowth rainforest type which consist of grasses and scattered trees but hard in many parts been modified with human activities such as building, road and land cultivation. The surface soils are largely of residual soils which are weathering product of the basement rocks. The soils are reddish to brownish in colour, having medium to coarse-grained mineral matter with some clayed materials. They are characterized by mottled and sticky features in some locations (www.iprojectmaster.com).

Satellite Images and Digital Image Processing

Cloud-free satellite images of sentinel-2 for the study period (Year 2017 to 2019) were downloaded from the archives of USGS Earth Explorer (http://earthexplorer.usgs.gov/).
The imageries were downloaded on 7th February, 2017 and 30^{th} October 2017 for dry and wet seasons respectively for the year 2017, 2018 images were downloaded on 23^{rd} January, 2018 and 24^{th} November, 2018 for dry and wet seasons respectively while 17^{th} February, 2019 and 24 December, 2019 were for dry and wet seasons respectively for the year 2019. Sentinel-2 data was calibrated using the data-specific utilities of ENVI (Ver. 5.3) software program, and the SNAP 7.0 software in which the sensor digital numbers were converted into spectral radiance in order to measure the amount of electromagnetic radiation reflected from a spot on the surface.
Normalized Difference Vegetation Index (NDVI): NDVI was calculated using NIR and the Red bands (Band 4 and 5 Table 3) of the Sentinel-2 images. These bands were processed using the raster calculator of the ArcTool Box in ArcGIS to derive the vegetation index using equation 1.

$$NDVI = (NIR – R) / (NIR + R) \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where NIR is the reflectance value of Near Infrared Band (Band 5) and R is reflectance value of Red (band 4).

Normalized Difference Water Index (NDWI): NDWI was calculated using NIR and VNIR bands (Band 5 and 6 Table 3) of the Sentinel-2 images. These bands were also processed using raster calculator of the ArcTool Box in ArcGIS to derive the vegetation index as:

$$NDWI=(NIR-VNIR) / (NIR+VNIR) \quad \ldots\ldots\ldots\ldots\ldots 2$$

where NIR is the reflectance value of Near Infrared Band (Band 5) and VNIR is the reflectance value of Visible Near Infrared Band (band 6).

Soil Adjustment Vegetation Index (SAVI): SAVI was calculated using NIR and R bands (Band 5 and 4 Table 3) of the Sentinel-2 images. These bands were also processed using raster calculator of the ArcTool Box in ArcGIS to derive the vegetation index using equation 2

$$SAVI = ((NIR- Red) / (NIR+ Red + L)) * (1 + L). \quad \ldots\ldots\ldots 3$$

where NIR is the reflectance value of Near Infrared Band (Band 5), R is the reflectance value of Red (band 4) and L is the soil correction factor which is defined as 0.5.

Analysis of vegetation indices and generation of maps for each vegetation index (NDVI, NDWI and SAVI) were generated with their corresponding index values. Climatic variables used for study (rainfall and temperature) were downloaded from NASA (National Aeronautics and Space Administration (https://power.larc.nasa.gov/data) using the geocoordinate of the study area. Local weather data was obtained for the Meteorological \observatory of the Department of Meteorology and Climate Science, Federal University of Technology, Akure, Nigeria. Data were analyses and trends presented accordingly.

RESULTS

Normalized Difference Vegetation Index (NDVI), years and seasons of land use types

The Normalized Difference Vegetation Index (NDVI) was calculated and extracted for the years of study and seasons (rainy and dry) (Plate 2a and b, 3a and b and 4a and b). NDVI values were extracted and maps generated for each land use type for years of study, rainy and dry seasons for each year. The NDVI trends among land use types during periods of study (2017 – 2019) during rainy and dry seasons showed that values were highest for rainy season compared with dry, highest values were obtained for 2018 an*d lowest in 017 observations. Highest NDVI intensities were recorded in the year 2018, followed by year 2019 and 2017 respectively.

NDVI intensities levels were ranked as Very High (which is very dense), High (Dense), Medium (light) and Low (very light) for land use vegetation cover patterns (Figure 1a and b). among the years of study, the decreasing order of intensity levels from Very-High, High and Medium intensities were: 2018, 2019 and 2017 respectively.

NDVI vegetation intensity of land use types is shown in Figure 1c and d for rainy and dry season periods

During the rainy season, among the vegetation covers, 2018 had higher values of NDVI followed by 2019 and 2017 (Figure 1c) and among land use types, agroforestry had highest NDVI value closely followed by Oil palm, Cocoa, Citrus and Maize field. Permanent land uses had highest value in 2019 and the least in 2017. **Th**e trends of NDVI among land uses during dry season showed that 2018 had highest values followed by 2017 and 2019 and for land use types, highest NDVI values were recorded for agroforestry followed by oil palm, cocoa, citrus and maize fields respectively (Figure 1d).

Normalized Difference Water Index intensity of vegetation cover of land use types

The Normalized Difference Water Index (NDWI) generated land use intensity maps for land use types and years of study (2017, 2018 and 2019) (Figure 2a to 2d).

For 2017, NDVI values were close among permanent crop fields compare with arable annual crop field (maize) under rainy season condition. For dry season, agroforestry was highest followed by oil palm and cocoa fields while values were similar for citrus and maize fields.

For 2018, NDVI values were close for agroforestry and oil palm fields and lowest for maize under rainy season and during the dry season, agroforestry maintained highest NDVI values during 2019 rainy season followed closely by oil palm field. During the rainy season 2017 had the highest NDWI intensity followed by 2018 and 2019 (Figure 2a). Dry season observations showed differences among the years, 2019 had the highest intensity followed by 2017 and 2018 (Figure 2b).

NDWI of vegetation cover among land use types differed between the rainy and dry season

Figure 2c and d present NDWI trends among land use types during periods of study (2017 – 2019). Among land use types, negative NDWI values were observed for maize, citrus and cocoa fields especially during the dry season. Compared with values of NDWI for the land use types for 2017, lower values were obtained for 2018 and 2019 rainy and dry seasons. During the rainy seasons of 2018, significantly lower values of NDWI were obtained for maize and citrus fields compare with oil palm, agroforestry and cocoa fields. During the dry season, NDWI values were lower compare with rainy. Highest NDWI was recorded on Oil palm field followed by Agroforestry, Cocoa field and Citrus field while the lowest values were recorded on Maize field (Figure 2c) The NDWI maps for dry season showed that highest values were obtained for 2019 followed by 2017 and 2018 (Figure 2d). Agroforestry had the highest values, followed by Oil palm, Ornamental plant field, Citrus and Maize field respectively. Agroforestry recorded highest NDWI in 2017 followed by 2018 and 2019. Oil palm field also recorded highest value in 2017 followed by 2019 and 2018, however, Cocoa, Citrus and Maize fields recorded highest NDWI values in 2019, followed by 2017 and 2018. Lowest NDWI value was recorded on Maize field in year 2018 (Figure 2b).

