Land Use Assessment in the Drylands of Sudan Using Historical and Recent High Resolution Satellite Data

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Abstract – The large number of new high resolution satellites provides a great potential for studies of land use and land cover change especially when combined with historical data such as aerial photographs. An alternative to aerial photographs are the panchromatic declassified satellite images called Corona. Since 1995, these images are available from 1960 to 1972 with a resolution of less than two metres. This study has used images from Corona and IKONOS in order to understand land use changes in parts of the African drylands from 1969 to 2002. The region is characterised as highly vulnerable drylands where a large number of people live and it is important to understand the main drivers of change in the region. The study focuses on one village in Sudan and investigates changes in area of cropland and fallow as well as the population of the village.

Keywords: Land use change, Corona, Ikonos, object-oriented classification, drylands, Sudan

1. INTRODUCTION

Remote sensing can be a valuable tool in land use and land cover assessments in the African drylands. For historical studies, aerial photographs are essential since the most common satellite sensors do not provide images prior to 1972 when the first Landsat vehicle was launched (McDonald, 1995). Thus, in 1995 satellite images from the 1960s became available when the Corona images were declassified. The images were important in intelligence collection and the formation of national security policies until its termination in 1972 (McDonald, 1995). The images are panchromatic and some have a resolution of less than two meters and can therefore serve as an alternative to aerial photography. Corona images have been used in land cover classifications in West Africa and the resolution has been satisfactory to count individual trees and shrubs in open field conditions (Tappan et al., 2000) as well as to distinguish forested and non-forested patches (Wardell et al., 2003). Today several high resolution satellites exist. One of them is Ikonos, which has been useful in mapping upland vegetation in the U.K. (Mehner et al., 2004) and to identify individual trees in tropical forests (Read et al., 2003). No studies have been found by the author that has employed Ikonos images in drylands.

It is time-consuming to visually interpret large areas of high resolution images. An alternative is object-oriented classification that recently has begun to receive widespread recognition within land cover classification and landscape ecological analysis (Devereux et al., 2004). Image segmentation, which is part of the object-oriented classification, is based on the fact that the human eye most often generalizes images into homogenous areas (Laliberte et al., 2004). According to Devereux et al (2004), results from object-oriented classification are likely to be more consistent and detailed in comparison with those from visual interpretation.

A challenge for remote sensing is to validate the analysis with ground data. This study combines remote sensing data, including training areas, with data from interviews in the same area. The interviews are a way of “socializing the pixels” as expressed in Liverman et al. (1998).

The aim of this study was to carry out a detailed study of one village and to perform a land use classification covering more than three decades with the focus on area of cropland and fallow as well as the population of the village.

2. STUDY AREA

The study area is located in Northern Kordofan in central Sudan. The village studied in detail is called Sararya Makawi (13.93ºN, 30.53ºE). The area is characterised by small topographic differences and sandy soils. During the period 1960-1999, the area received an average rainfall of 227 mm according to the Sudan Meteorological Department. Not only is the precipitation low, but also varied. The households in the region depend on rainfed agriculture and practise a low level of mechanisation.

3. DATA AND METHODS

2.1 Satellite images

2.1.1 Data and image pre-processing

2.1.1.1 Corona

Corona did not provide global coverage since the main targets were areas of intelligence interest. There were two dates available for the study area: 17 November 1968 and 10 February 1969. The 1969 images were chosen because of the cloudiness in the 1968 images. The images were acquired with the KH-4b sensor with the highest resolution of 1.83 m. The images are panchromatic (USGS: EROS Data Center, 2005).

The Corona images were acquired with film-return systems (Leachtenauer et al., 1998) and by the time of order no digital format was available. The images were ordered as positive film and scanned with a resolution of 3600 dpi. The images have panoramic distortions. The areas studied were all located in the central parts of the images where the geometrical distortions were smaller. No radiometric correction was carried out as no radiometric data is available (Tappan et al., 2000).

The images were geometrically corrected to Ikonos with the location of villages.

2.1.1.2 Ikonos
Ikonos was launched in September, 1999. The spatial resolution is 1 meter in the panchromatic band and 4 meter in the multi-spectral bands (Dial et al., 2003). One image, acquired on the 8th September 2002, was available for the study area. No radiometric correction was carried out since the change detection study does not rely on comparing absolute brightness of different images (Laliberte et al., 2004). The Ikonos image was corrected geometrically with ground control points collected in the area.

Training areas were collected in February 2004. A total of 31 areas were classified into cropland or fallow. Since no Ikonos data was available for the same time period*, reference data was only collected from fields where the land use had not changed since 2002. Only the panchromatic band was used.

