Utilization of high-resolution satellite images to improve the statistics of sweetpotato cultivated area in the District of Kumi in Uganda

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Abstract

Sweet potato (SP) is a staple crop for poor households in rural Africa. Nevertheless, the area under SP and its distribution is difficult to assess due to the existence of very small plots ubiquitously distributed, including the roadsides. Multispectral (XS) and panchromatic (P) SPOT satellite images -registered on May 6 and October 15, 2006, with a resolution of 10 and 5 m, respectively- were used to evaluate the area under SP in the Ugandan Kumi district. The methodology was based on the use of high-resolution SPOT imagery, complemented with field radiometric evaluations using the Handheld ASD Field Spec Spectroradiometer. An unsupervised classification was initially carried out using clustering algorithms for assessing land use variability and plant coverage. Subsequently, a supervised classification was conducted. Spectral patterns recorded in the fields were used to generate a Maximum Likelihood Classifier for assessing the area cultivated with SP, which was further ground-truthed during May and November 2006. The cumulative area under SP for both cropping seasons, gave a total of 44,620 ha. No official statistics were available for 2006; however, the official data for the period 1992 – 2003 ranged from 21,000 to 28,000 ha. Projecting the linear trend from the statistics to 2006 gave a value of less than 30,000 ha which represented only 67 % of the registered area in our study. The results suggest a significant underestimation of the area planted with SP in Kumi, which is probably the case for most countries in Africa.

Keywords: Remote sensing, statistics, sweetpotato, Uganda.

Introduction

Crop statistics information is important for the implementation of research and development projects. Agricultural statistics are utilized for decision-making with regard to the planning of development activities to benefit the populations that occupy a target region. FAO (1999, 2003) points out that in order to plan agricultural research and rural development strategies it is absolutely necessary to have an information system that provides reliable data on the total area cultivated under a specific crop, the size of the production units, the agro-ecological areas where the crops are found, the soil and climate characteristics, the socioeconomic condition of the producers and the cropping schedule, among others.

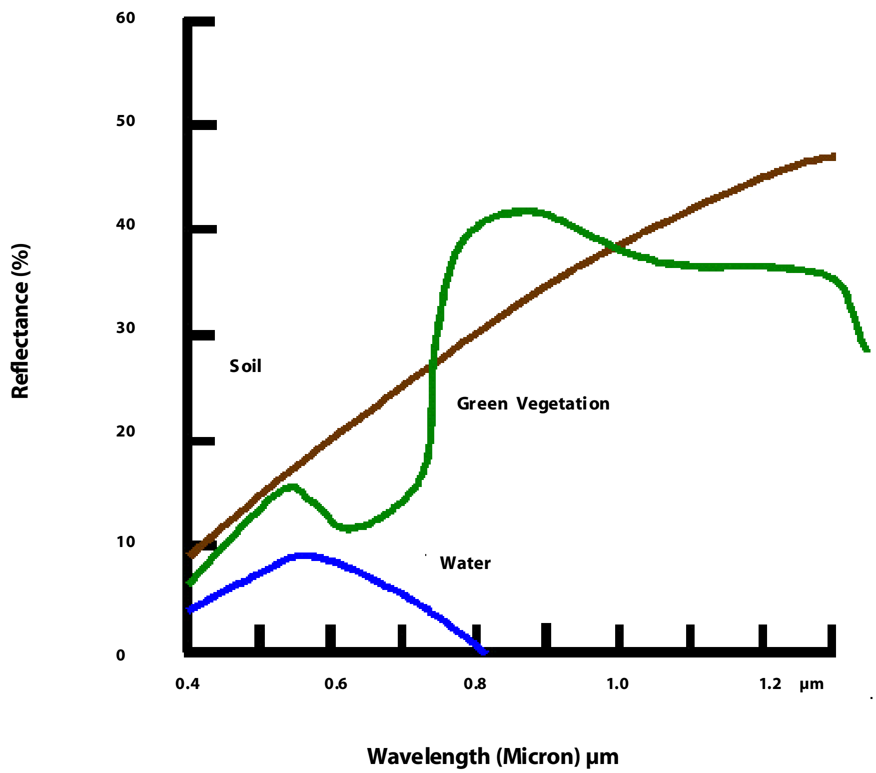
There are reasons to believe that current statistics on SP extensions cultivated in Africa do not bear a relation to the actual cultivated area. This reasonable doubt is based on the fact that crop statistics related to small producers, are obtained through field sampling and survey techniques that have some limitations. It is hypothesized that the accuracy of SP statistics can be improved with the introduction of remotely sensed data. The objective of this research was to quantify the area under sweet potato in the Ugandan Kumi district

