106 Base Cartography for Land and Water Management in Sub-Saharan Africa

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Abstract

Base cartography at proper scale for land and water management is rarely available in Least Developed Countries (LDCs). Despite the massive presence of international cooperation programs and projects carried out in various LDCs, a low budget is usually allocated for base data retrieval, which could be helpful for a wide range of on-site actions. A food security project in Burkina Faso, aiming at increasing the agricultural production through supporting farmers' unions, is herein used as a case study. In this framework update cartography at large scale was needed in order to plan Soil and Water Conservation (SWC) interventions at catchment scale. However, best existing official maps, dated 1984, were at 1:50.000 scale, which is a highly coarse detail level to intervene at large scales. Data at higher resolution were available at the national cartographic institute, obtained from aerial surveys performed in the last decade. Aerial imagery allowed then to perform feature extraction over the areas of interest, thus updating the existing cartography and making it suitable for land and water management planning.

Keywords

Feature extraction • Change detection • Erosion • Land and water management • Burkina Faso

106.1 Introduction

Burkina Faso is strongly affected by the effects of climate change such as the reduction in the number of rainy days and the increase in the number of extreme precipitation events (Hamed et al. 2002). Those conditions, together with the intensive human exploitation, are causing soil erosion, the progressive disappearance of the vegetation and the extension of soil surface crusting. Several international projects and national programs have been trying to cope with these issues since the '80.

Although various national and interregional programs, together with national cartographic institutes, have often provided cartographic outputs at small/medium scales, the gap in the large scale map availability is still a matter of concern for policy makers and land management planners (Williamson 1983). Land and water management planning would certainly require appropriate base cartography at a scale directly related to the size of the intervention (Vezza et al. 2009; Wellens et al. 2008).

In the Sub-Saharan region, recent law regulations concerning water management require watershed-based interventions. In Burkina Faso, where the study area is located, the current law foresees the implementation of Integrated Water Resource Management (IWRM) plans, which have to

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be developed for each sub national catchment (MAHRH 2003). The application of this national strategy is realized with a bottom-up approach, therefore it starts with the small sub-catchments since only the local acquisition of awareness and good practices could guarantee the successfulness of an IWRM plan. A watershed management plan normally requires: (i) the assessment of water uses and users; (ii) the understanding of former and ongoing water and soil degradation processes; (iii) the assessment of ongoing and foreseen water conflicts; (iv) the proposal and implementation of measures aiming at better managing the water resource and at controlling, and eventually decreasing, erosion processes and reservoir siltation (Petit and Baron 2009).

A food security project located in the Boulbi catchment (central Burkina Faso), with the purpose of increasing the agricultural production through supporting farmers' unions, is herein used as a case study. The goal of the present work is the update of the existing cartography for its use in land and water management planning, including hydrological modeling and stakeholders capacity building in the use of a customized cartographic representation of owned land. In particular, an updated cartography at large scale (i.e. 1:10.000) was needed in order to plan and design Soil and Water Conservation (SWC) measures at the catchment scale. These interventions are part of a comprehensive catchment management plan which has to be implemented in the near future. The existent official map of the study area, dated 1984, is at 1:50.000 scale and does not constitute the appropriate cartographic support to intervene at the suitable scale for local land-use planning. However, data at higher resolution, available at the national cartographic institute (Institut Géographique du Burkina Faso, IGB), were obtained through aerial surveys performed in the last decades. The present study investigates the suitability of locally produced remote sensed data to perform feature extraction over the area of interest.

106.2 Data and Methods

The collaboration with an international cooperation project offered to the authors the occasion to deal with the above mentioned issues. The project, funded by the Bureau de la Coopération Suisse au Burkina Faso, is developed in cooperation with a farmer cooperative that exploits the water impounded in a reservoir of about 1 million cubic meters. The Boulbi dam, built in 1960, supplies water to a downstream irrigation system covering around 70 ha of rice fields. The catchment is highly urbanized in the northern part, where it borders the capital Ouagadougou, while sparse rural settlements are present in the rest of the area (CISV 2011).

Aerial frames over the area of interest were available at the IGB. A total of 8 frames and 6 frames were respectively acquired in 2012 and 1996. The characteristics of the frames are resumed in Table 106.1.

Moreover, onsite topographic surveys were performed in 2011 and 2012 along main rivers and streams and a field campaign was conducted in the same years for locating the erosion sites through a GPS survey.

The available material was suitable for obtaining two different products: a cartographic output containing a change detection analysis and a Digital Elevation Model (DEM) over the area of interest.

