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Amelie Robert, Jean-Louis Yengue, S. Servain. Remote-Sensing and Landscapes, Limits of Smaller Scale Generalization and Reproducible Method. Lecture Notes in Computer Science, 2014, Computational Science and Its Applications - ICCSA 2014 14th International Conference, Guimarães, Portugal, June 30 - July 3, 2014, Proceedings, Part I, 8579, pp.408-422. 10.1007/978-3-319-09144-0\_28. hal-01053809

**HAL Id: hal-01053809**

**<https://hal.science/hal-01053809v1>**

Submitted on 8 Aug 2023

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# Remote-Sensing and Landscapes, Limits of Smaller Scale Generalization and Reproducible Method

## Case Study in Burkina Faso

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**To quote this article:** Robert A., Yengué J. L. & Servain S., 2014, “Remote-Sensing and Landscapes, Limits of Smaller Scale Generalization and Reproducible Method: Case Study in Burkina Faso”, *Lecture Notes in Computer Science*, vol. 8579, Computational Science and Its Applications – ICCSA 2014: 14th International Conference, Guimarães, Portugal, June 30 - July 3, 2014, Proceedings, Part I, B. Murgante *et al.* (Eds.), Springer International Publishing Switzerland, p. 408-422

**Abstract.** Because the cartography is often deficient, the use of the satellite images is the best way to know the landscapes 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 on sites of Burkina Faso. 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 landscapes disappears.

**Keywords:** Remote-sensing, Landsat, landscapes, Africa, Burkina Faso, agricultural calendar, vegetation indices, limits.

## 1 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 (Yengué and Cochonneau, 2013), which includes a knowledge of landscapes. Because the cartography is often lacking, the use of the satellite images is the best way to acquire this knowledge. Indeed, these raw data are easily available from 1972; some, like Landsat ones, are even freely available and they need a shorter processing than aerial photographs, all the more since the studied area is large (Robert, 2011). But they also include drawbacks; some are known (*ibid.*; Yengué, 2001-a, 2001-b and 2002), this paper intends to demonstrate some others, by comparing results of unsupervised classification at different scales, from village to the area covered by the entire images, and on different sites.

## 2 Materials and Method

Three villages were chosen by the research project Biosol to study different methods of ecological intensification, their environmental consequences and the conditions of support by the populations. They're located in different areas of Burkina Faso, in varied cultural and pedo-climatic contexts: Barani in the West, Sampieri in the East and Bandougou in the South. The two first ones are included in the Sudano-sahelian climatic area (between isohyets 600 mm and 900 mm, Lerebours Pigeonnière and Menager, 2001), Barani being situated nearer from the Sahelian area; the third one is in the Sudanese climatic area (from 900 mm to 1300 mm of annual precipitation, Lerebours Pigeonnière and Menager, 2001). As the vegetation, the landscape differs and it allows to study the possibility to find a method which could be easily reproducible in varied contexts of land use. Materials, like methods, should be quite similar for the three studied areas; an adaptation was however necessary between the first studied village, Barani, and the two others to improve the results.

## 2.1 Materials

To know the landscapes, when cartography is lacking, some choices are necessary. The satellite images are preferred to aerial photographs because their processing needs shorter time and because their availability is greater (Robert, 2011). Images differ according to the satellite from which they're taken. To select the more relevant, several criteria have to be considered (*ibid.*). 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 and thus the size of the smallest object which can be identified; on the other hand, the spectral one, which determines the number of bands, therefore the easiness to identifying the objects. 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, at least in Barani (Cochonneau, 2012). 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 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. Landsat 8 was only launched on February 2013; that's why, its images were not available yet for the first studied village, Barani, and the map of land use was drawn from Landsat 5 TM images, whereas, for the two other villages, images from Landsat 8 OLI/TIRS have been preferred (Table 1). Indeed, for Sampieri and Bandougou, the ground survey was lead later, in October 2013, and, for this year, the only images freely available were those from Landsat 8 OLI/TIRS.

Launched in 1999, Landsat 7 ETM+ is more recent than Landsat 5 TM but since May 2003, one of its correctors (Scan Line Corrector) doesn't work anymore.

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, Lerebours Pigeonnière and Menager, 2001) than in the Sudanese area (6 months). This season (from May-June to September-October) is the period of cultivation. This 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 to remove any ambiguity between cultivated lands and other land use categories. J. L. Devineau and G. Serpantié (1991), who also intended to map the Burkinabe 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, 1991, translated) but to identify the main land use categories. Thus, two images were acquired for each studied areas (Table 1), in order to draw up an inventory of current landscapes.

