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Remote Sensing of Industrial Palm Groves in Cameroon

Prune Christobelle Komba Mayossa^{1,2*}, Sébastien Gadal¹ and Jean-Marc Roda^{2,3}

The measurement of biomass can be obtained from remote sensing analysis and modelling, the impacts of which are related to oil palm cultivation in industrial plantations. Our study aims at producing a spatial model for oil palm biomass estimation, at different scales of spatial analysis. The study was carried out in the industrial plantations of the Cameroonian Society of Palm Groves (SOCAPALM). The developed methodology combined: (i) the mapping of palm groves (Kumar, 2015), (ii) the characterisation of palm groves (Gadal, 2013), (iii) biomass estimation, and (iv) the comparison of the obtained results with Spot6, Landsat 7 ETM+ and Landsat 8 OLI images from 2001 to 2015. The first results were obtained for the mapping of the SOCAPALM industrial palm groves between 2001 and 2015. The obtained maps were highly correlated (Kappa of 0.91 for Spot 6, 0.92 for Landsat 7 and 0.82 for Landsat 8), however, because of the presence of mixed pixels, some confusion between oil palm and other classes were observed. One of the factors affecting biomass estimation is spatial accuracy. Several improvements have been suggested: (1) mapping palm groves at a subpixel scale using super-resolution mapping; (2) developing a classification system of cartographic products. The use of satellite images with different spatial resolutions may also help to generate new data taking into account the level of spatial analysis.

Key words: Palm groves, biomass, remote sensing, spatial accuracy, energy, modelling

INTRODUCTION

In Cameroon, oil palm gained great economic importance along with industrialization dating from the colonial period (Elong, 2003). The income generated from oil palm cultivation have developed agro-industries such as SOCAPALM (Cameroonian Society of Palm groves). These activities have high-yields but low costs of returns (Rival, 2013) and have also caused socio-environmental damages including deforestation, loss of biodiversity, pollution, etc. The measurement of biomass can be obtained from remote sensing analysis and modeling, the impacts of which are related to oil palm cultivation in industrial plantations. Biomass is an important variable in many ecological, environmental and agricultural studies. It is a renewable source of energy used to monitor, and quantify agricultural production.

In the oil palm industry, remote sensing has become the main source of biomass estimation (Lu, 2005). Using remote sensing, several studies have been developed to monitor the production and yields of oil palm. However, these studies only focused on palm grove expansion (Thenkabail, 2004), age assessment of palm groves (Chemura *et al.* 2015) and the conversion of forest areas into oil palm cultivation (Morel *et al.* 2011).

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Being the first survey of its kind in the Congo basin, this work is related to the long-term management of oil palm resources. More precisely, in the context of the opposition between biodiversity conservation and oil palm agricultural strategies, and in the REDD context, it characterises the relationship between people/agriculture and biodiversity. This work aims to:

- Produce a spatial model for oil palm biomass estimation at different scales of spatial analysis.
- Establish the link between agricultural strategies of palm groves, biomass and the produced energy.

The study is focused in the industrial palm groves of the Cameroonian Society of palm groves (SOCAPALM). The largest agribusiness of oil palm in Cameroon is located in the south west of this area.

MATERIALS AND METHODS

Satellite images between 2001 and 2015 were used: Landsat ETM+, Landsat 8 OLI-TIRS and Spot-6 of the same season but with different acquisition dates. The methodology adopted combined the mapping of palm groves (using per-pixel classification), biomass estimation (using the combination of a linear regression model and biophysical variables) and third, the comparison of the obtained results for the earth observation platform.

RESULTS AND DISCUSSION

First, results were obtained for the mapping of palm groves from 2001 to 2015 (Figures 1, 2 and 3).

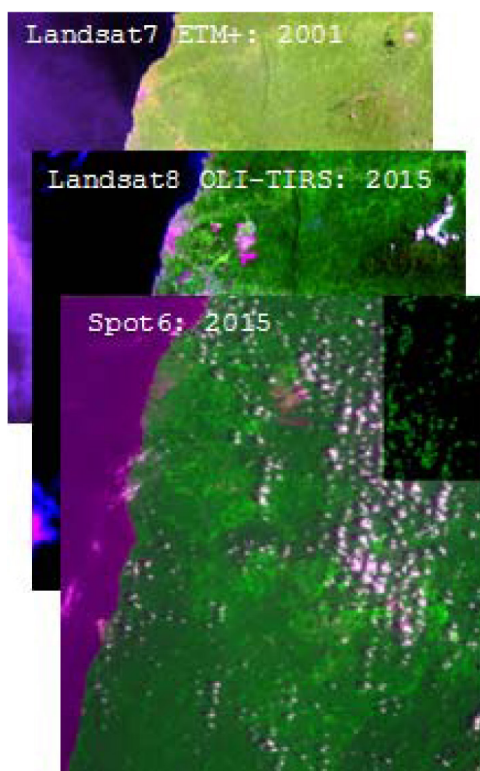


Figure1. Data

Table1. Sensor specifications

| Sensor | Acquisition date | Mode | Resolution | Cloud cover |
|----------|------------------|--------|------------|-------------|
| ETM+ | 26/04/2001 | MS/PAN | 30m/15m | 30% |
| OLI-TIRS | 26/04/2015 | MS/PAN | 30m/15m | 30% |
| SPOT-6 | 01/01/2015 | MS/PAN | 8m/2m | 40% |

