Classification of anthropogenic landscapes

A case study in Northern Benin

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Abstract—**Several vector-borne diseases thrive in and emerge from transition areas between urban, rural and natural areas. In West Africa, these are generally difficult to map because they are composed of complex mixtures of land cover types. In this paper, we use weekly NDVI time series to map transition environments. The high temporal resolution increases the chance of obtaining cloud-free images and allow to study landscape phenology. While NDVI time series data are mostly used for the study of natural vegetation, this paper focusses on human modification of the landscape. The resulting maps of human landscape utilization are useful for assessing the exposure to disease vectors.**

Keywords— NDVI, time series analysis, anthropogenic landscapes, semi-arid savanna, land use.

I. INTRODUCTION

Settlements in rural and suburban areas are widespread in Benin. The human living environment is however not continuously built-up everywhere, and rural settlements are surrounded by an agro-forest mosaic. Most of the country is covered by a agriculture-forest mosaic of small subsistence farms, farmland, and degraded forest. Existing land cover classifications abound, yet they represent strictly land cover, being the approximate percentage of grass, shrub and tree coverage in a pixel and lack an indication on land use, or the intensity of human pressure on the vegetation. An intensive utilization of natural areas by people increase their risk of exposure to disease vectors in the natural environment. Using vegetation phenology for classification has proven useful for classifying drylands in the Sahel [1], irrigation agriculture [2] and urban ecoregions [3]. The working hypothesis of this paper is that different types of anthropogenic land use have distinct NDVI profiles under a given precipitation regime. The objective is to map the different land utilizations in a West-African setting along an urban-forest gradient.

II. METHODOLOGY

A. Study area

Benin, officially the Republic of Benin, borders Togo to the west, Nigeria to the east and Burkina Faso and Niger to the north (Fig 1). Benin's climate is hot and humid. The total yearly precipitation is between 1,000 and 1,300 mm. The north of the country has one short rainy season, with a high precipitation peak in August.

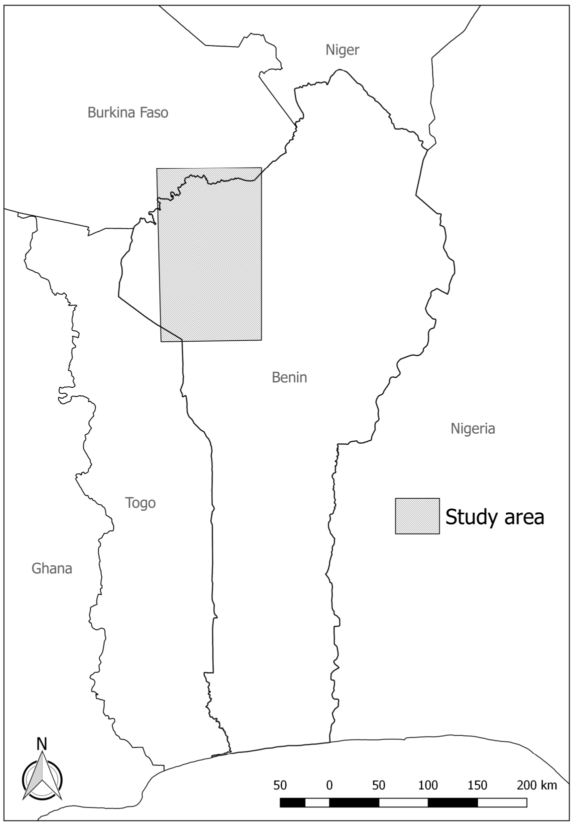

Fig. 1. Situation of the study site in Northern Benin

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The study area is situated in northern Benin, ranging from the city of Natitingou to the forest reserve of Pendjari (Fig 2). It covers a clear urban-rural-forest gradient. The town of Natitingou is home to about 100.000 people, and is located in a semi-valley between two mountain ridges. The second largest town in the study area is Tanguita, housing a population of 50.000. The local economy relies on agricultural production of sorghum, maize, yams, and cotton. More than 60% of the population in the study area is rural. In the north lies the Pendjari national park, a transboundary park between Benin, Burkina Faso and Niger. It provides a protected habitat for big game such as lions and elephants and various bird populations.

B. *NDVI time series & precipitation data*

Land surface seasonality greenness values were downloaded from the CCI website. The NDVI time series represents the mean weekly NDVI over the 1999-2012 period as measured by SPOT-VGT, representing the yearly reference dynamic of the vegetation at a spatial resolution of 1km [4]. Rainfall data was extracted from the "The Climate Hazards group Infrared Precipitation with Stations" (CHIRPS) dataset [5], giving pentadal estimated rainfall values between 1981 and the present. This data is based on a combination of weather station data and satellite imagery and has a resolution of approximately 5 km. These were averaged over the same time period as the NDVI images (1999-2012) and resampled to the extent and cell size of the NDVI series using the nearest neighbor algorithm.