2.1.2 Image processing
The Ikonos and Corona images were classified with an object-oriented approach, which is based on segments instead of pixels. Segmentation is described as " …the process of partitioning a digital image into a set of discrete, non-overlapping regions on the basis of internal homogeneity criteria" (Devereux et al., 2004). Object-oriented classifications are based on the information contained in relationships between adjacent pixels such as texture and shape which are not always visible in single pixels. The classification was performed with the software eCognition Professional 4.0 (Definiens Imaging).

2.2 Interviews
Structured interviews were carried out in 2002 with all households in Sararya Makawi on issues related to land use and livelihood (Warren, 2003). Semi-structured group interviews were carried out in 2004 with the aim to understand changes in population and land use since the end of the 1960s.

4. RESULTS AND DISCUSSION

4.1 Analysis of the satellite images
Sararya Makawi is part of a group of three villages of which it is located furthest to the north. The land of all households, referred to as total village area, is located to the north of the village. The village border has been constant since the village settled and was measured in the field with a GPS. The total village area was 16 km^2.

The proportion of cropland in Sararya Makawi in 1969 was 19% and increased with 7% to 26% in 2002 as seen in Fig. 1a and 1b. The rest of the land was classified as fallow land or settlement. In 1969, the cropland was mostly concentrated to the southern part of the total village area. In 2002 the cropland was more scattered and was also present in the northern part of the total village area.

* Ikonos can also be pre-ordered for a specific area of interest which is more costly.

(a)

(b)

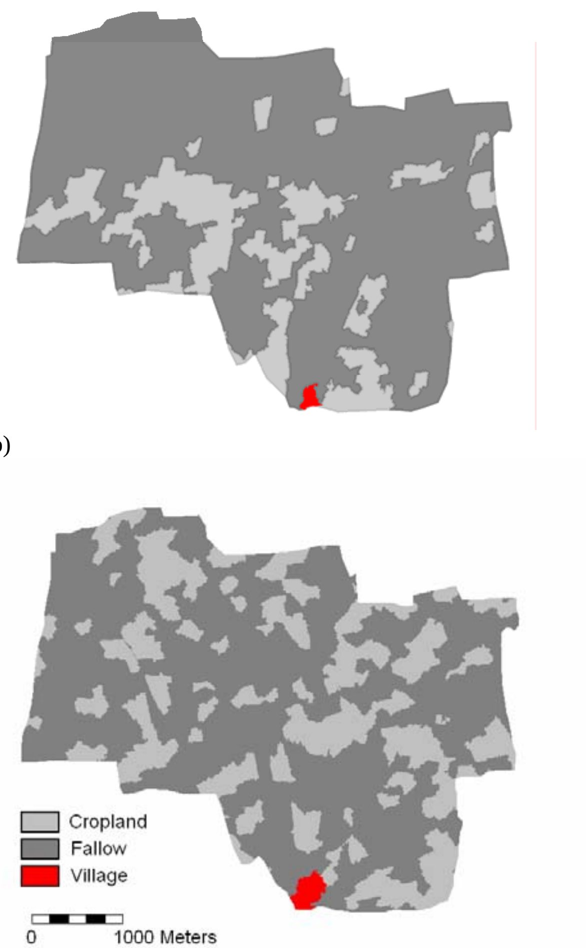

Figure 1. (a) Land use classification based on Corona images from February 10, 1969 and (b) Ikonos image from September 8, 2002. The total area was 16 km^2 and the location of the Sararya Makawi village is 13.93ºN, 30.53ºE.

4.2 Analysis of the interview responses
The average proportion of cropland was 29% (range: 25-32%) according to the interviews covering the years of 1997-2000 (Warren, 2003). No value was available for 2002, but it is assumed to be of the same order.

The number of households of Sararya Makawi in 1969 was 7 and the population 48. In 2002 the number of households increased to 46 and the total population to 314. The population density in 2002 was about 20 persons/km^2, which can be considered as a low population density since other areas in the drylands can have densities of 300-500 persons/km^2 (Mortimore, 1998).

4.3 Uncertainties and future challenges
Uncertainties were introduced in this study by the lack of training areas for the 1969 image. Further uncertainties resulted from the fact that the two images were acquired

during different seasons of the year. The study could be improved by using images from additional years to avoid the snap-shot situation. A challenge for further studies is to upscale the high resolution images in order to cover larger areas as the high resolution images still are very costly.

5. CONCLUSIONS

The population increase during the period 1969-2002 was much higher than the increase in cropland area. The area of cropland per household decreased from 0.4 km^2 to 0.1 km^2. This decrease can have several explanations such as intensification of agriculture and increase in off-farm incomes. The debate on intensification is often referred to in the literature of African land use. Although in Sararya Makawi, the ways to intensify agriculture have been few. More probably has the increase in off-farm incomes, observed in the village (Elmqvist et al., Submitted), resulted in a relatively lower importance of agriculture and consequently the cropland area per household has decreased. However the drivers of land use changes are complex.

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