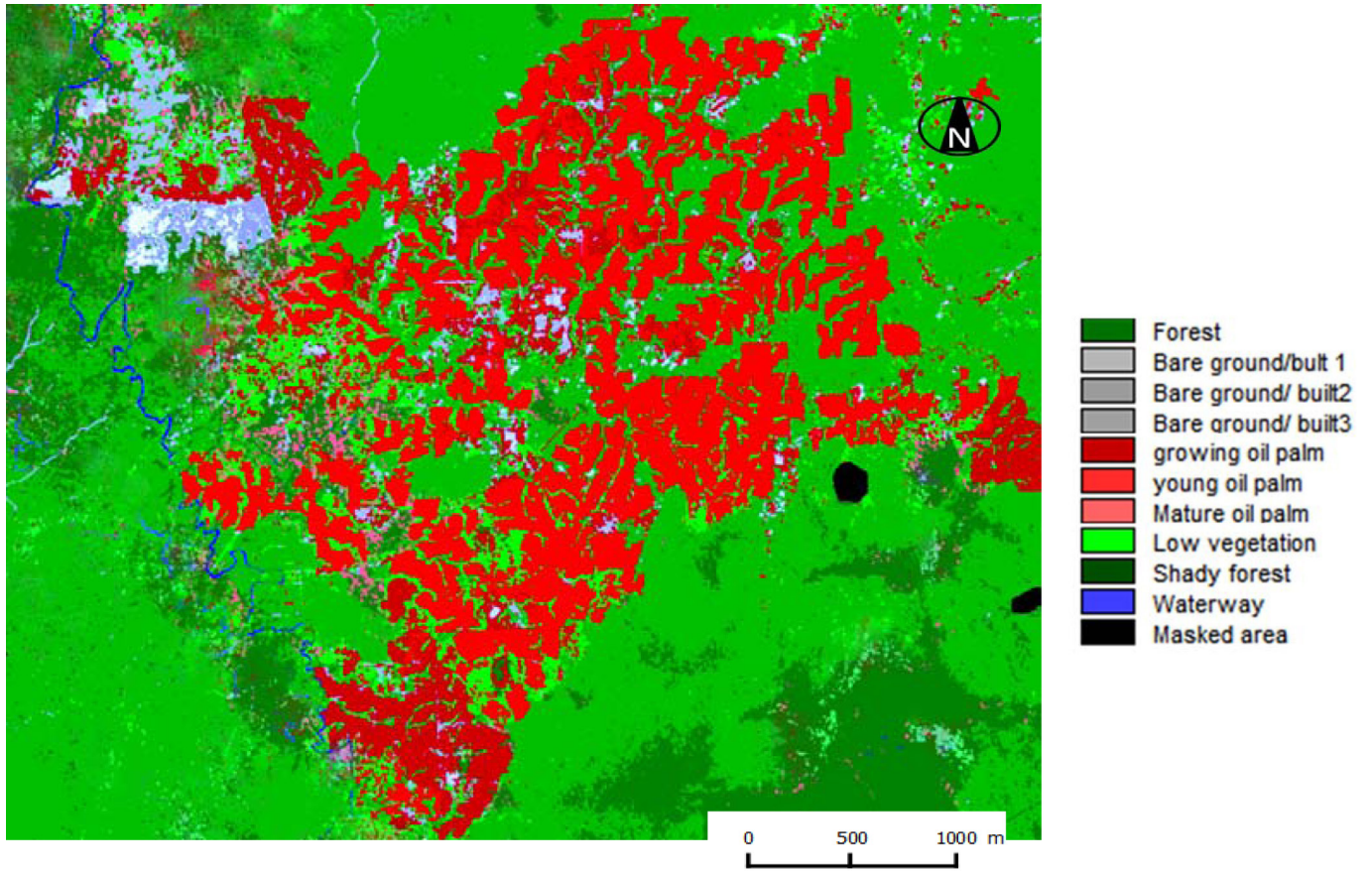


Figure 2. Land cover map from Landsat 7 ETM+ (2001), CNRS ESPACE UMR 7300

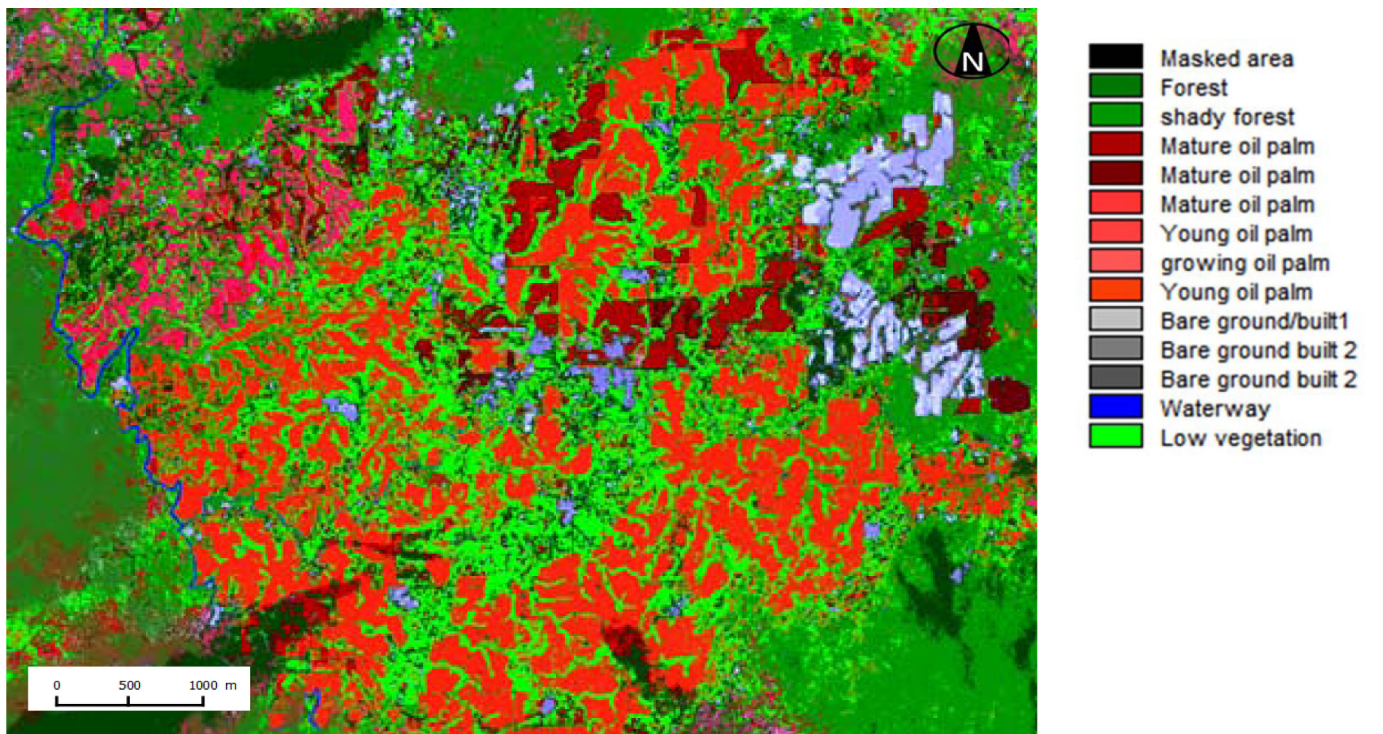


Figure 3. Land cover map from Landsat 8 OLI-TIRS (2015) CNRS ESPACE UMR 7300

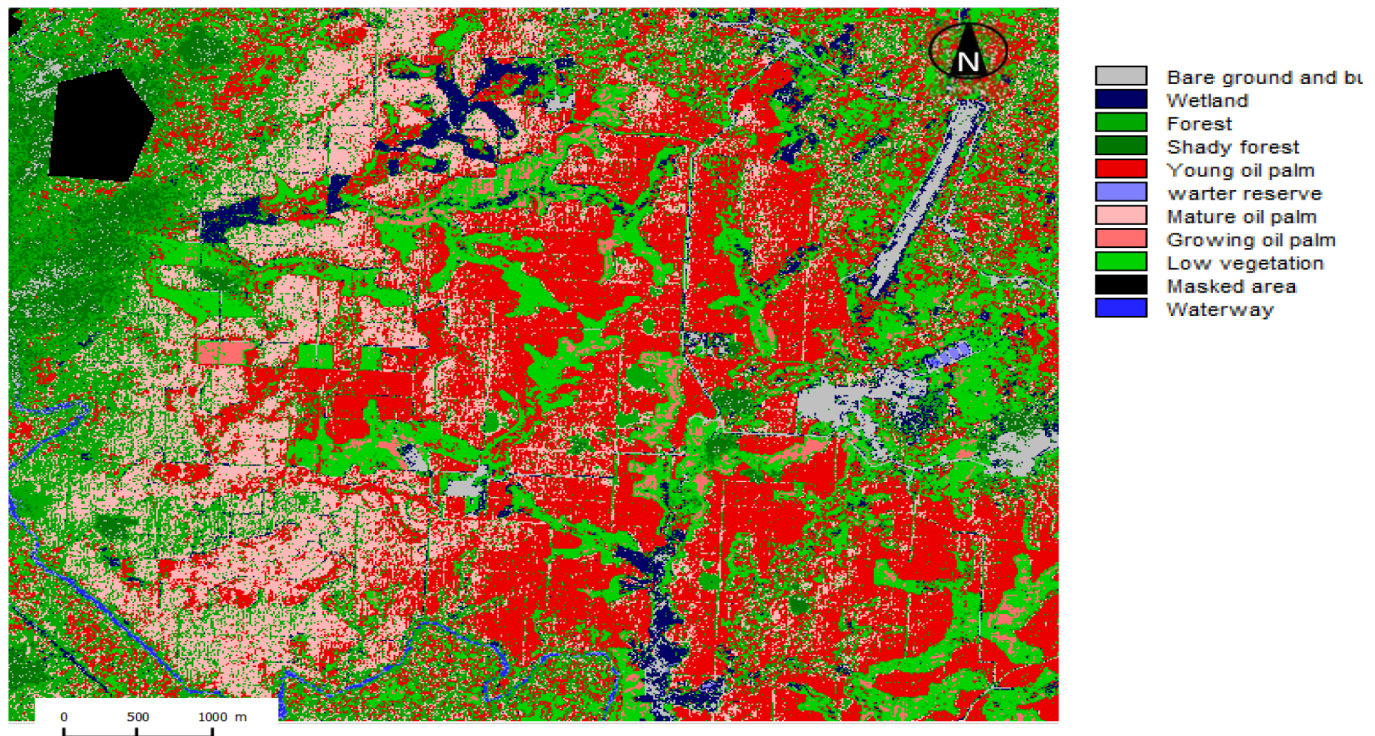


Figure 4. Land cover map from Spot6 (2015) CNRS ESPACE UMR 7300.

Highly correlated maps with overall accuracies of 90% for Landsat 7, 80% for Landsat 8 and 93% for Spot 6 respectively, were obtained. However, despite the high values of Kappa (0.91 for spot 6, 0.86 for Landsat 8 and 0.92 for Landsat 7) between oil palm classes, or oil palm and vegetation classes, some confusion was observed between forest and mature oil palms (17%); and between young and growing oil palms (5.4%).

- As some components may be common to different classes, (for example low vegetation pixels in the growing or young oil palm classes), distinct classes may share mixed pixels (Komba Mayossa, 2014).
- On the other hand, to validate the produced maps, control areas could be digitised with Arcgis software in many classes as estimated for each image. The resulting manual classifications could then be crossed with the maximum likelihood classification