Soil Adjustment Vegetation Index intensity of vegetation cover of land use types

The Soil Adjustment Vegetative Index (SAVI) map for the land uses of the study area were generated. (Figure 3a to 3c). The year 2017 had lowest SAVI intensity levels compared with 2018 and 2019 for which the trends in magnitudes were similar

The seasonal trends of SAVI intensity showed that during the rainy and dry seasons of 2017, the highest NDWI values were highest for rainy season compare with dry. During the rainy season of 2018 recorded the highest SAVI values followed by year 2019 and 2017 (Figure 3a). However, 2017 was the highest values of SAVI values for the low-intensities followed by 2018 and 2019. During dry season 2018 had the highest SAVI values, followed by 2017 and 2019. However, year 2017 recorded the highest values at the Low-intensity level (Figure 3b). Observations showed that SAVI intensities during dry season differed among the years for all the levels of SAVI (Very High to low) (Figure 2b).

SAVI of land use vegetation cover patterns.

Across the land uses, maize field had significantly lower SAVI values and highest were observed for agroforestry followed by oil palm. The observations of SAVI among land use types during rainy season showed differences among the land uses and years (Figure 3c and d). The decreasing order were 2018, 2019 and 2017 for the land uses. For years 2017 and 2018, maize field had significantly lower SAVI values while the highest but close values were observed for oil palm and agroforestry. For year 2019, increasing values of SAVI were: citrus, cocoa, maize, oil palm and agroforestry

Rainy season of 2018 recorded the highest SAVI values followed by 2019 and 2017 Fig. 3c showed the SAVI trends at different land uses, Agroforestry recorded the highest index followed by Oil palm field, Cocoa field and Citrus field while the least SAVI values were recorded on Maize field. Cocoa field had highest SAVI value in 2018 followed by 2017 while the least was observed for 2019 while maize field recorded 2019 as the highest followed by 2018 and 2017 respectively. The dry season of 2018 recorded the highest SAVI values followed by 2017 and 2019. (Figure 3d). Among land use types, SAVI values were highest for agroforestry, followed by Oil palm field, Cocoa field and Citrus field and the least was recorded on Maize field. However, maize field had highest SAVI in 2017.

Table 2 presents trends in NDVI, NDWI and SAVI values for permanent and arable crop fields during rainy and dry seasons of the study period (2017 to 2019). Consistently, NDVI values were higher for rainy compare with the dry season, and for permanent over arable crop fields across the years of observation. This observation is consistent for both NDWI and SAVI. For 2018, negative NDWI values were found for arable crop for both rainy and dry seasons.

The relationships among the vegetation indices (NDVI, NDWI and SAVI), showed that the correlations were very strong with very high R^2 values) (Table 3). The highest R^2 value extracted from the relations of NDVI and NDWI was recorded in 2017 followed by 2019 and 2018 respectively. The relationships were significant ($P \leq 0.05$) in 2017 and 2019 but not for 2018. The relationships between NDVI and SAVI showed strong correlation ($P \leq 0.05$) producing high R^2 values which were similar for all the years. Similar results were obtained in these relationships for both rainy and dry seasons

Temperature and rainfall differed among the months and years of study is presented in Figures 4a and b.. Temperatures were highest for March, April and May of 2017, 2018 and 2019 (Figure 4a). Rainfall was highest for September of 2017 and 2018 and in October 2019. Significantly lower rainfall amounts were received for January, February, November and December in 2017 while in 2018 and 2019, lowest rainfall was observed for January, February, March and December. Increasing rainfall amounts were observed from May to September of each year (Figure 4b).

Discussion

Effect of Land Use and Season on Vegetation Indices

Results of the indices of vegetation intensity of the study site showed that the vegetation was healthiest in 2018 compared with 2019 and 2017 during the respective rainy and dry seasons. Furthermore, NDVI and SAVI values recorded showed that in 2018, the vegetation experience low stress conditions. Higher values of the vegetation indices NDVI and SAVI) were obtained during rainy season than dry season. The vegetation indices responded to variability seasonal weather conditions considering factors of temperature and rainfall. The results were consistent with those of Yuan et al. (2015), Edith et al. (2020), Antonio et al. (2021) and Adaeze et al. (2022) that NDVI is sensitive to weather variability. It is important to report that across the land uses, the vegetation was deep green during 2018 than other years of study. Roznik et al. (2022) reported that the higher vegetation index (NDVI) values denote greater potential for growth and vigour. USGS recommended the use of Soil Adjusted Vegetation Index (SAVI) for correcting Normalized Difference Vegetation Index (NDVI) in order to explain soil brightness in areas where vegetation cover is low. The strong correlation of NDVI and SAVI (R^2 =1) among the years of study and seasons is consistent with the reports of Vani and Venkata (2017) and Shibani et al. (2023). The normalized difference water index (NDWI) and its intensity indicate vegetation responses to water availability in the ecosystem (soil and air) Water was more available during the year 2017 compared to 2018 and 2019 during the rainy season. Adebayo, (2021) and Tajudeen (2022) reported the importance of rainfall to crop productivity and Mosunmola et al, (2020) and Farmsquare, (2023) reported the effects of rainfall variables such as onset, cessation and length of growing season on agricultural productivity.

Lowest NDWI value for study site was observed in 2019 during the rainy season. However, 2019 recorded the highest NDWI value for the dry season compare to 2018 and 2017. Rainfall amount was high in 2019 in addition to high temperature which offered a more favourable growing environment. Diaz and Osmond (2017) attributed good vigour of vegetation to favourable rainfall and temperature of the growing season. NDVI values of the land use types showed that the land use types had healthier vegetation in 2018 except Maize field that recorded its highest NDVI in 2019 during the rainy season. This observation showed the intensity of farming activities on maize field in 2019. This result supported the findings of Sulimar et al. (2018) and Mugabowindekwe (2020) that NDVI correlate with agricultural activities and productivity. Among land uses, the results of the vegetation indices showed that Agroforestry, Oil palm, Cocoa and Citrus field recorded higher values compare to Maize field. Gurima and Prashant (2021) opined that vegetation index of forested areas are lower than those of other land uses especially annual crop land. However, Sentongo et al. (2017) and Khaple et al. (2021) reported that vegetation index values of forested area were higher than land cultivated for annual crops.