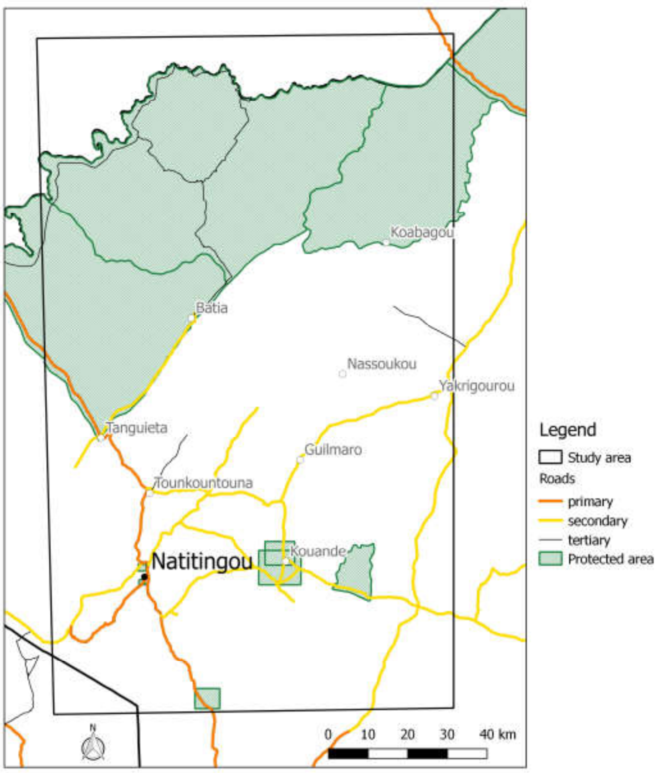

Fig. 2. Layout of the study area

C. *Classification rationale*

The NDVI time series data cube was submitted to an unsupervised classification using hierarchical clustering and Ward's linkage. The number of clusters to retain was determined based on a scree-plot. In a second stage, the clusters were analyzed and characterized using zoom-in-views of Google Earth and ancillary land cover data [2], such as Land Cover CCI 2010. Average NDVI profiles were extracted for all classes and analyzed in relation to the prevailing rainfall regime.

D. *Analysis environment*

All statistical analysis were carried out in the R statistical language version 3.2.3 [6]. All maps were prepared using the QGIS software [7].

III. Results

In a first step, six clusters were retained based on the commonly used 'broken stick' rule (Fig 3). The curve flattens out to a slight decrease when the data was clustered in more than six groups. A second 'flat' was reached when clustering the data in 12 groups.

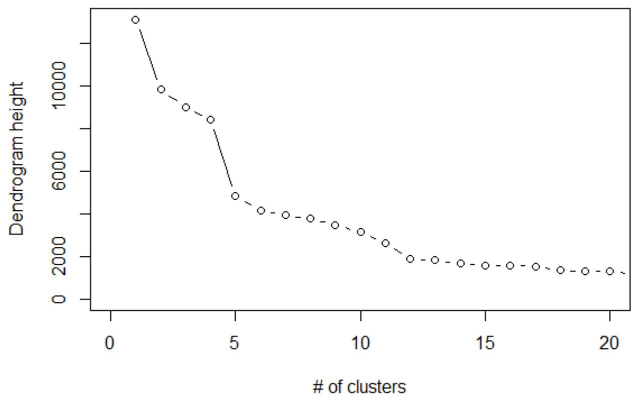

Fig. 3. Scree plot for the hierarchical clustering

This very straightforward classification found a clear difference between the populated area in the southeast and the protected park of Pendjari in the northwest of the study area. Two types of vegetation were distinguished within the park (Class 1 & 2), and three outside of the park – class 3, 5 & 6 (Fig 4). One class – class 4 - was located partly within and partly along the edges of the park, and its main entry point, the town of Tanguieta.

The temporal profiles over time for each of the clusters are visualized in Fig 5, where the x-axis represents the time, either months or weeks within one year, and the y-axis represents NDVI (in green), and precipitation (in blue). Although the precipitation profiles seem similar at first sight, there are some differences, one indicating a trend of lower rainfall in the clusters in the north, and higher rainfall in the clusters in the south. A second difference lies in the amount of rainfall early in the season. Clusters 5 and 6 have a more pronounced early rainy season.

Considering NDVI, the two classes in the Pendjari Park represented typical profiles of natural vegetation with a considerable shrub cover, featuring NDVI values that closely follow the precipitation pattern throughout the year. Greening up of the vegetation occurs at the beginning of the rainy season. Further to the south, two NDVI peaks were observed. In clusters 2 and 4 the secondary peak was not very distinct, but in clusters 3, 5 and 6, the primary and the secondary NDVI peak were nearly of the same height. The difference between the height of the primary and secondary peak was lowest in cluster 3 and 6, which were the clusters with the highest proportion of tree cover.

