Remote sensing and land use in Africa
Case of Sampieri (Burkina Faso)

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Abstract—Because the cartography is often deficient, the use of satellite images is the best way to know the land use of Africa. But to extract a reliable map from these raw data is not an easy task. The aim of this study was to find a method to map the main landscape units, a method which can be easily reproducible. Satellite images were chosen according to the agricultural calendar, among those freely available, i.e. Landsat images. The results appear satisfactory on a local scale, where ground control points have been chosen. But the generalization to the entire images shows the limits to map the landscapes from satellite images. Ground survey points are to be chosen on the entire area. Thus, the advantage of satellite images to generalize the knowledge of land use disappears.

Keywords- Remote-sensing; Landsat; land use; Africa; Burkina Faso; agricultural calendar; vegetation indices; limits

I. INTRODUCTION

The present study was conducted in the perspective of a research project, Biosol (Biological stimulation of soil and socio-economic management of agrosystems in Burkina Faso, funded by the region Centre in France), which aims to promote new knowledge on the ecological intensification, to ensure environmental and socio-economic development in different regions of Africa. The first results showed that solutions are relevant only if they are based on a diagnosis and a rigorous and reliable inventory of the situation [1], which includes knowledge of land use.

This paper aims to propose a method of characterization of land use in the absence of any pre-existing mapping, as it is often the case in Africa. Satellite images prove to be currently the most relevant way to know the landscape. Easily available on the dates you want (from 1972), they require a time much shorter than the aerial photographs treatment, especially if the covered area is vast. We are particularly interested in Landsat images, some of which are free to access.

II. MATERIALS AND METHOD

A. Materials

Sampieri was chosen by the research project Biosol to study different methods of ecological intensification, their environmental consequences and the conditions of support by the populations. It’s included in the Sudano-sahelian climatic area (between isol yets 600 mm and 900 mm [2]). The main activity here is agriculture: traditional crops (millet, fonio, sorghum, beans, peas potatoes, peanuts, sesame, hibiscus, corn, etc.) and animal husbandry.

To select the best images, several criteria have to be considered. One of the most important is the resolution because the identification of the Earth’s objects depends on it: on one hand, the spatial one, which sets the pixel size; thus, the smallest object can be identified; on the other hand, the spectral one, which determines the number of bands, therefore identifying the objects becomes easier. The choice depends on the aim of the research and on the specificities of studied areas; it depends also on the characteristics of objects which we intend to identify. Within the framework of this research, the objects are the main land use categories (cultivated land, spontaneous vegetation and bare land) and the focus is mainly on the fields, whose area is between 0.38 and 26 ha [3]. Thus the sensor should offer high spectral and spatial resolutions. Far to be the only ones, Landsat 5 TM and 8 OLI/TIRS can work together because their spatial resolution is 30 x 30 m and because they measure the luminance in the visible and infrared bands. Above all, the images taken from these sensors are freely available at the selected dates and they cover an area large enough to include the studied area, with a 185 km cross-track field of view.

The climate in Burkina Faso is characterized by two seasons, a dry one and a rainy one, which is shorter in the Sudano-sahelian area (4-5 months, [2]) than in the Sudanese
area (6 months). This season (from May-June to September-October) is the period of cultivation. This piece of information had to be considered to choose the images, taken at the best dates, to obtain the greater discrimination between the three main land use categories. These were supplemented by an empirical knowledge, acquired on the ground. In June, because they have been recently planted, the cultivated lands can be distinguished more easily from herbaceous formations but can be mistaken for bare or few plant-covered lands on images. In September-October, the chlorophyllian activity is important; the crops are ready to be harvested and can be mistaken for herbaceous formations but these lands can now be better distinguished from bare lands. Using images taken at these two periods allows removing any ambiguity between cultivated lands and other land use categories. J. L. Devineau and G. Serpantié [4], who also intended to map the Burkina faso landscapes by remote-sensing, using satellite images, advocated to add a third image, taken in January. In this study, the latter didn’t appear because the aim was not to obtain a “fine discrimination of various plant groups” (Devineau and Serpantié, translated) but to identify the main land use categories. Thus, two images were acquired. We chose images from Landsat 8 OLI/TIRS, the only free and available images in 2003 (June, 7 and October, 13), the year of our ground survey.