Physical basis of the discrimination between crops

When radiant energy strikes on any material an interaction occurs between them. Thus, the crops interact with solar radiation. A fraction of incoming radiation is absorbed by the plant pigments Chlorophyll, Carotenoids, Xanthophylls and others, another fraction is transmitted toward the bottom of the canopy and the soil, and a further fraction is reflected back to space (Colwell *et al.,* 1983).

The property that is utilized to obtain information on the interaction between the radiant energy and the objects on the surface of the earth is the reflectance, which is the ratio of the energy reflected in a given wavelength to the incoming energy (Lillesand and Kiefer, 1994). The vegetation, the soil, and the water bodies have distinct spectral patterns of reflectance, which makes it possible to differentiate them (Figure 1). Furthermore, each plant canopy has distinct spectral patterns or spectral signatures (Jensen, 1996; Richards, 1993) that are utilized to distinguish them from other plant coverage and land uses, making it possible to quantify their respective areas. This differentiation between plant covers is based on the radiometric differentiation of the classes being considered (Lemoine and Kidd, 1998) Sweet potato can be differentiated both in the range of the visible spectrum, where it shows a low reflectance attributed to the pigmentation of the foliage and the total soil coverage, and in the near infrared where the reflectance is very high. This high reflectance of sweet potato fields in the near infrared spectrum is instrumental in distinguishing it from other crops.

To accommodate the diversity of plot sizes, crop species, varieties, clones and cropping systems found in a region, satellite products at an appropriate level of spatial, spectral and time resolutions are needed. These products are used for different purposes in constructing statistics in developed countries (e.g. Allen *et al.*, 2002; Csornai *et al.,* 2006; Fang, 1998; Hanuschak and Delince, 2004; MacDonald and Hall, 1980; and Roller and Colwell, 1986). In developing countries, higher resolution imageries are needed due to field sizes.



Source: http://landsat.usgs.gov/resources/remote_sensing/remote_sensing_applications.php

Figure 1. Spectral patterns of the vegetation, soils and water

Materials and methods

The district of Kumi, located in the northeast of Uganda at latitude 1º 29’15” N and longitude 33º 55’ 58” E, was chosen as a pilot site for the presence of sweet potato cropping fields. This district has an area of 2,848 km^2, a population of 388,015 inhabitants, and a population density of 136.24 inhab./km^2 that is higher than the national average. Most of the population (97.8%) lives in the rural area. Two areas were stratified as a function of annual precipitation. In the dry area there is limited cultivated land, mostly used for drought tolerant crops such as millet and sorghum and some sweet potato. The moist area has much more cultivated land with crops such as sweet potato, peanut, corn, manioc, Chinese beans, and other species

Material and equipment

- Cartographic material
- Multispectral (XS) and panchromatic (P) images from the SPOT satellite. , captured on May 6, 2006 (Figure 4) and on October 15, 2006, respectively.
- Handheld ASD FieldSpec Spectroradiometer
- Magellan Platinum Global Positioning System
- Laptop Dell Inspiron 600 m
- Canon Digital Camera
- Environment for Visualizing Images (ENVI) v. 4.1 Software