**Table 1.** Satellite images chosen for each studied areas, dates and sensors

Studied areas	Dates		Sensor
Barani	June 24, 2009	October 7, 2009	Landsat 5 TM
Sampieri	June 7, 2013	October 13, 2013	Landsat 8 OLI/TIRS
Bandougou	June 3, 2013	October 25, 2013	Landsat 8 OLI/TIRS

Chosen and acquired, the images should then be processed, according to a defined method.

## 2.2 Method

Before specifying the method adopted for this research (Fig. 1), it should be noticed that the processing was carried out in two phases and the method underwent a few changes, a few adaptations – the used software differed, Envi for the first phase, Idrisi for the second one.

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 rely on two indices, whose choice was strengthened by pre-existing research, those of J. L. Devineau and G. Serpantié (1991):

- vegetation: like these authors in their study, we used the NDVI (Normalized Difference Vegetation Index) for the first studied village, Barani. The results appeared satisfactory, according to our knowledge of the reality of the ground; but it worked only for this area, not for Sampieri, as we will see later. NDVI is the most commonly used vegetation index but it's not necessarily the most adapted to the studied area (San Emeterio, Lacaze and Mering, 2012), especially because it doesn't compensate for the soil effects. This compensation allows isolating more the signal produced by the only vegetation (Caloz and Collet, 2001). It is particularly important in semi-arid areas, where the vegetation cover is

low; according to the soil types, NDVI can change (Huete and Tucker, 1991). Thus, for the two other studied areas, NDVI was replaced by TSAVI (Transformed Soil Adjusted Vegetation Index); both were tested for Sampieri images and TSAVI offered the highest discrimination between savannah and cultivated lands, at least for the local window.

- brightness: this index was also used by J. L. Devineau and G. Serpantié (1991). Whereas vegetation index aims to stand out the vegetation, the brightness index aims to stand out the bare lands.

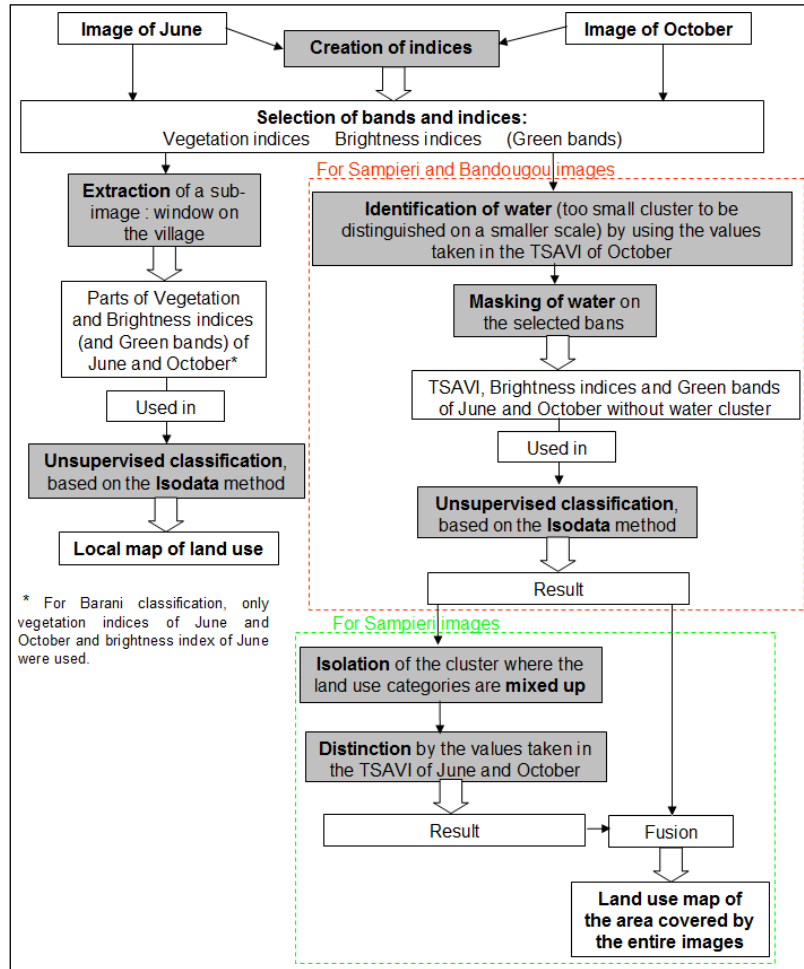


Fig. 1. Summary of the method

Because of the possibilities offered by Idrisi software in the chosen classification (see below) – to process until 7 bands –, another band was considered for Sampieri and Bandougou images: 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 (Table 1) – were processed within the framework of an automatic classification, except for Barani; for the latter, because of the software used – Envi –, we only based the classification on three bands, NDVI of June and October and brightness index of June.

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 (1965). 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 a 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.