Eludoyin et al. (2017) and Uzoh (2021) described wet and dry seasons of Nigeria in such that the rainy (wet) season occur from April to October with moderate rainfall of 1500 to 2000 mm and average temperature of 28^0C. Results from this study showed that plant thrived well during rainy season across the land uses compared to the dry season that is characterized by high temperature (average of 30^0C) with little or no rainfall. Dry season last for 4-5 months in the rainforest belt of

Nigeria. The results of the vegetation indices measured indicated that plants were stressed during dry season compare to rainy season which are supported by the reports of Trujillo et al. (2020) and Batunqwanayo et al (2020). Dry season is characterized by little or no rainfall and high soil and air temperatures. This condition further enhance soil evaporation (Agele, 2021, Adaeze et al., 2022).

Response of vegetation cover to weather variables

The dynamics of the vegetation cover under the land uses appeared to be influenced by seasonal weather and soil conditions. Duveiller et al. (2018) opined that climate variables are critical determinant of vegetation and land cover characteristics of ecosystems including agroecosystems. Results from this study showed the relationships among vegetation indices (NDVI, NDWI and SAVI) with temperature and rainfall for the years of study. NDVI response to temperature was weak and negative. It was observed that the higher the value of Temperature, the lower the value of NDVI. This result conforms to the findings of Ghebrezgabher et al. (2020) that the values of NDVI decreased at high temperature. It was however observed that NDVI responded to rainfall with a strong relationship. This result confirmed the findings of Ghebrezgabher et al. (2020), that NDVI responds to rainfall trends than temperature. Wang et al. (2010) and Garai et al. (2022) also stated that rainfall has primary influence on NDVI resulting in strong relationships. Naif et al, (2020) showed in their findings how NDVI negatively correlated with temperature and positively correlated with precipitation.

NDWI does not only indicate vegetation cover but also to water content within the landscape (Jovanovic et al., 2014). Result from this study as shown on Figure 2a and b and Table showed NDWI responded to variation in rainfall more than NDVI, thereby indicating a better understanding of vegetation water status (Karamihalaki et al., 2016). The relations of NDWI with weather variables (temperature and rainfall) during rainy seasons showed in 2017, NDWI indicated a stronger relations with rainfall trend (good spread) despite the fact that 2019 had the highest total rainfall. It is therefore important to consider the amount and time spread of rainfall for each year. It was recorded that 2017 had good rainfall spread during rainy season more than other years of study. However, during the dry season, NDWI had strong relations with total rainfall and weak and negative relationship with temperature (Table 3). This result conformed to the findings of Amel et al. (2023) that NDWI is more sensitive to drought than NDVI. NDWI was described by Gu et al, (2007) describes NDWI indicate the more sensitive indicator of vegetation (plant) water content. It is therefore a very good proxy for plant response to water stress.

Conclusions

The vegetation indices (NDVI, NDWI and SAVI) indicated vegetation cover patterns, health and water contents differed among land use types, seasons and years as well as responses to weather variables (rainfall and temperature in particular). The results showed that vegetation of the land use types was healthier in 2018 compared to 2019 and 2017 during both rainy and dry seasons. NDWI complemented NDVI as tool to analyze vegetation health and responses to rainfall (water availability in the ecosystem) NDWI indicate vegetation interception of rainfall (soil water availability) for each land use and effects on water status of vegetation cover, the vegetation of the land uses had more water content (received more rainfall) for 2017 compared with 2018 and 2019 during the rainy season while during the dry season of 2019, NDWI was highest compared to 2018 and 2017 due to high rainfall received towards the end of 2019. Soil Adjusted Vegetation Index (SAVI) corrected NDVI as indicator of canopy gaps (high soil brightness in areas where vegetative cover is sparse. Results of the vegetation indices showed that, permanent land uses recorded higher vegetation intensity compared to annual (maize) crop land. Relationships among NDVI, NDWI and SAVI were very strong (R^2=1) indicating relevance of SAVI as tool to improve efficacy of NDVI. The biophysical findings from this study may advance capacities to cope with climate change challenges and ecosystem conservation. Information generated will find applications in the development of strategies for ecologically sound sustainable land use and management systems in policy formulation for mainstreaming climate adaptation and disaster risk reduction in in the study area

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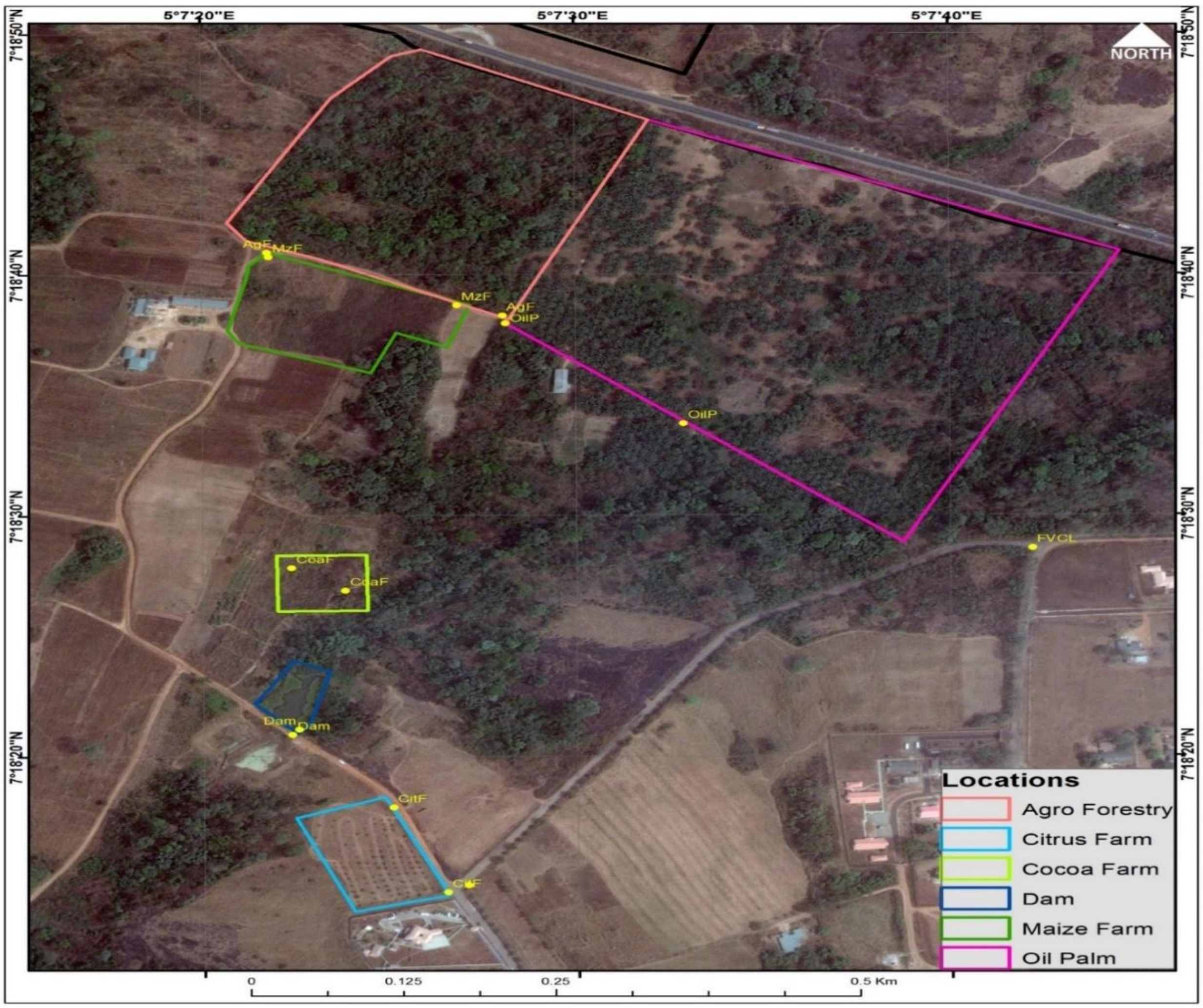