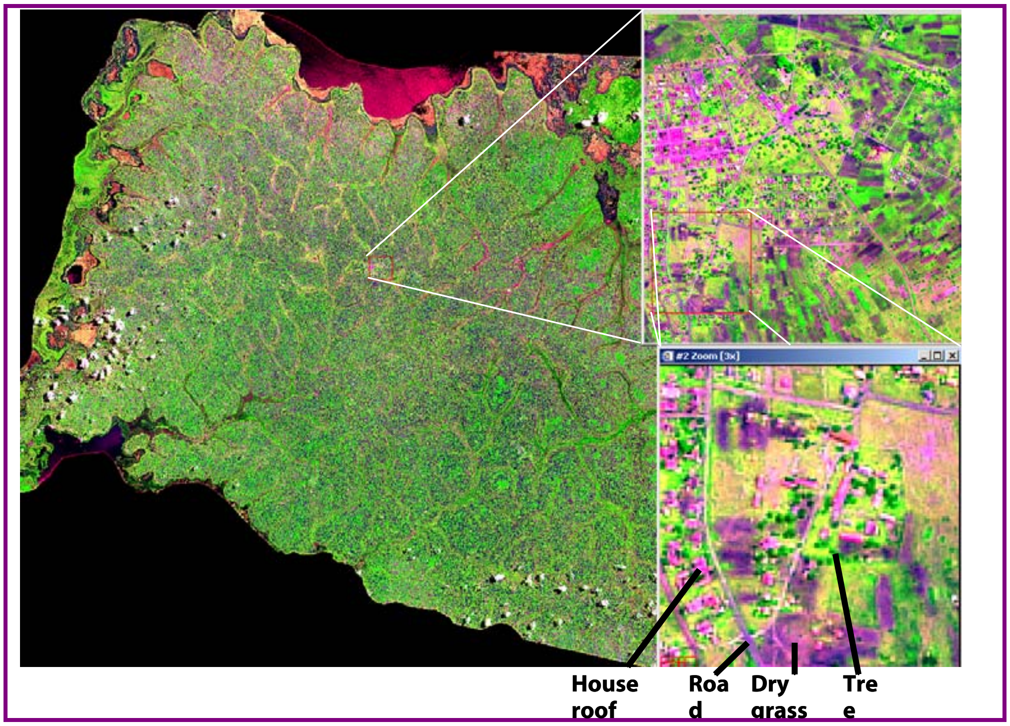
Methodology

Multispectral (XS) and panchromatic (P) SPOT satellite images -registered on May 6 and October 15, 2006, respectively- were used to evaluate the area under SP in the Ugandan Kumi district. (Table 1) (Figure 2). The initial spatial resolution in the multispectral scene was 10 m and the panchromatic band with a 5 m resolution was used for resampling the scene to this resolution. Since the photogrammetric chart for the geometric correction was not available, the requested scenes were corrected with the parameters of navigation of the SPOT 5 satellite.

Table 1. Characteristics of the Sensors, and resolution of the satellite SPOT 5

Sensors	Electromagnetic spectrum	Pixels size	Spectral bands
SPOT 5	Panchromatic B1 : green B2 : red B3 : near-infra-red B4 : short-wave infrared (SWIR)	2.5 m or 5 m 10 m 10 m 10 m 20 m	0.48 – 0.71 μm 0.50 – 0.59 μm 0.61 – 0.68 μm 0.78 – 0.89 μm 1.58 – 1.75 μm

Source: www.spotimage.com



Source: SPOT Image

Figure 2. SPOT image of Kumi

The methodology was based on the use of high-resolution SPOT imagery, complemented with field radiometric evaluations using the Handheld ASD Field Spec Spectroradiometer. An unsupervised classification was initially carried out using clustering algorithms for assessing land use variability and plant coverage. Subsequently, a supervised classification was conducted. Spectral patterns recorded in the fields were used to generate a Maximum Likelihood Classifier for assessing the area cultivated with SP, which was further ground-truthed during May and November, 2006 (Zorogastúa *et al.*, 2007)

Results and discussion

Figure 3 shows the different spectral patterns of the main crops and land uses in Kumi. Sweet potato can be differentiated both in the range of the visible spectrum, where it shows a low reflectance attributed to the pigmentation of the foliage and the total soil coverage, and in the near infrared where the reflectance is very high. This high reflectance of sweet potato fields in the near infrared spectrum has been instrumental in distinguishing it from other crops.

