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Exploring the Relationship Between Climate and Forest Conditions in Forest Classee De La Mondah (GABON) using Remote Sensing Data

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Abstract: This study aims to examine the relationship between temperature and precipitation as climatic factors and the vegetation characteristics in Forêt Classée de la Mondah (Gabon). A pixel based spatial analysis procedure with QGIS was used to extract vegetation characteristics from MODIS on Terra, NDVI band, data from February 2000 to December 2015, while temperature and precipitation were monitored from January 1980 to December 2015 to highlight climate fluctuations in the study area. Two regression analyses were conducted : one between temperature and NDVI and the other one between precipitation and NDVI. Results showed that temperature and precipitation did not vary significantly and the overall linear correlation between climate factors and NDVI was not significant. However, a close to medium correlation was found between temperature and NDVI during the long dry season. The authors are conducting a similar study in a broader scale (at country level), based on polygon as a spatial analysis procedure to extract MODIS data, in order to obtain further information about the relationship between climate and vegetation in this region and highlight the fact that vegetation may respond differently to climate effects depending on different micro climate.

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1. Introduction

Climate change and its impacts on vegetation are a subject of special attention that is characterized by numerous publications on this topic. It results, among others, by a significant increase in global mean temperature, especially in higher latitudes, and by a change of rainfall regime causing heavy rainfall in some areas and dry and hot periods in others.

A climatic variability implies modifications of its indicators throughout time. Previous researches showed that major modifications of climate indicators occurred in most of tropical regions. Climatic factors such as precipitation and temperature are direct and proximal factors influencing vegetation distribution. That is, either they have a known direct influence or they are considered to have a direct physiological influence on vegetation species, the most causal variables exhibit physiological responses (Hao et al. 2012; Watling et al. 2013). Previous studies have shown the influence of climate on forest ecosystem processes, among other factors, by the response of vegetation to climatic variables through the application of remote sensing, which proved to be a good tool for the description of vegetation dynamic (Okin et al. 2001).

This study aims to describe an approach on how geospatial tools can be applied in the sciences while examining the relationship between temperature and precipitation, used as climatic variables, and the vegetation characteristics in Forêt Classée de la Mondah (FCM, in Gabon). For this purpose, the free and open source software (FOSS) QGIS is used for processing and extracting satellite time series data in order to conduct regression analysis and determine the correlation between the variables mentioned above.

2. Material and Method

2.1. Study area

FCM is a forest dedicated for scientific researches of the National College of Water and Forest of Gabon, under the administrative authority of National Agency of National Parks of Gabon. Gabon, located in the west central Africa, is a country covered 85% of tropical rainforest. There are 4 seasons : two rainy seasons, long (February ~ May, warm weather with lots of precipitations and a cloudy sky) and short (September ~ November, warm weather with lots of precipitations and a cloudy sky); and two dry seasons, long (June ~ August, cool weather with a negligible rate of precipitation and a clear sky) and short (December ~ January, few precipitations, pretty warm weather and a cloudy sky). The total annual precipitations are from 2000 mm to 3800 mm while the monthly mean temperature is around 22 and 29. Its climate is classified to the Equatorial of transition.

FCM has an area of 102 km² and spans about 10 kilometers from 9°18' to 9°24' East longitude, and approximately 11 km from 0°37' to 0°29' North latitude. Figure 1 below shows the location in the country and administrative boundaries of the study area.