Map1. Satellite image of the site of study indicating the land use types

Table 1. Sentinel-2 Band Information

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra-blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Near Infrared (NIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

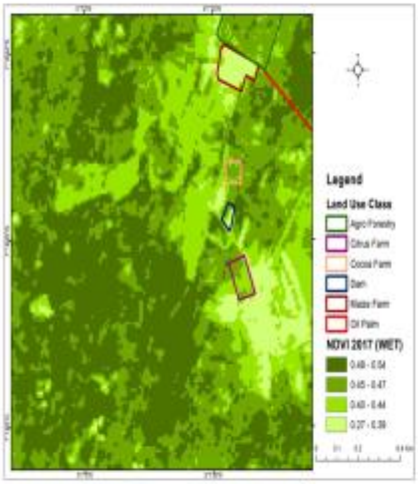
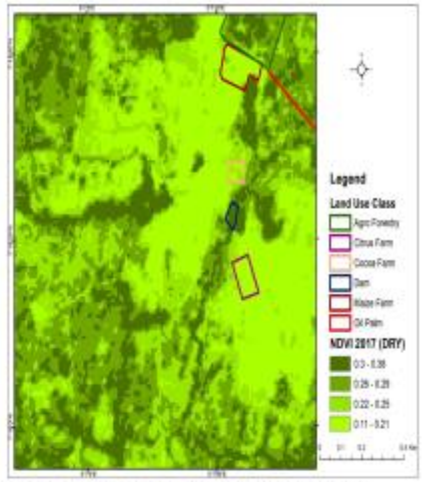
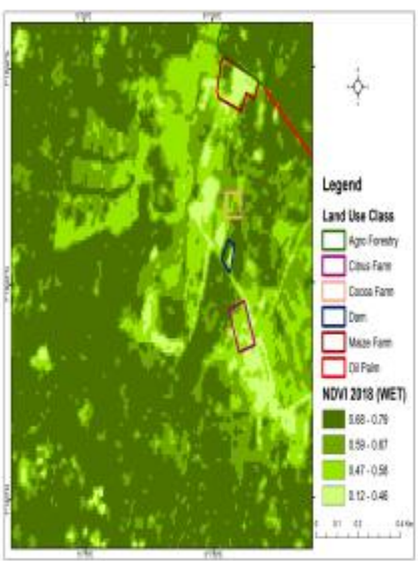


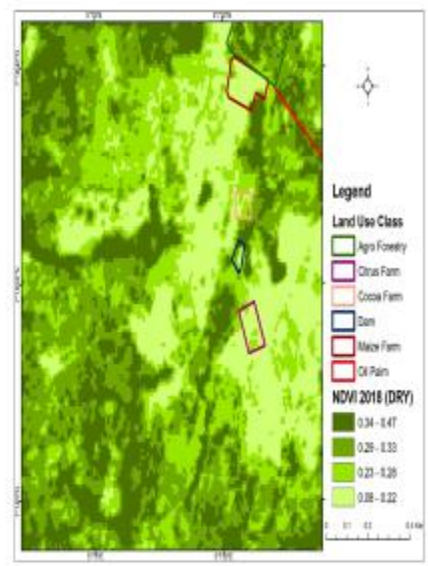
Plate 1a: Normalized Difference Vegetation Index (NDVI) map, rainy season 2017



- Plate 1b. Normalized Difference Vegetation Index (NDVI) map dry season 2017



- Plate 2a. Normalized Difference Vegetation Index (NDVI) Map rainy season 2018



- Plate 2b. Normalized Difference Vegetation Index (NDVI) map dry season 2018

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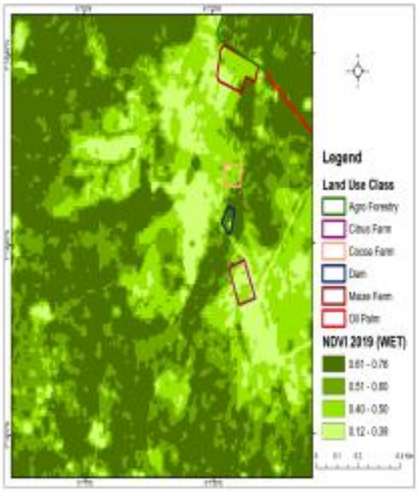