### 3 Results

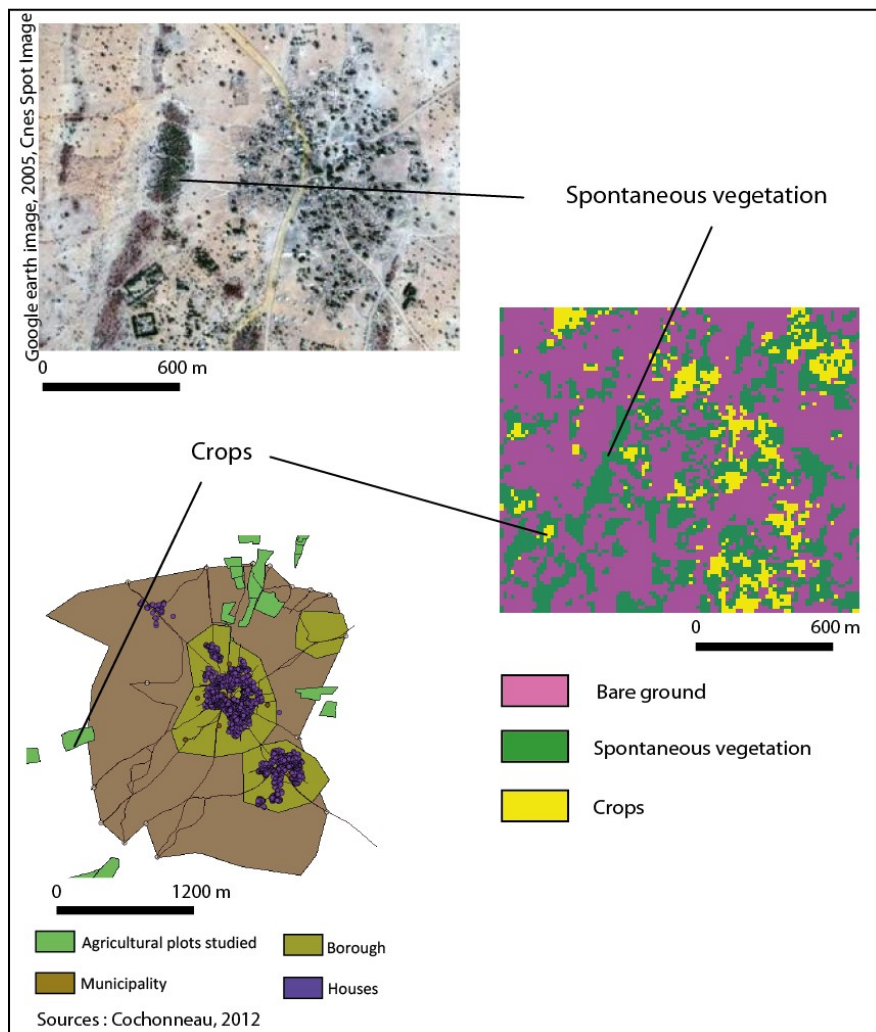
Due to some differences, the results are discussed separately according to the studied areas, in accordance with the evolution of the research.

### 3.1 Barani

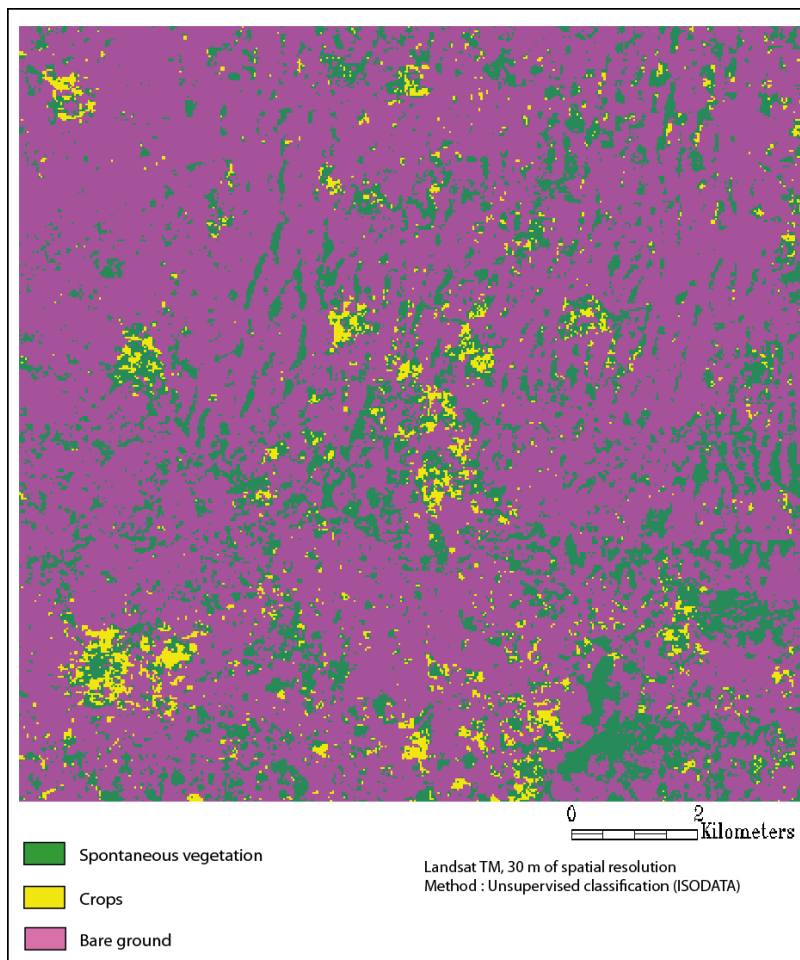
For the three studied areas, the more relevant classification included a number of clusters higher than the number of clusters we desired. In the case of Barani images, this classification had five clusters; these ones were identified, associated with the matching land use categories and, for some, joined together to finally obtain three clusters, the three main land use categories. The association between these clusters and these categories was based on the study of the spectral signatures of these clusters and of color composites but also on the knowledge of the reality on the ground, with a specificity for Barani images. The ground survey was carried out before the beginning of images processing and with a different aim, to know the spatial organization of some facts in connection with agricultural practices in the village; the satellite images should allow a later generalization, considering all main land use categories at a smaller scale. This ground survey had to be completed by another source, Google Earth image, which revealed the localization of spontaneous vegetation. This external and complementary information allowed validating the classification (Fig.2). This one could be considered as a reliable and relevant map according to the aim of the research, revealing the land use in Barani in 2009 (Fig. 3). The result being satisfactory, the processing stopped here.

