# Understanding urban sprawl in a West African metropolis: A case study of Abidjan city in Ivory Coast

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## ABSTRACT

Urban growth in Sub-Saharan Africa is progressing rapidly since the 1960. Abidjan city (Figure 1) is one of the biggest metropolises in francophone region in West Africa and is following the same fast-growing development. To get a deeper knowledge of the city expansion and predict its future pattern, this case study adopts the remote sensing data, Machine Learning (ML) tools and Cellular Automata (CA). The research methodology consists of firstly classifying LANDSAT images using LightGBM algorithm for the years 1987, 2000 and 2014, secondly evaluating the influence of the proximity to the road and the industrial centres, the slope of the terrain and the population density by applying the Geographical Weighted Logistic Regression (GWLR) and thirdly predicting the urban fabric of the city from 2000 to 2014 using the Cellular Automata with a transition rules based on the Machine Learning technique: Support Vector Machine (SVM). The research findings have demonstrated the good performance of the Gradient Boosting Machine algorithm LightGBM in the supervised classification of remote sensing data; proximity to roads and industrial centres have a positive contribution to urban growth while the slope and the population density are not positively linked to the city spreading; the assessment of the CA model prediction revealed an Area Under the Curve (AUC) of 67.45% which is relatively accurate. The machine learning techniques are fit for purpose in the image classification and decision rules in the CA, but the researcher need to have a deeper knowledge of the input data in order to understand the output values from ML algorithms. Likewise, the GWLR are performing better than the global model regression although some important variables are missing and could be included such as the master plan of the city.

## METHODOLOGY

The research strategy adopted here to understand the urban sprawl of Abidjan city is a case study. In other words, this strategy fits with the overall objective of this research which the aim is an in-depth understanding of driving factors of urban sprawl in Abidjan. The Abidjan case could be considered as an example of metropolis in African countries as most of them are sharing the same past, development path and characteristics (Myers, 2011). Of course, case study presents some weaknesses identified by Denscombe (2014). Indeed, He argues that this approach does not clearly define the boundaries of the studied case so that the replication of the same experiment by other researchers could be challenging (Denscombe, 2014). Nevertheless, for the purposes of this work, quantitative data as well as statistic procedures will be the core techniques to be developed. And to support our choice, a case study suits well with quantitative research by being easy to understand for the readers and highlighting problems that may arise in a broader context (Wellington, 2015).

## METHODOLOGY (continued)

An overview of the different techniques and processes applied is represented in a workflow (Figure 2). Thus, satellite images from LANDSAT will be processed using a supervised classification based on Gradient Boost algorithm. DEM files from SRTM will be utilised to calculate the slope in the city while the proximity to primary roads and industrial hubs will be estimated. Moreover, the influence of driving forces of urban sprawl identified here for Abidjan city will be evaluated using the Logistic Regression. Then after, a training dataset are prepared and fed into the Support Vector Machine (SVM) algorithm. Next, a cellular automata (CA) analysis is applied to predict the future of the urban extent based on the results from SVM assessment. The outcomes from the CA analysis will be compared to a more recent satellite image from 2014. This comparison will help to measure the accuracy of CA prediction.