Plate 3a. Normalized Difference Vegetation Index (NDVI) map rainy season 2019

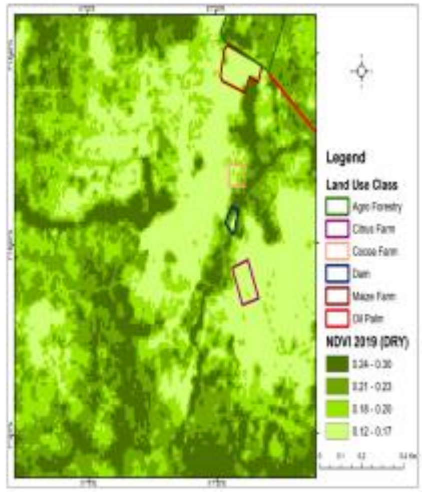

Plate 3b. Normalized Difference Vegetation Index (NDVI) map dry season 2019

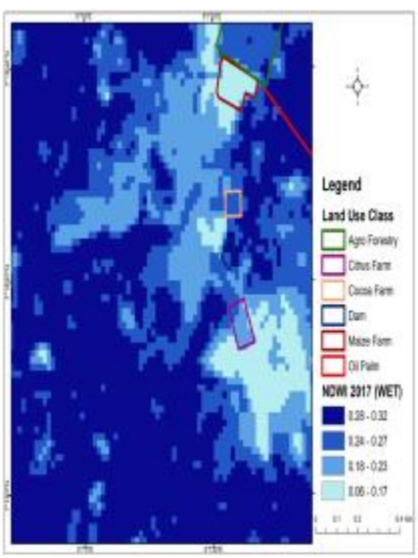

Plate 4a. Normalized Difference Water Indices (NDWI) map rainy season 2017

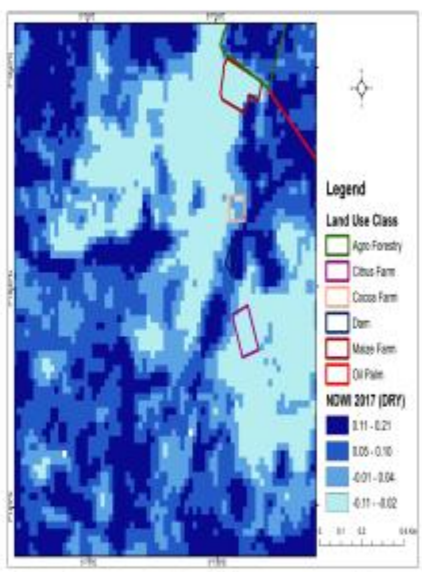

Plate 4b.: Normalized Difference Water Indices (NDWI) map dry season 2017

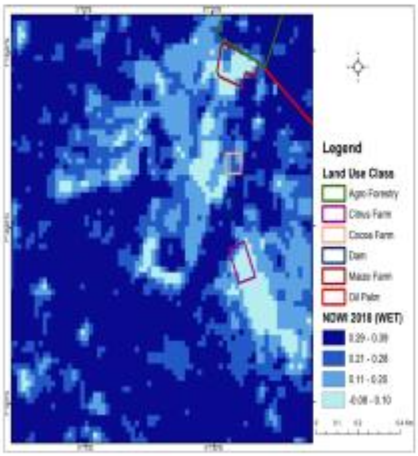

Plate 5a. Normalized Difference Water Indices (NDWI) map rainy season 2018

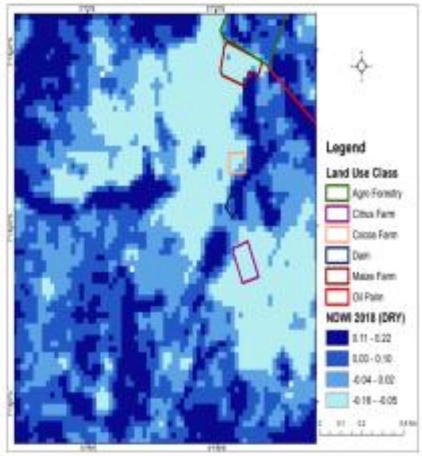

Plate 5b. Normalized Difference Water Indices (NDWI) map dry season 2018

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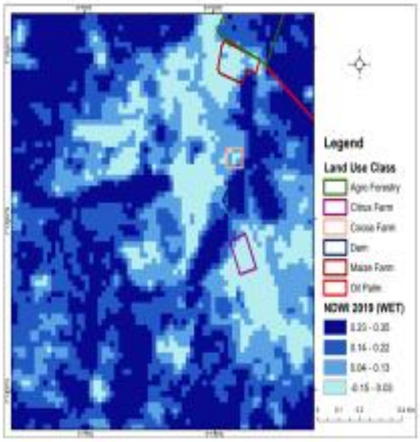
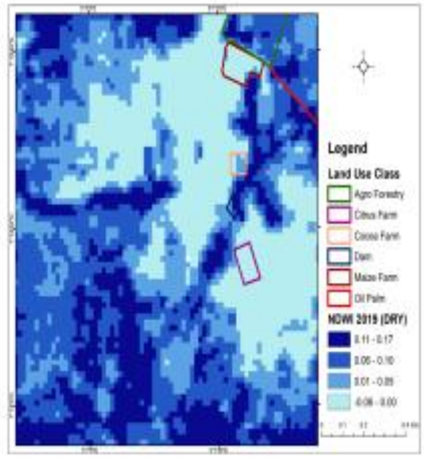
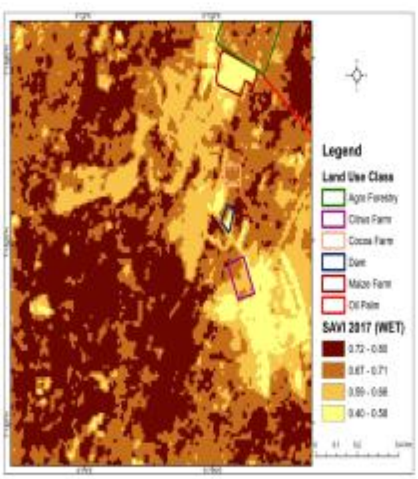


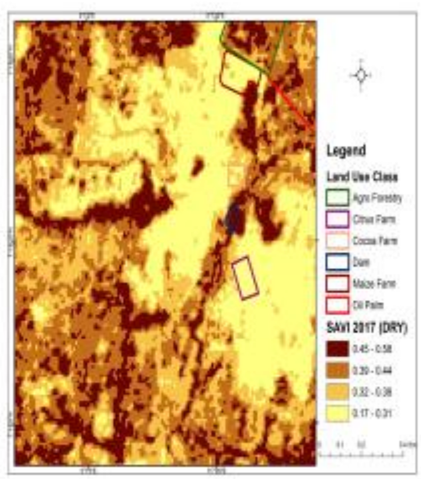
- Plate 6a. Normalized Difference Water Indices (NDWI) map rainy season 2019



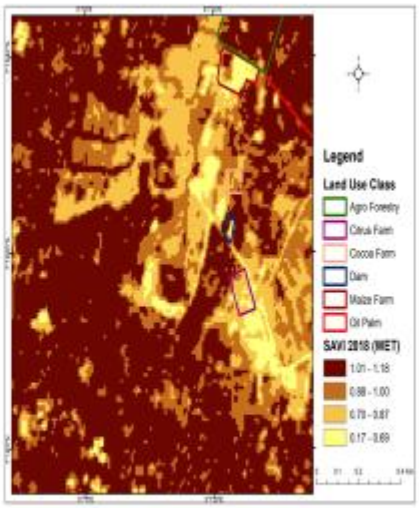
- Plate 6b. Normalized Difference Water Indices (NDWI) map dry season 2019