### Discussion

At this stage of the research, Barani was the better known studied area and that's why it was chosen to build the method of images processing and to check its efficiency. This study showed that the Landsat images were well adapted to the characterization of landscapes in dry Africa. Unlike many authors, who systematically cross these images with those taken by other sensors – SPOT for example – (Viet Bui and Goïta, 2007; Nicolas *et al.*, 2002; Eric, 1988), we demonstrated the sufficiency of a simple and reproducible method using only freely available images, Landsat; the only constraint is the crossing of two images taken at different times of the plant cycle. Thus the same method was applied to Sampieri images, in the second stage of the research, which revealed that some adaptations were necessary but these didn't compromise the method and its first results.



**Fig. 2.** Validation of the kept classification by confrontation with the SIG (ground survey) and Google Earth image (from Yao, 2013)



**Fig. 3.** Land use map, Barani, 2009 (from Yao, 2013)

### 3.2 Sampieri

The study on Sampieri, like on Orodara, corresponds to the second stage of the research. The purpose was to be sure that the method is easily reproducible, without any changes or with few adaptations. For these two studied areas, the ground survey was carried out in October 2013, with the only aim to validate the classifications obtained by the processing of the satellite images; it appeared as a better solution to acquire images of 2013, the year of the ground survey, and to take them from Landsat 8 OLI/TIRS, the only ones available, instead of those from Landsat 5 TM, considered for the first stage of the research, to improve the value and the relevance of the validation.

Like for Barani images, several unsupervised classifications, based on NDVI of June and October and on brightness index of June, were tested, with a various number of clusters desired. But none of these classifications gave relevant results, especially according to ground control points. Some clusters couldn't be associated to only one land use category; the main problem was the mixing-up between spontaneous vegetation (savannah) and cultivated land: the two land use categories, for some parts, were always included in the same cluster(s). Thus we tested other classifications, based on NDVI, brightness indices and green bands of the two images – of June and October –, but the results were still disappointing, especially because of this mixing-up. The solution had to be searched in the possibilities of the different kinds of vegetations discrimination which had to be increased. This could be obtained by another vegetation index, TSAVI. New classifications were tested, replacing only NDVI by TSAVI, and we finally found a relevant and reliable one, validated by all the ground control points. But this concerned only a window at the village scale, where the ground survey was carried out (Fig. 4).