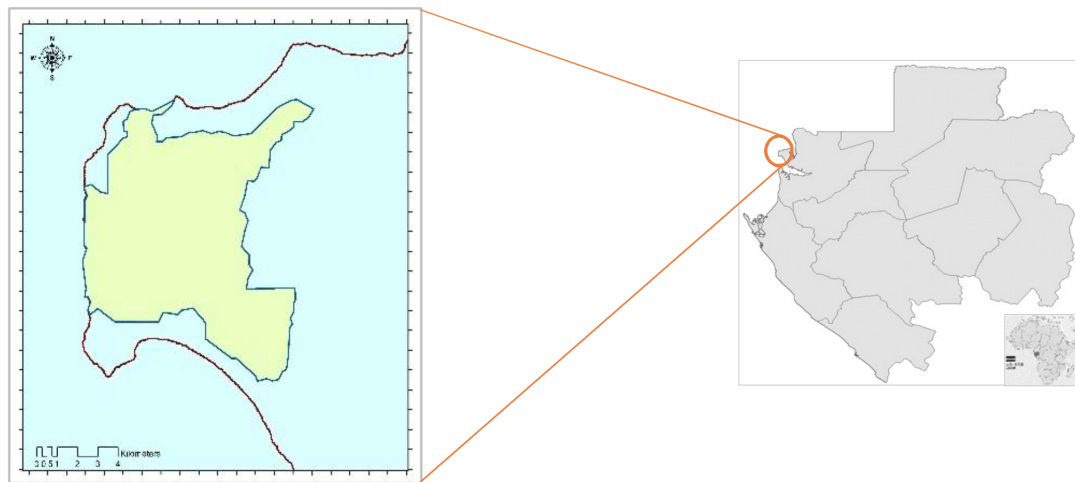


Figure 1: Location of Forêt Classée de la Mondah (FCM). The map on the right side locates FCM in the country while the map on left side shows the limits of FCM.

2.2. Data source and preparation

MODIS/Terra images were used in this study. A total of 191 MODIS/Terra monthly composite NDVI images (MOD13A3, NDVI) were downloaded from Land Processes Distributed Active Archive Center (LP DAAC). Mean temperatures and precipitations of the study area were acquired from National Oceanic and Atmospheric Administration (NOAA) and cover a period of 35 years, from 1980 to 2015. In order to remove seasonal changes and get a more accurate analysis in NDVI, temperature and precipitations time series, anomaly was calculated for every considered period in the datasets. It is worthwhile to note that anomaly is the departure from reference value (long-term average of a considered period). In case of temperature, for instance, a positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that the observed temperature was cooler than the reference value (NOAA 2017; Anonymous 2017).

2.3. Selecting appropriate locations for extracting pixels

In order to emphasize the photosynthetic activity and exclude the potential effects of anthropogenic activities during the regression analysis process, a pixel based spatial analysis procedure with QGIS was used so that any NDVI value less than 0.156 over the whole time series was excluded from the analysis. These excluded NDVI values were representative of bare soil (Mollalo et al. 2014). Raster product tool allowed to create a binary raster (mask) of desired pixels in addition to delineate the targeted area in every single raster by multiplying the so created mask by the original time series. In this last case raster product tool is run as batch processing. In order to avoid erroneous results, the same spatial reference (WGS 84, UTM zone 32N, datum D WGS 1984) was set to the whole time series using Warp reproject tool and to the polygon of the study area as well. Then, satellite data were clipped and a mask created on the fly using raster calculator (from processing toolbox) run as batch processing (figure 2).