B. Method

The different bands of a given image are often correlated; in order to synthesize the information contained in these bands, new bands were created for each chosen image, with the advantage to reduce data to the most useful ones, according to the purpose of the study. These created bands are two indices:

— of vegetation: we used the TSAVI (Transformed Soil Adjusted Vegetation Index); that gives a better discrimination between savannah and cultivated lands.

$$\text{TSAVI} = \frac{(\text{NR}-\varepsilon)(\text{RED}-\delta)}{\text{RED}+\text{NR}-\varepsilon-\delta}$$

where

- $\text{NR}$ = reflectance in the near infrared band (expressed as reflectance)
- $\text{RED}$ = reflectance in the red band (expressed as reflectance)
- $\varepsilon$ = slope of the soil line
- $\delta$ = intercept of the soil line

— of brightness ($\sqrt{((\text{Rouge})^2 + (\text{PIR})^2)}$)

The vegetation index aims to stand out the vegetation and the brightness index aims at standing out the bare lands.

Another band was considered, the green band, which gives information about the chlorophyllian activity, especially because the most difficult task was to distinguish spontaneous vegetation (savannah) from cultivated land.

The three chosen bands – vegetation and brightness indices and green band – of the two images – of June and October – were processed into the framework of an automatic classification

Because the method had to be easily reproducible, we have opted for an unsupervised classification, based on the Isodata method – aggregation around mobile centers – suggested by G. H. Ball et D. J. Hall [5]. The advantage of such a classification is also that no a priori knowledge on the land use is necessary – even though the validation of the classification can’t be done without such knowledge – and that it is based more on spectral signatures of objects to be identified. To get the more relevant results, we tested different combination of bands – the best including the bands mentioned above –, various number of desired clusters, knowing that the relevance of the results was judged according to control points, whose land use was studied on the ground.

The figure 1 synthesizes the method used (Fig. 1).

III. RÉSULTS AND DISCUSSIONS

The approach was applied initially on a small window (Figure 2). We did field surveys to better calibrate the treatment. The result of the classification has been validated by all control points.
After having identified and masked “water” cluster, too small to be distinguished on a smaller scale by unsupervised classification, the same processing was applied to the entire image but it ended up in a quite different result, disappointing at a village scale (Fig. 3).

It can be explained by the fact that the entire images include different landscape units from those included in the only local window. Thus, to solve this problem, we tried to change the number of studied clusters but it was a failure; we had then to look for a new method. We had to go back to the upstream of the processing and analyze indices and bands. It appeared that some mixing-up, some failures could be removed thanks to the distinction of the values taken by the objects to be identified in TSAVI. This vegetation index was therefore used to improve the clusters of the best classification, which suffered from mixing-up, to separate the land use categories included in the same cluster. The result was confronted to the ground control points taken in the studied village; the map obtained (Fig. 4 and 5) is a compromise between the land use on the map and in the entire area covered by images, knowing that the a priori knowledge of the land use on such a small scale was imprecise.

On these two scales, the result is not completely satisfactory; the bare lands, for example, differ from these identified by processing on a local scale: too small, they’re now included in “land covered by a scattered spontaneous vegetation” and other bare lands appear according to the land use knowledge on a small scale, whereas they have been...
classified as savannah on the figure 3. These lands, which concern a large area at the scale of the images, are not really bare but more exactly covered by spontaneous vegetation, more scattered than on the “land covered by scattered spontaneous vegetation”. Because the result are a compromise, not completely satisfactory, we can affirm that the generalization of the land use knowledge from a local scale to a smaller scale, basing on satellite images, shows its limits, especially when different landscape units are included on the smaller scale. The solution could be to process separately the parts of images corresponding to the different landscape units. It was tested for the unit, which includes the studied village, using a larger window, but the result was also different from the one which had been obtained at a local window; that’s why, because the aim was to find a method easily and quickly reproducible, this solution was not kept.

IV. CONCLUSION

We defined a method that appears satisfactory on a local scale; the results for the studied villages windows are close to the reality of the land use on the ground. Based on an unsupervised classification, the method is easily reproducible on other sites of Burkina Faso, or of West Africa, and allows knowing the main land use categories around villages, in the absence of any available map. The method only requires the use of images at two periods of the agricultural calendar, being freely available, taken by Landsat sensors. It uses TSAVI, brightness indices and the green bands of the two images. Nevertheless, satisfactory on a local scale, the method becomes disappointing – or, at least, needs adaptations – when it’s applied to the entire images; new land use categories appear and some of those identified on the village window become marginal. The results are different according to the considered area, between a window on the studied village and the entire images. The generalization to a smaller scale without any ground survey can’t give reliable results. The advantage of satellite images, which allows generalizing the knowledge on landscapes, thus disappears.

REFERENCES