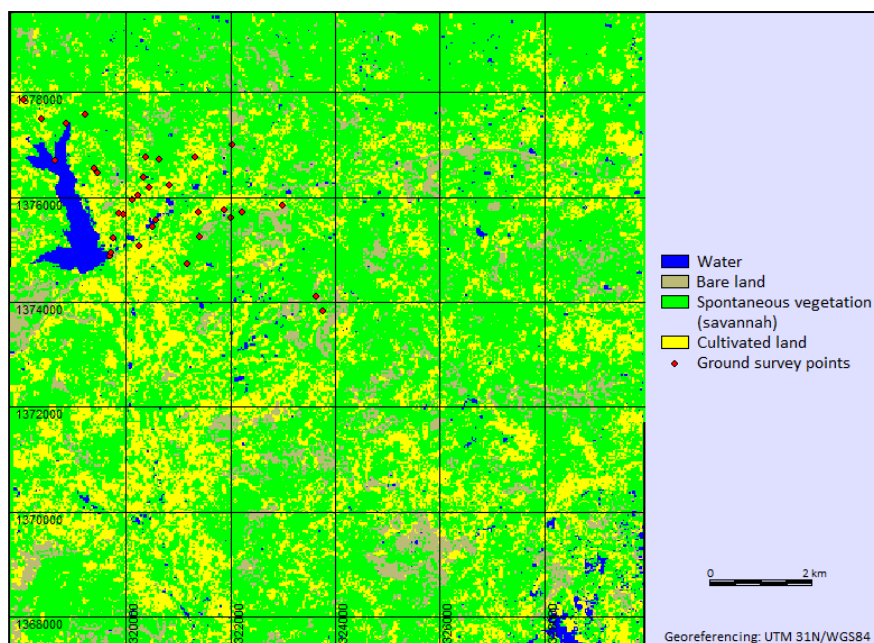
After having identified and masked “water” cluster<sup>1</sup>, too small to be distinguished on a smaller scale by unsupervised classification, the same processing was applied to the entire image but it ended up in a quite different result, disappointing at a village scale (Fig. 5). It can be explained by the fact that the entire images include landscape units different from those included in the only local window. Thus, to solve this problem, we tried to change the number of clusters desired but it was a failure; we had then to look for a new method. We had to go back to the upstream of the

<sup>1</sup> “Water” cluster was identified by using the values taken by this object in the TSAVI of October.

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 of 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. 6 and 7) is a compromise between the land use in the village 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 were classified as savannah on the figure 4<sup>2</sup>. These lands, which concern a large area at the scale of the images, are not really bare but more exactly covered by a spontaneous vegetation, more scattered than on the "land covered by a scattered spontaneous vegetation".

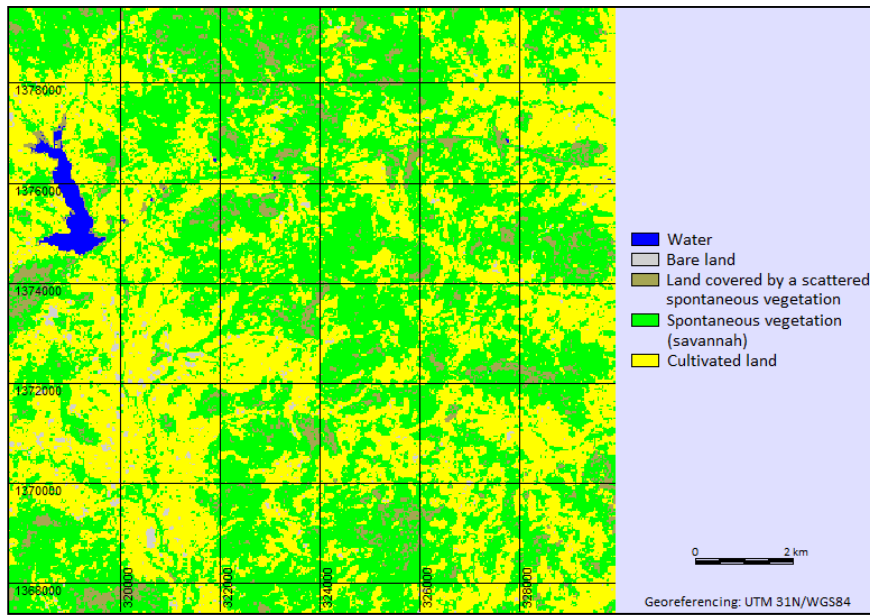
## Discussion

Because the result has to be 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 the limits, especially when different landscape units are included on the smaller scale. A 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 was 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. Above all, this work shows the difficulties to generalize the knowledge of land use basing on satellite images and ground survey on a local scale, whereas the advantage of the satellite images is to have a knowledge of the landscapes on a smaller scale without surveying the entire area on the ground. This study also demonstrates the difficulties to find an easy reproducible method of images processing, even in similar climatic areas, where the vegetation is more or less the same; the method is not compromised but needs some adaptations. Is it also the case for the other studied area, Bandougou, located in another climatic area?