On the one hand, only aerial frames dated 2012 were suitable for DEM extraction, due to the lack of stable and detectable points in 1996 frames. Nevertheless, available points obtained through the field campaign, onsite topographic surveys and 1:50.000 cartography were not precise enough in order to obtain a proper DEM; a field campaign has therefore been requested in order to detect 8 plano-altimetric points, with positioning accuracy better than 10 cm, needed to perform the aerotriangulation and thus derive the DEM. The latter will be performed in the near future with Intergraph-ERDAS LPS photogrammetry software, once received the ancillary data essential for the DEM provision.

On the other hand, a subset of the frames was used for the production of a cartographic output; 1 out of 2 overlapping frames was discarded for this task. The most updated aerial frames were processed at first, due to the higher number of detectable points (e.g. buildings, paved streets, etc.) to be used for the georeferencing procedure; the oldest frames were indeed coregistered on the obtained results. No Ground Control Points (GCP) obtained by in situ surveys were available, therefore the following methodology was used: firstly, a central frame was registered by means of points detected on Google Earth high resolution images, secondly the other frames were linked to the first one. This procedure was considered acceptable since the main interest was in the thematic content rather than in the achievable planimetric accuracies. For the registration of the first frame 16 points were used, while a number of points varying between 15 and 20 was used in the other cases. The coregistration of the 1996 frames was more difficult due to the lack of stable

Table 106.1 Aerial frames technical details

Year	Number of frames	Frame scale	Bands	Forward overlap	Lateral overlap
1996	6	1:25.000	1 (B/W)	60 %	20 %
2012	8	1:20.000			

points; most of the buildings were not present at that time, neither was the solely paved street, and the hydrological network was subject to morphological changes in the considered time laps: therefore a greater number of points (from 15 to 30) was used for the registration of each frame.

The extraction of the features of interest from 2012 frames (i.e. hydrological network, built-up areas, point of interests, eroded zones) was obtained through photo-interpretation, performed with a GIS software. The process was assisted by the use of support materials such as the 1:50.000 national cartographic base and the results of onsite topographic surveys whereas the GPS survey was used to preliminary identify a few eroded sites to be used as test sites.

106.3 Results

The following features were extracted: (i) hydrology, (ii) transportation, (iii) land use, (iv) erosion affected areas. A model of the extracted features is provided in Fig. 106.1.