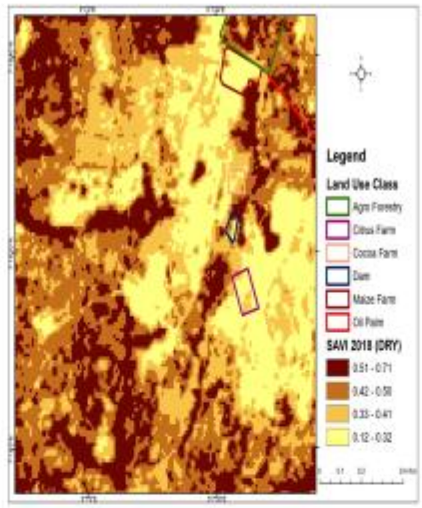
- Plate 7a. Soil Adjusted Vegetation Index (SAVI) map 2017 rainy season



- Plate 7b. Soil Adjusted Vegetation Index (SAVI) Map 2017 dry season



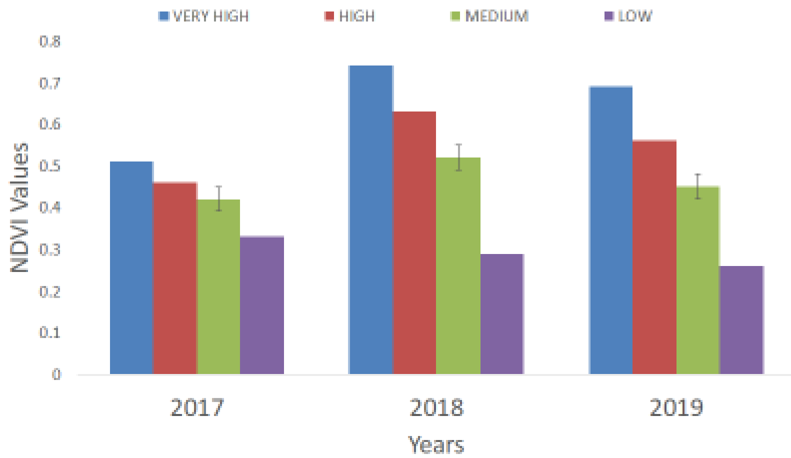
- Plate 8a. Soil Adjusted Vegetation Index (SAVI) map 2018 rainy season



- Plate 8b. Soil Adjusted Vegetation Index (SAVI) map 2018 dry season

Table 2. Summary of land use types, vegetation indices and seasons during period of study

	Years	2017		2018		2019	
		Land uses					
Veg. Indices	Season	Permanent Land uses	Cultivated Land uses	Permanent Land uses	Cultivated Land uses	Permanent Land uses	Cultivated Land uses
	Rainy	0.4541	0.3030	0.6073	0.3808	0.5156	0.4929
NDVI	Dry	0.2352	0.1875	0.2529	0.1594	0.1912	0.1590
	Rainy	0.2492	0.0630	0.2181	-0.0298	0.1228	0.0209
NDWI	Dry	0.0413	-0.0850	0.0037	-0.1217	0.0340	-0.0301
	Rainy	0.6811	0.4545	0.9108	0.5712	0.7733	0.7393
SAVI	Dry	0.3529	0.2812	0.3793	0.2390	0.2867	0.2385



- Fig.1a. NDVI intensity of vegetation cover (rainy season)

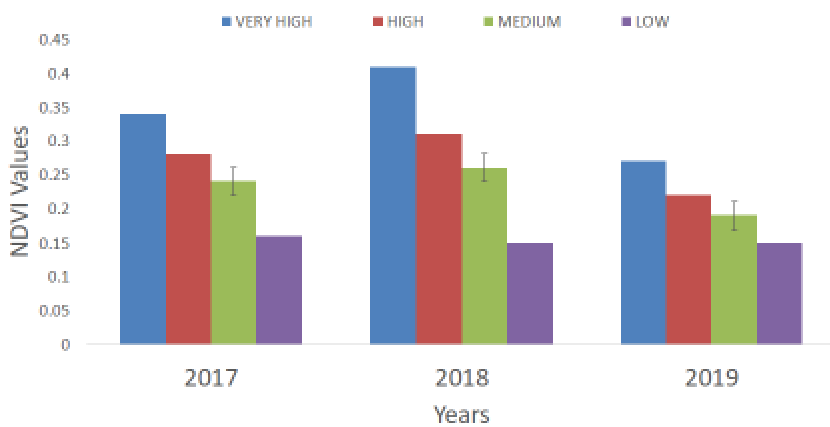


Fig. 1b. NDVI Intensity of vegetation cover (dry season)

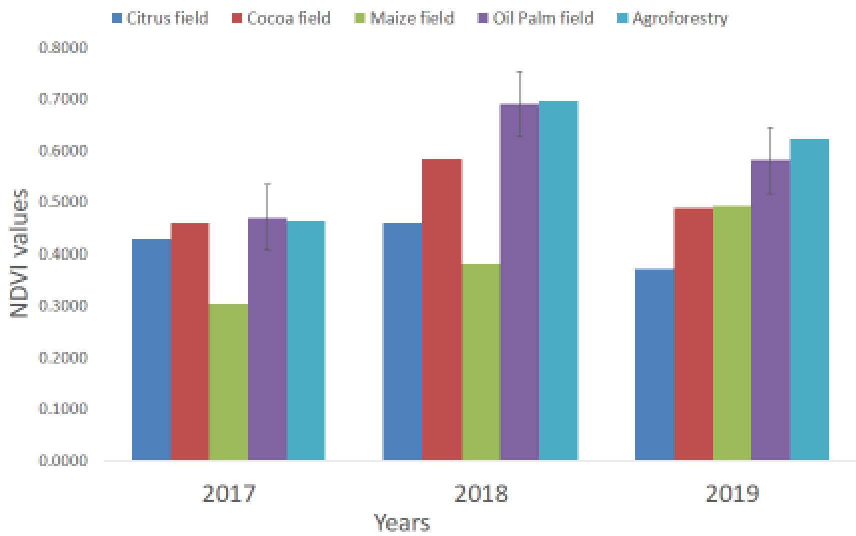


Fig. 1c. NDVI of land use vegetation cover (rainy seasons)