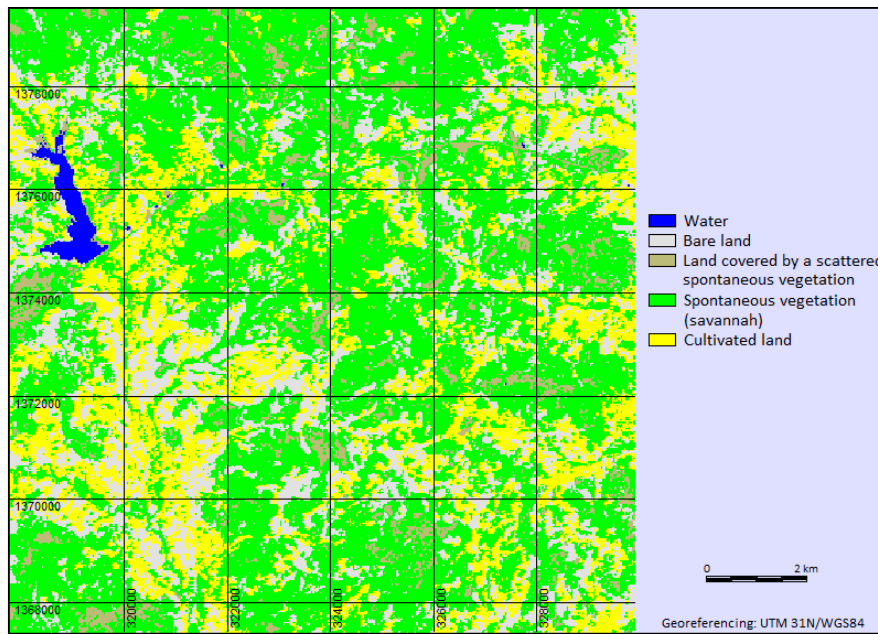


**Fig. 4.** Land use map, Sampieri, 2013 – Classification obtained by processing on a window of the images, on a local scale

<sup>2</sup> The same problem appears for the classification obtained by generalizing the processing used for the window to the entire images. By comparing with the figure 4, on the figure 5, the land covered by a scattered spontaneous vegetation could be classified as bare land but it can't according to the reality of this cluster on the entire images. For the same reason, the cluster "bare land" is thus classified, even if the concerned areas are classified as savannah on the figure 4.



**Fig. 5.** Land use map, Sampieri, 2013 – Classification obtained by generalizing the processing used for the window (fig. 3) to the entire images, extract (window on Sampieri)



**Fig. 6.** Land use map, Sampieri, 2013 – Classification obtained by adapting the processing to the entire images, extract (window on Sampieri)



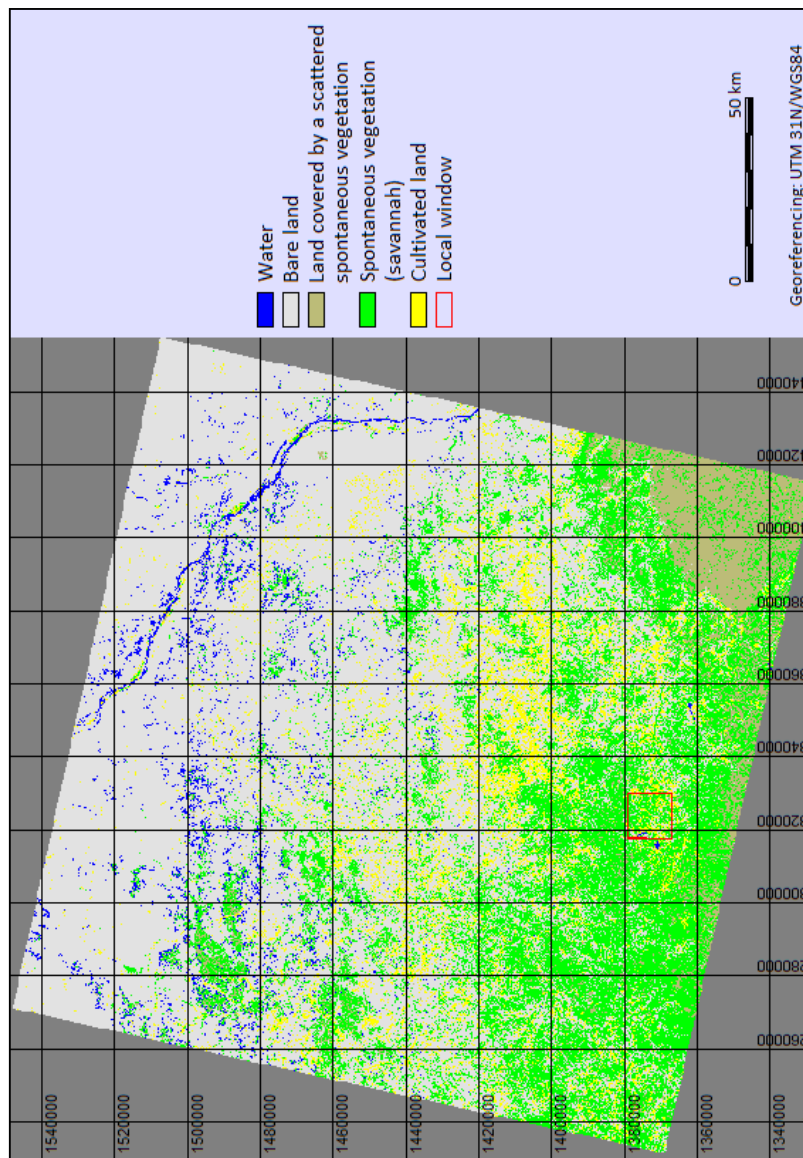
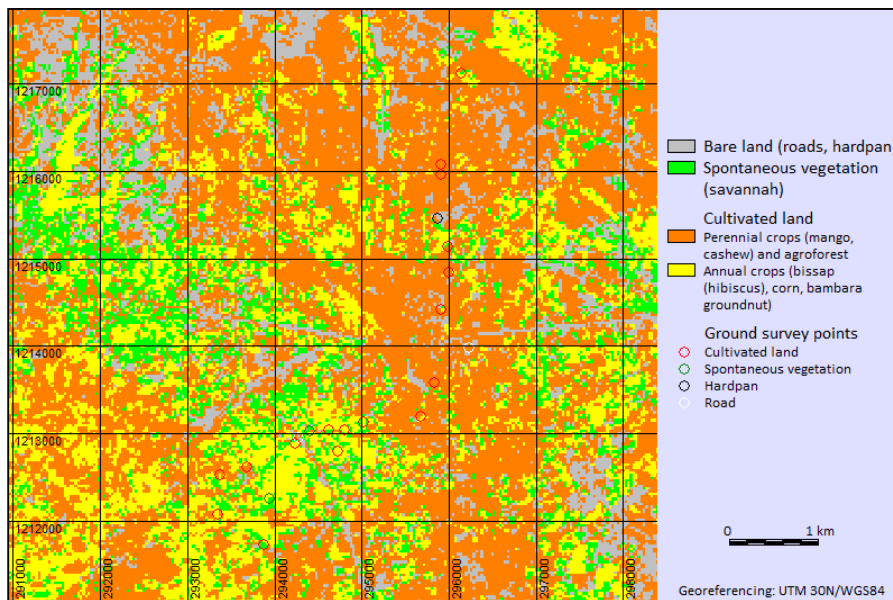