result, to produce a confusion matrix and Kappa index. The ground truth plays an important role in map accuracy. The knowledge of the ground is an important key; and results can be obtained from the validation of the digitised map and classifications. Landsat images have a resolution of 30m. The photo-interpretation is difficult especially in a heterogeneous landscape, as in the current study area, errors occur during the sampling step, which cannot take into account the within-plot heterogeneity. Thematic confusions caused by the presence of mixed pixels affects map accuracy (Chitroub, 2007). These mixed pixels result from spectral and spatial characteristics of the studied objects in the landscape, and from the methods used to map.

CONCLUSIONS

Limitations of the spatial accuracy of oil palm grove mapping is related to class heterogeneity, attendant mixed pixels and the method used. Several ways for improvement are possible.

- For the mapping of industrial palm groves

Firstly, per-pixel classification assumes that each pixel represents a single class only. The maximum likelihood algorithm, used to map palm groves, ignores the mixed pixel problem. One of the solutions is to use a technique which allows mapping at the sub-pixel scale, such as super-resolution mapping (Priya and Sanjeevi, 2013; Muad and Foody, 2012). Secondly, as the map validation method may enhance or reduce the accuracy of the produced map, the development of a classification system of cartographic products becomes very interesting. Indeed, further studies should be focused on the evaluation of the reliability of the produced map.

- For biomass estimation

One of the factors affecting biomass estimation is the spatial resolution. The use of data with different spatial resolutions allows taking into account the issues related to the spatial accuracy of produced models. This also helps to generate new data, taking into account the level of spatial analysis.

The purpose of this work was to develop a model for oil palm biomass estimation at different scales of spatial analysis, that links agricultural strategies, biomass and produced energy for oil palm plantations in a tropical area. This may open prospects for the implementation of an environment observatory for the monitoring of agricultural areas, considering socio-economic and geographical features.

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