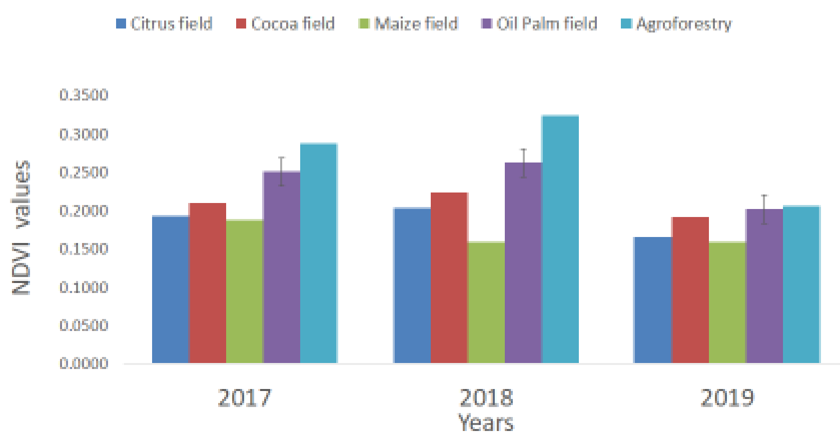


Fig. 1d. NDVI of land use vegetation cover (dry season)

Fig. 2a. NDWI intensity of vegetation cover (rainy season)

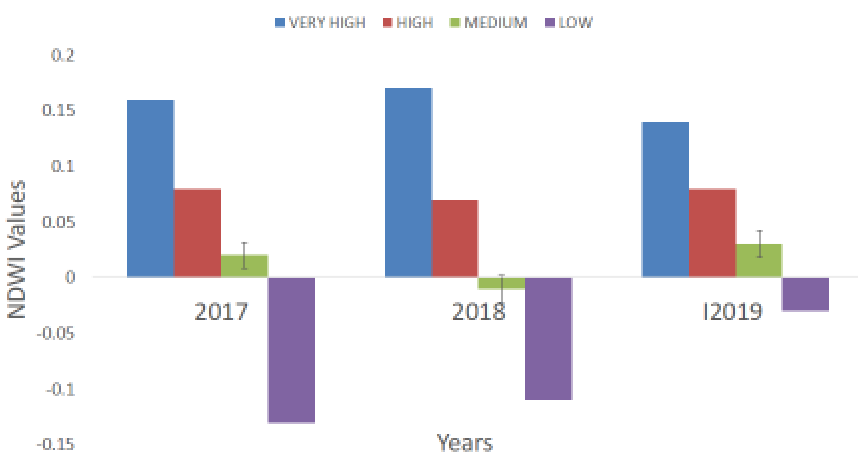


Fig. 2b. NDWI intensity of vegetation cover (dry season)

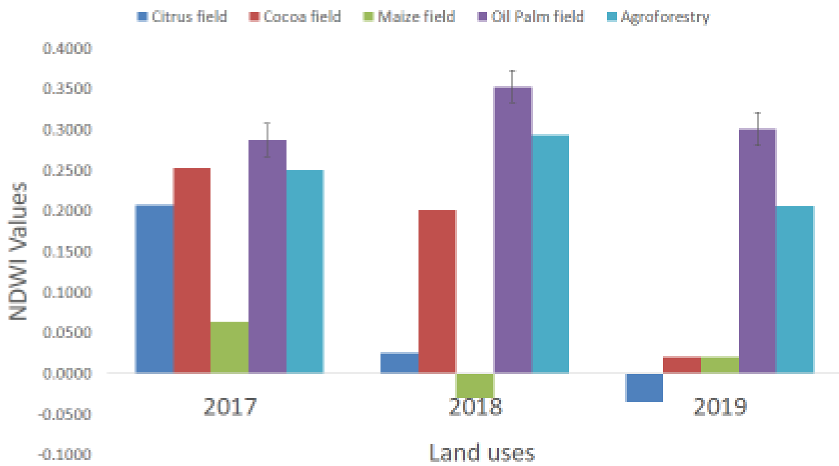


Figure 2c: NDWI of vegetation cover (rainy season)

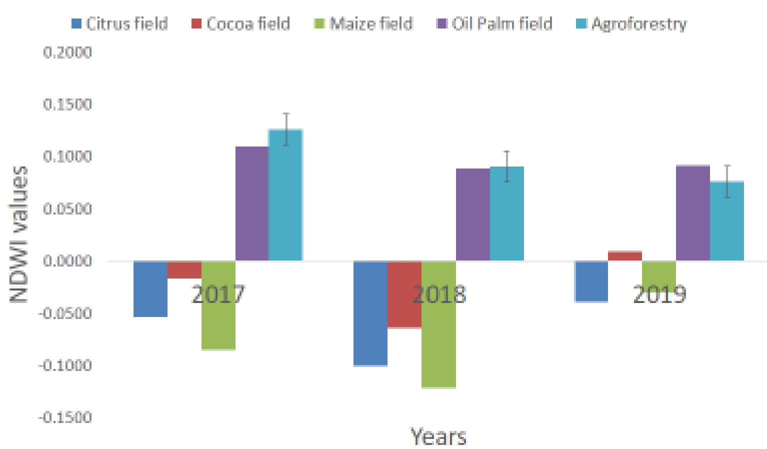


Fig. 2d. NDWI of vegetation cover (dry season)

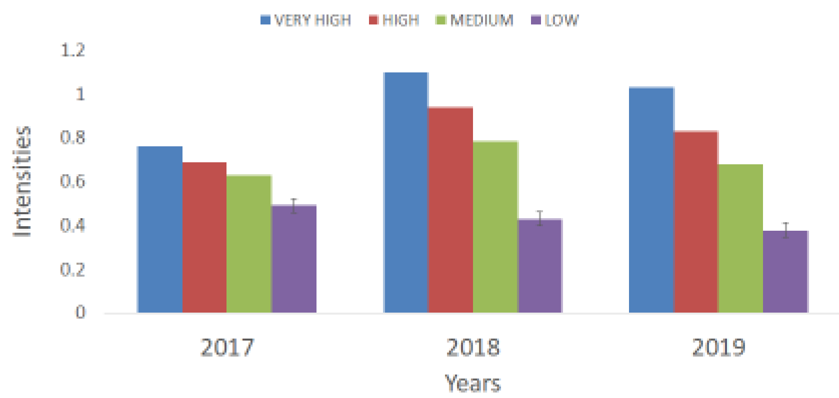


Fig. 3a. SAVI intensities of vegetation cover (rainy season)