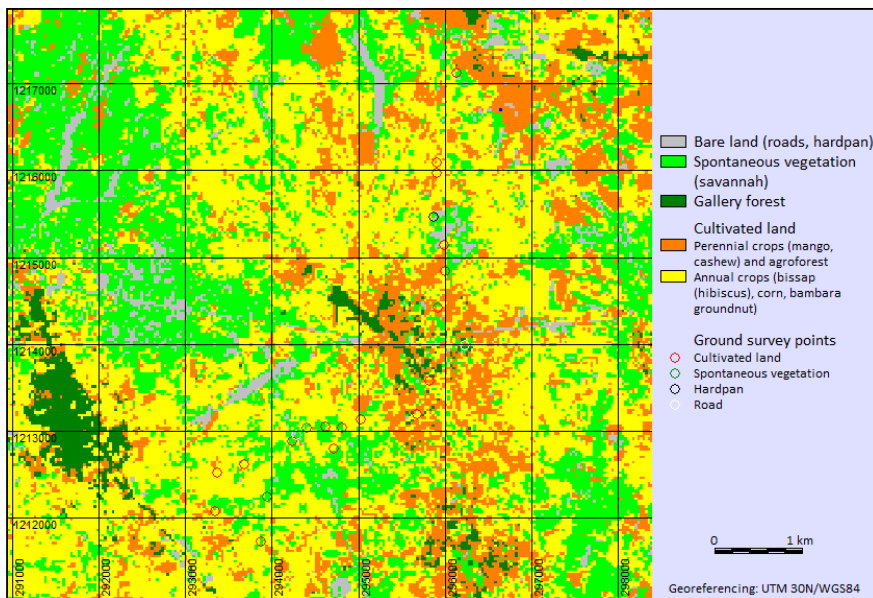
Fig. 7. Land use map, Sampieri, 2013 – Classification obtained by adapting the processing to the entire images