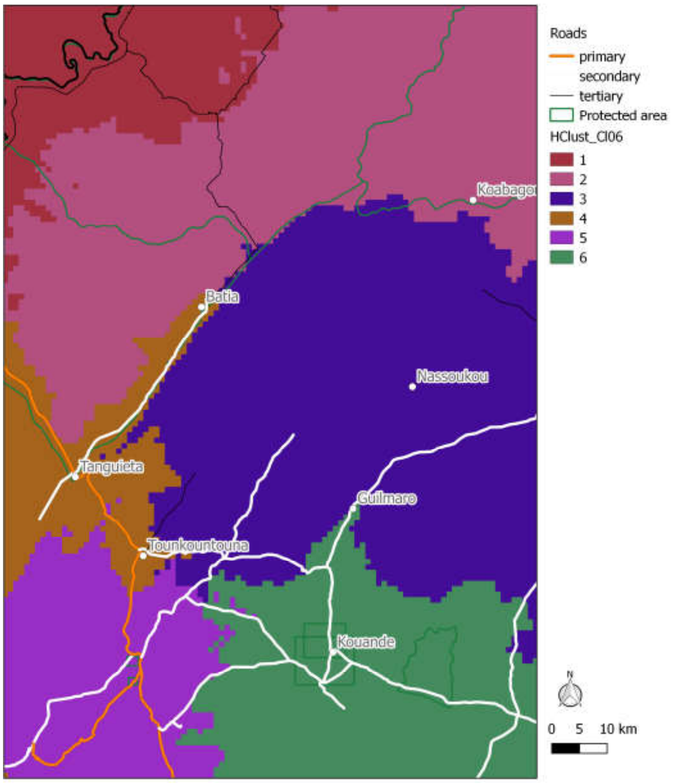

Fig. 4. Classification of the study area

The differences between the NDVI profiles of different clusters were sometimes quite subtle; such as a slight shift in the location in the vegetation greening at the beginning of the rainy season. In cluster 4, vegetation greens up slightly before the heavy rains. This might indicate a higher proportion of tended crops.

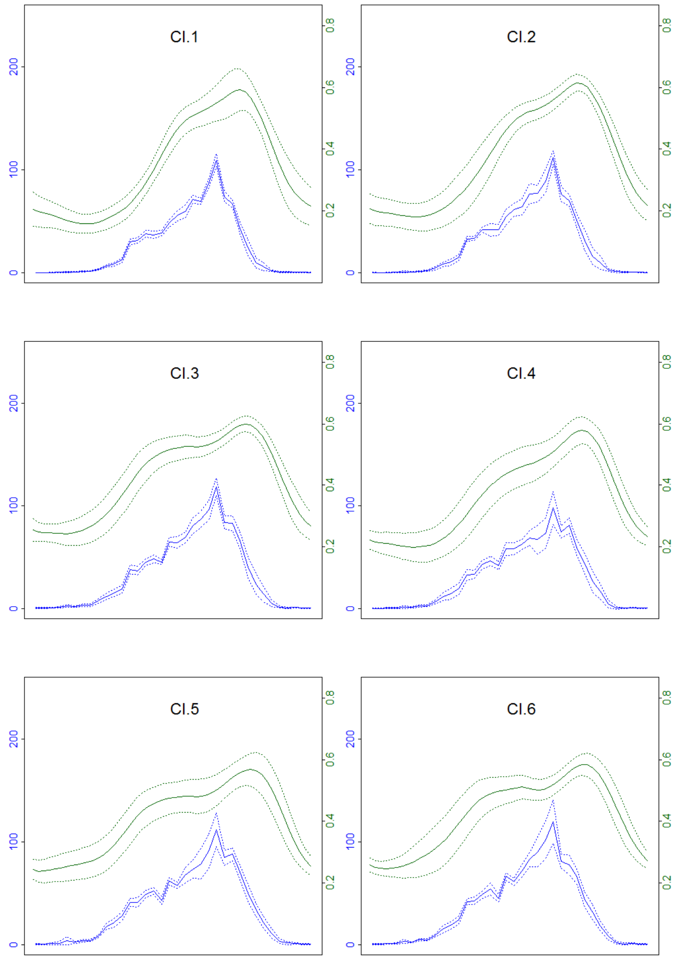

Fig. 5. Characterisation of the 5 land use classes. The yearly NDVI profile is represented in green on the right axis, and the prevailing precipitation regime is represented in blue on the left axis. Solid lines indicate means, and the dotted lines indicate the confidence interval.

IV. Discussion and Conclusion

Although the unsupervised clustering approach used in this study might seem simplistic, it does provide an accurate classification of the urban-forest landscape, highlighting the protected areas and the inhabited areas. It allows formulating hypotheses on a possible typology of human settlements in a rural context. It goes without saying that this method could be improved by increasing the number of classes within the human-modified areas to obtain a more accurate description of rural settlements. More detailed data, such as NDVI profiles with a finer resolution, or higher quality rainfall data, could also provide a better understanding of the structure of West-African anthropogenic landscapes. Also information on land use obtained through participatory mapping could prove invaluable in validating this classification.

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