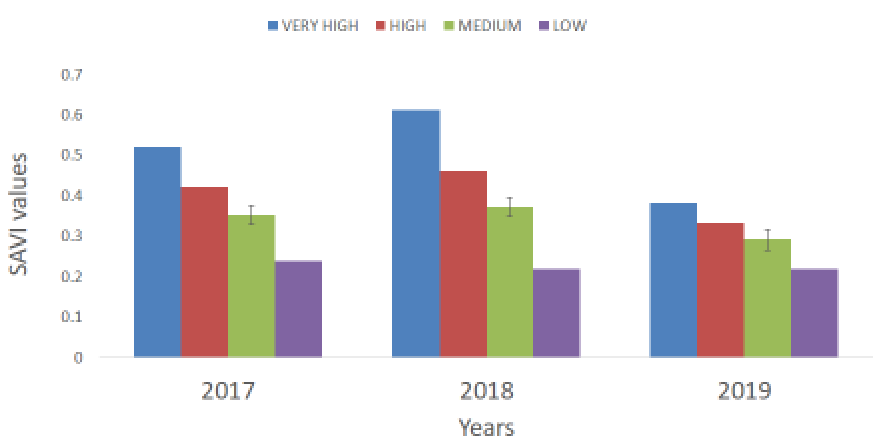


Fig. 3b: SAVI intensities of vegetation cover (dry season)

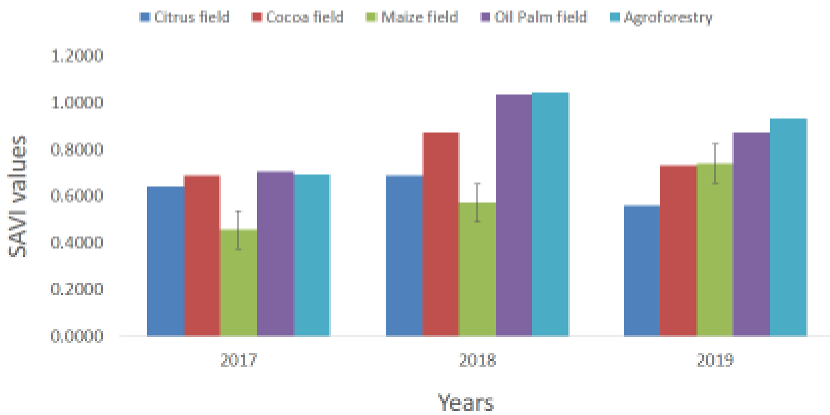


Fig. 3c. SAVI trends for land uses (rainy season)

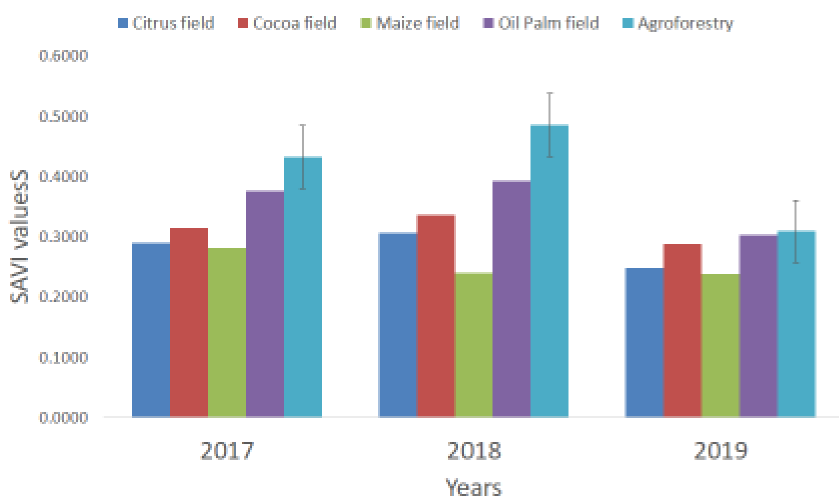


Fig. 3d. SAVI trends of land uses (dry season)

Table 3. Relationship and correlation of NDVI with NDWI and SAVI

Vegetation Indices	Seasons	R^2 2017	2018	2019	P value (0.05) 2017	2018	2019
NDVI VS NDWI	Rainy	0.980	0.970	0.740	0.001	0.002	0.06
	Dry	0.930	0.820	0.830	0.008	0.031	0.024
NDVI VS SAVI	Rainy	1.000	1.000	1.000	0.000	0.000	0.000
	Dry	1.000	1.000	1.000	0.000	0.000	0.000

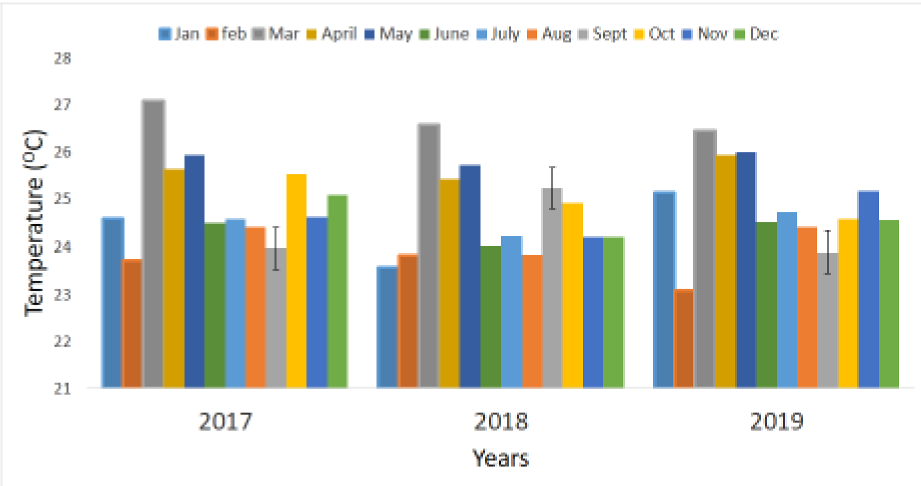


Figure 4a. Mean monthly temperature trends for the years of study

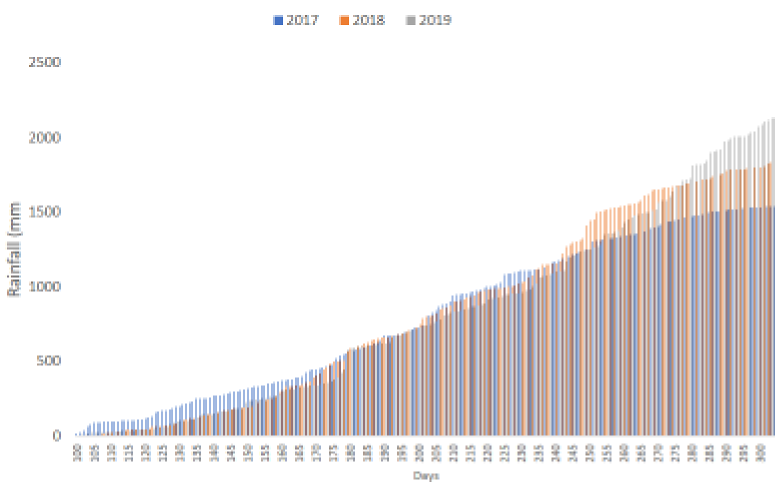


Figure 4b. Rainfall trends for period of study