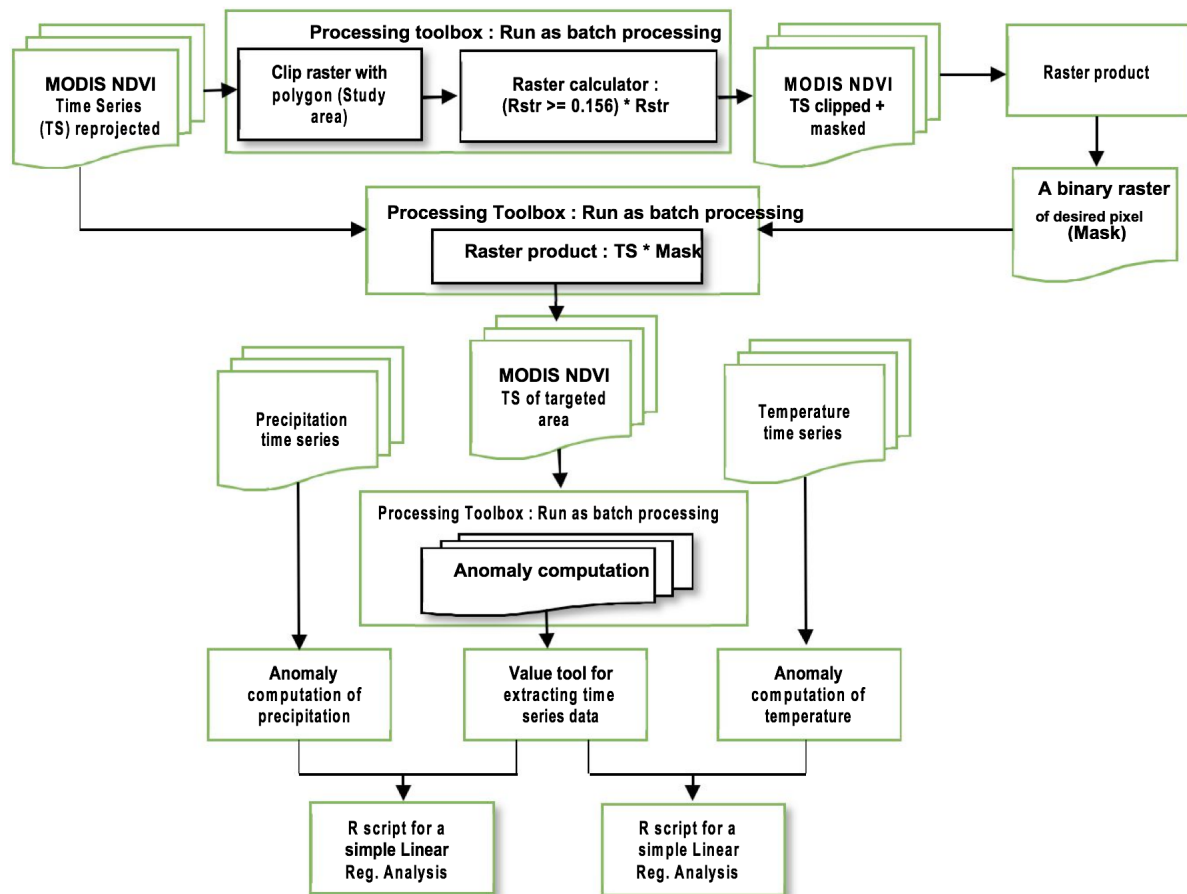


Figure 2: Approach for locating the targeted area and extracting time series data for the regression analysis using R script.

2.4. Approach for regression analysis between climate variables and NDVI

In order to account for the overall fluctuations of climate in the study area, an analysis of the trend of monthly mean temperature and precipitation anomalies was performed from 1980 to 2015. Then, temperature and precipitation time series were matched with NDVI time series, in order to conduct the regression analysis from February 2000 to December 2015. After anomaly was calculated, pixels were extracted from the targeted area (Figure 2) of the whole NDVI time series by using the Value tool plugin. Then, two linear regression analyses (One between temperature and NDVI and the other one between precipitation and NDVI) were conducted using R script so as to model the statistical relationship between climate variables and NDVI according to equation 1:

$$y = a + bx \quad (1)$$

Where a and b are the slope and intercept; x is independent (or explanatory) variables representing temperature or precipitation while y is dependent (or response) variable, representing NDVI.

To perform the analysis through R script, data were imported and attached using the commands `read.delim` and `attach` respectively. Then, after plotted scatter plot included the regression line (`plot` and `abline` commands), the linear regression was fitted to data using the `lm` command and the summary of the model was returned, displaying relevant information for the

analysis such as the slope and intercept, the residual and residual standard error, R squared and adjusted R squared... The confidence interval for statistic test was set to 0.95 using the confint command. Finally, some regression diagnostic plots (residual plot, QQ plot, ...) were produced in order to check the validity of the model.