### 3.3 Bandougou

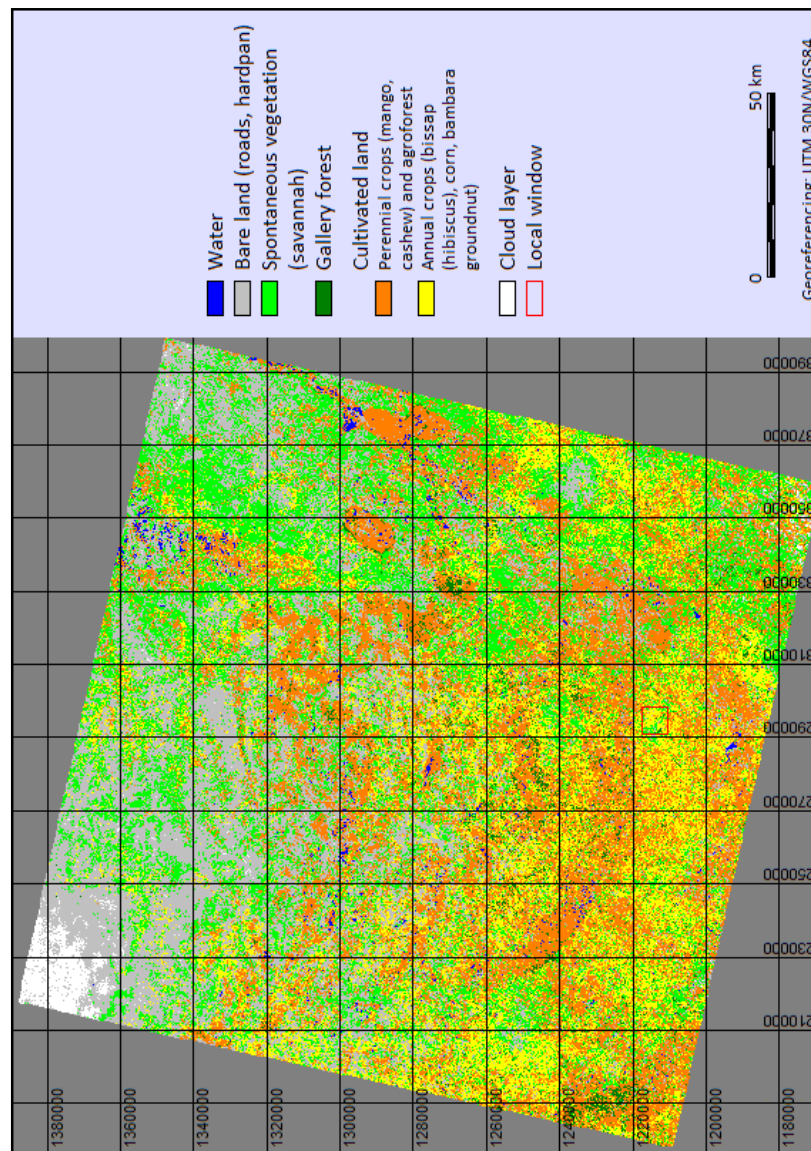
The method defined for the processing of Sampieri images showed limits, because the results depended on the considered area. However, this method needing only adaptation appeared to be the best one, of those we tested. That's why the same processing – using TSAVI, brightness indices and green bands of the June and October images in an unsupervised classification – was applied to the images of Bandougou. The aim was also to know if the same problem appears, if the results also differ according to the considered area, between the village area and the entire images, to know if the generalization based on satellite images is reliable or if, for all studied areas, it needs adaptations.



**Fig. 8.** Land use map, Bandougou, 2013 – Classification obtained by processing on a window of the images, on a local scale



**Fig. 9.** Land use map, Bandougou, 2013 – Classification obtained by generalizing the processing used for the window (fig. 7) to the entire images, extract (window on Bandougou)



**Fig. 10.** Land use map, Bandougou, 2013 – Classification obtained by generalizing the processing used for the window (fig. 7) to the entire images

A difference should be noticed between Sampieri and Bandougou: a new land use category appears in this area; the cultivated land had to be separated in annual crops and perennial crops. Even if it was defined in the absence of these crops, because it had first been defined to learn about Sampieri landscapes, the method allowed to obtain a quite satisfactory land use map on a village scale, validated by the ground survey (Fig. 8). Thus the reproducibility of the method was demonstrated on a local scale; could we come to the same conclusion on a smaller scale? According to the result obtained for Sampieri, the answer was *a priori* negative – or, at least, the method needed adaptations – and this revealed true; but, for the two studied areas, we came to another kind of conclusion, not in terms of land use knowledge but in terms of generalization possibilities, using image satellites. Indeed, the processing used for the local window (Fig. 8) was applied to the entire images, changing only the number of clusters desired to obtain the best result but this one (Fig. 9 and 10) is different. In Bandougou (Fig. 9), the perennial crops are less vast, quickly replaced by annual crops, and a new land use category had to be created: gallery forests<sup>3</sup>.

## Discussion

Thus, we came to the same conclusion than for Sampieri; the method, satisfactory for a local window, needs adaptations

<sup>3</sup> On the figure 9, some gallery forests appear inside Bandougou because of mixing-up between these forests and the perennial crops.

when it's applied to the entire images, to obtain the same result, closer to the reality of the land use on the ground.

## 4 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, where climate and vegetation are quite similar to those of the studied areas; it allows to know 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, freely available, taken by Landsat sensors. It uses TSAVI, the 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 allow to generalize the knowledge on landscapes, thus disappears.

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