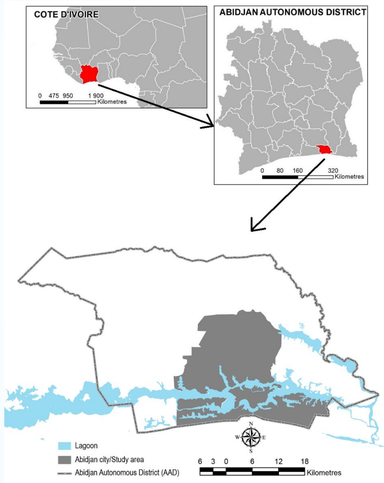


Figure 1: Location of the study area: Abidjan city

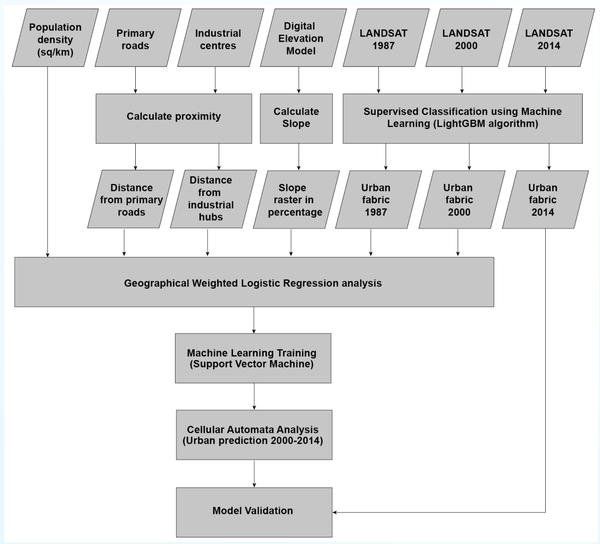


Figure 2: Workflow with the overall methods and techniques used in this research

## RESULTS

The expansion of Abidjan has slowed from 1987 to 2000, a decrease of 3.29% of the urban area. Conversely, from 2000 to 2014, the city has grown of about 35.12%. These results from the supervised classification, are displaying an accuracy over 90%. The regression analysis reveals that the explanatory variables: proximity to roads and industrials centres, have positive contribution to the development of the city. On the other hand, the slope and the population density have a negative contribution. But, when looking at the significance of the data, it is acknowledged that the t-test of both variables (the slope and the population density) are not statistically significant in most part of the city. The other independent factors: proximity to roads and industrial centres, are performing well in the t-test. About the cellular automata analysis, the spatial pattern of urban growth can be predicted with a precision close to 68% (Figure 4). These data are contributing to understand the urban growth of Abidjan city as stated in the aim of this research.

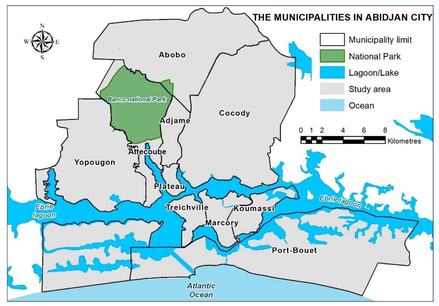


Figure 3: The administrative boundary of Abidjan city with 10 municipalities

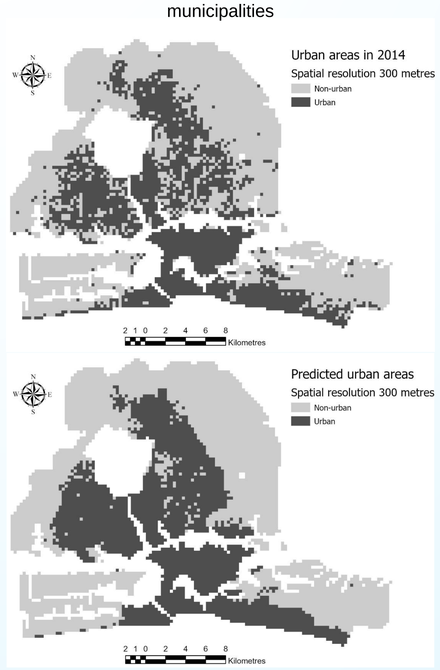


Figure 4: Urban areas in 2014 from LANDSAT images and the predicted areas from the SVM-based cellular automata.

## CONCLUSION

Urban growth in Africa as revealed by the literature has a different development path compared to western cities. Many authors are advocated for a new approach in defining African cities and suggested the inclusion of new stakeholders such as local leaders, NGOs, businesses, etc. in the decision-making process (Devas, 2001). Furthermore, several factors which are contributing to the spreading of the cities in developing countries have been identified including population and road network which are the most cited driving forces in urban development. As new tools to understand the urban dynamics have been elaborated, machine learning and cellular automata have appeared to successfully identify urban patterns but also simulate the urban growth for the next years. Thus, using a recent machine learning algorithm LightGBM, urban and non-urban zones have been classified with a satisfactory accuracy for the years 1987, 2000 and 2014. It is understood that there is an in-filling and edge-expansion of the city in the north, northeast, northwest and southeast respectively in the municipalities of Abobo, Cocody, Yopougon and Port-Bouet (Figure 3). However, an important number of misclassified pixels have been detected in the southwest peninsula.

Understanding the reasons of this growth has required the application of the Geographical Weighted Logistic Regression. As suggested by the literature review, four variables were integrated in the GWLR equation that is the population density, the proximity to the road network, the proximity to industrial hubs and the slope of the terrain. The outcome of the regression has displayed a positive contribution of both proximity to the road and the industrial zones and a negative coefficient for the population density and the slope. It is shown that the relief and the population have no incidence in urban expansion but the proximity to the road is one of the big contributors. But the overall deviance of the local model is accounting for 56% whereas the global regression is just showing 26%. This performance is impacted by the Modifiable Area Unit Problem and the missing of key other variables. Nevertheless, with more than half of the deviance explained by these variables, they can be used to help the prediction of Abidjan city's extent.

## References

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