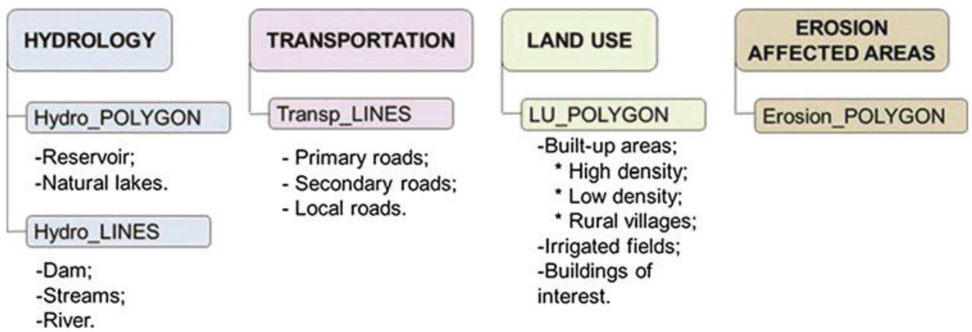

Fig. 106.1 Model of the extracted features

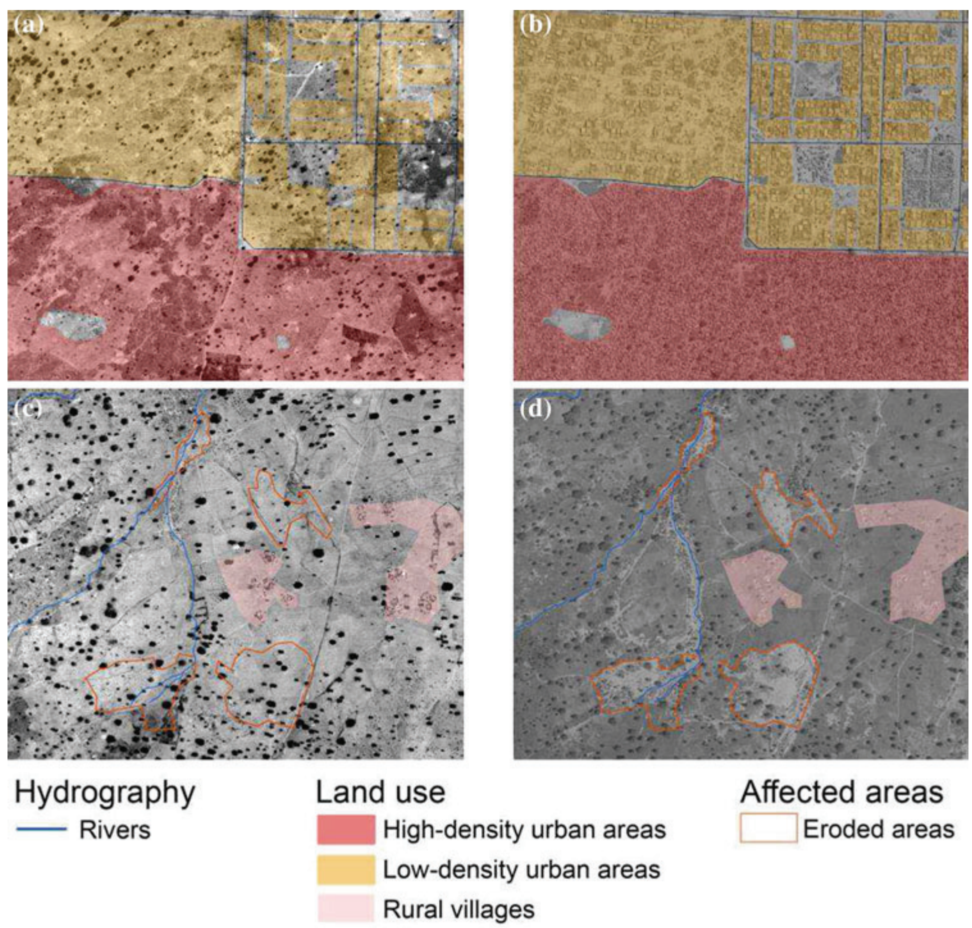

Fig. 106.2 Examples of change detection analysis (1996 on the *left*, 2012 on the *right*): built-up areas (**a** and **b**) and erosion sites (**c** and **d**)

The delineation of eroded zones was performed through the comparison between the old and the recent frames, after co-registration. A preliminary recognition of the eroded sites was carried out by means of GPS points acquired during the field campaign of November 2012 (Angelucetti and Coviello 2012). A surface of more than 200.000 m^2 of eroded zones was detected. A change detection was then performed on the extracted features through a fully visual processing performed in a desktop GIS environment. The 15 year time laps allowed the identification of visible changes on every feature. The greatest changes were identified at the built-up area level. Around 7 km^2 of new built-up area were identified all over the catchment, of which the vast majority is part of Ouagadougou. A strong urbanization phenomenon is detectable in the northern part of the catchment; two patterns of newly built constructions are distinguished: a parceled part that likely follows the master plan of the capital Ouagadougou, and a spontaneous one, which represents the majority, constituted of small houses built without any apparent scheme. Nevertheless the hydrological network is modified not only in the northern part of the catchment due to the ongoing urbanization process, but also all over the rest of the catchment, probably due to the high instability of the ephemeral channels (Castillo et al. 2007). Roads, both paved and unpaved, have also evidently changed over the considered period. An example of change detection result is reported in Fig. 106.2.

106.4 Conclusions

The proposed methodology can be seen as a starting point for the production of cartography for land and water management in a deprived environment. The update of national cartography surely remains an issue, however the need for supporting the ongoing local projects is a current need. The use of aerial photogrammetry is a feasible way to extract basic information at a catchment scale (Wellens et al. 2008), and provide a viable solution since open source data are not suitable for data retrieval at the desired detail scale (i.e. 1:10.000).

The extracted features can furnish a clearer view on the overall land use. For instance, it can be stated that the urbanization process is brushing the reservoir and that the northern tributary is almost completely surrounded by built-up areas. The localization of the eroded sites and of the surrounding villages could be helpful in the planning of SWC works construction; in fact a rough evaluation of works dimensions and position, the accessibility of each eroded site and the estimate of the potential manpower that would participate in the construction could also be inferred.

More information can also be retrieved from aerial imagery. In particular, the average slope of the streams and rivers can be inferred from a Digital Elevation Model of the catchment. The latter will be obtained by processing the whole frames stack. This topographic information is needed in order to design the SWC works and to measure a posteriori their effectiveness on the bedslope reduction (Grimaldi et al. 2013). Further developments would thus concern the DEM extraction on the basis of 2012 frames; moreover if the GCPs to be acquired will be recognizable also on 1996 frames, a second DEM will be extracted in order to analyze soil erosion occurred in the time interval.

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