3. Results

3.1. Fluctuations of climate variables over 35 years

The general trend of temperature and precipitation anomalies did not vary significantly, the coefficient of variation being near normal conditions for both precipitation and temperature. Nevertheless, the trend line showed (Figure 3A) a slightly increase of temperature and precipitation. The periods from early 1980s to middle of 1990s and from late 2008 to 2013 represent deficit years in temperature while over-years are from 1996 to 2008. On the other hand, over-years in precipitation were observed (Figure 3B) for 1980-1988 and 2008-2015 while deficit in precipitation occurred at the period 1988-2008. So then, the climate conditions fluctuated around three different periods : cool and wet, hot and dry and hot and wet.

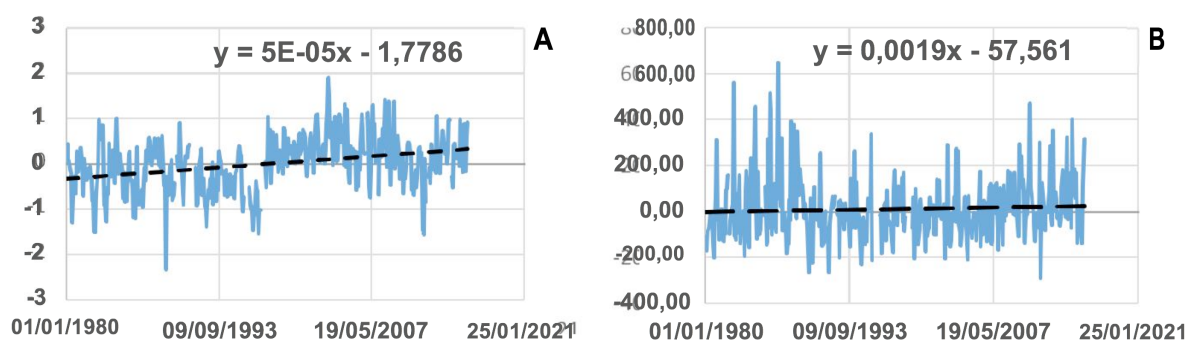


Figure 3: Trend of temperature (A) and precipitation (B) anomalies for 35 years.

3.2. NDVI trend in relation to climatic variables

The regression analysis applied showed that the overall correlation between monthly NDVI and either temperature or precipitation was non-significant. A close to medium positive linear correlation between NDVI and temperature (Coefficient of correlation of 0.47) was found during the long dry season. Yet, only 22% of variation in NDVI can be explained by variation in temperature ($R^2 = 0.22$). A weaker correlation was observed between NDVI and precipitation for the same season (Coefficient of correlation equals to 0.23).

4. Discussion and Conclusion

The system of climatic variables reveals generally stable weather conditions over 35 years. However, the trend analysis revealed a slightly increase of precipitation and temperature even though they are stable, oscillating around normal conditions. The observations of NDVI trend report a similar trend in the vegetation pattern as temperature for the period 2000-2015.

QGIS is a FOSS which has at its disposal functionalities and plug-ins allowing to realize in an easy and fast way tasks which could be tricky to perform otherwise, especially for non

advanced users. Indeed, performing tasks as batch processing, for instance, is a convenient option that QGIS provides, especially while dealing with repetitive tasks over a huge amount of data. R script is a supplementary functionality which opens big possibilities, although it requires some basic knowledge of R language.

The value tool has proved to be particularly useful especially for retrieving time series data. However, it quickly shows its limits when the study area is huge and requires that data are aggregated based on polygons. For this reason, the authors are conducting a similar study in a broader scale (at country level), based on polygon as a spatial analysis procedure to extract MODIS data, in order to obtain further information about the relationship between climate and vegetation in this region and highlight the fact that vegetation may respond differently to climate effects depending on different micro climate.

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