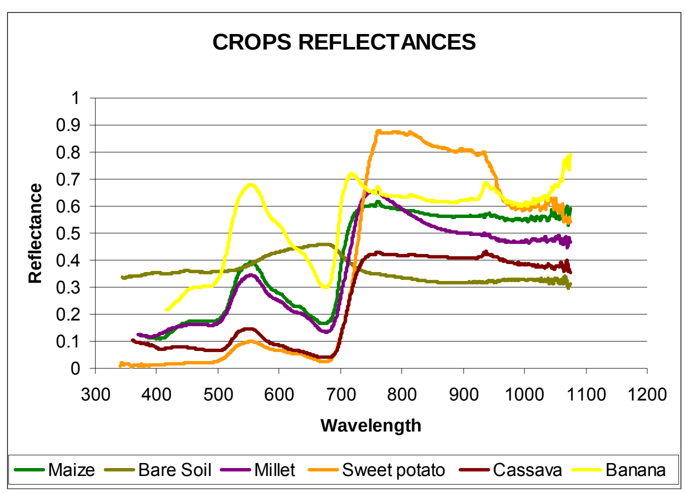
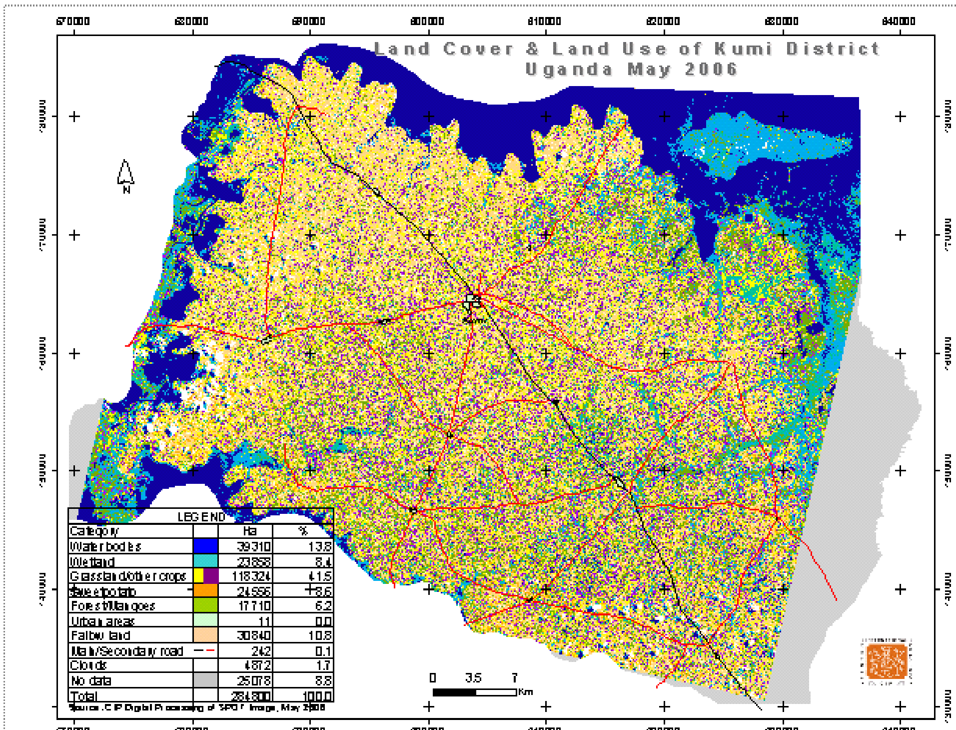


Figure 3. Spectral patterns of the main crops and land uses in Kumi

Figure 4 is the supervised classification carried out with the May 2006 image. It shows that most of the sweet potato fields were located in moist areas while the drier areas were primarily covered by grasses. For ease of reading, the legend of Figure 5 is represented in Table 2. The table shows that sweet potato covered 24,556 ha on the date the satellite image was captured. This area, representing 8.6% of the area of the district, corresponds to the sweet potato crop in the first growing season only. On the other hand, the satellite image captured in October 2006 (Figure 5), processed and ground truthed with the same methods as the other image, shows that sweet potato covered 20,064 ha, or 7% of the area of the district. It appears that this decreased cropping area observed in the second season was due to abnormally delayed rains. Adding up the sweet potato cropping areas observed in the images from the two cropping seasons, the yearly total for 2006 amounts to 44,620 ha. However, the more recent official data from the Department of Statistics of Uganda (Figure 6), point out that in the whole year of 2003 the area cultivated with sweet potato in Kumi was 28,000 ha. Assuming that this estimation remains approximately constant for the following years, including 2006, our remote sensing data suggests that the official statistics record just the 67% of the sweet potato cropping area in Kumi district. In years with normal precipitation, the shortage of the official data would be even greater. If the proportion holds true for other areas, the total area of sweet potato in Uganda might well exceed 1 M ha.



Source: CIP, NRM Geospatial Analysis Laboratory, based on a SPOT scene of May 6, 2006

Figure 4. Classified SPOT Image of the Kumi district, May 2006

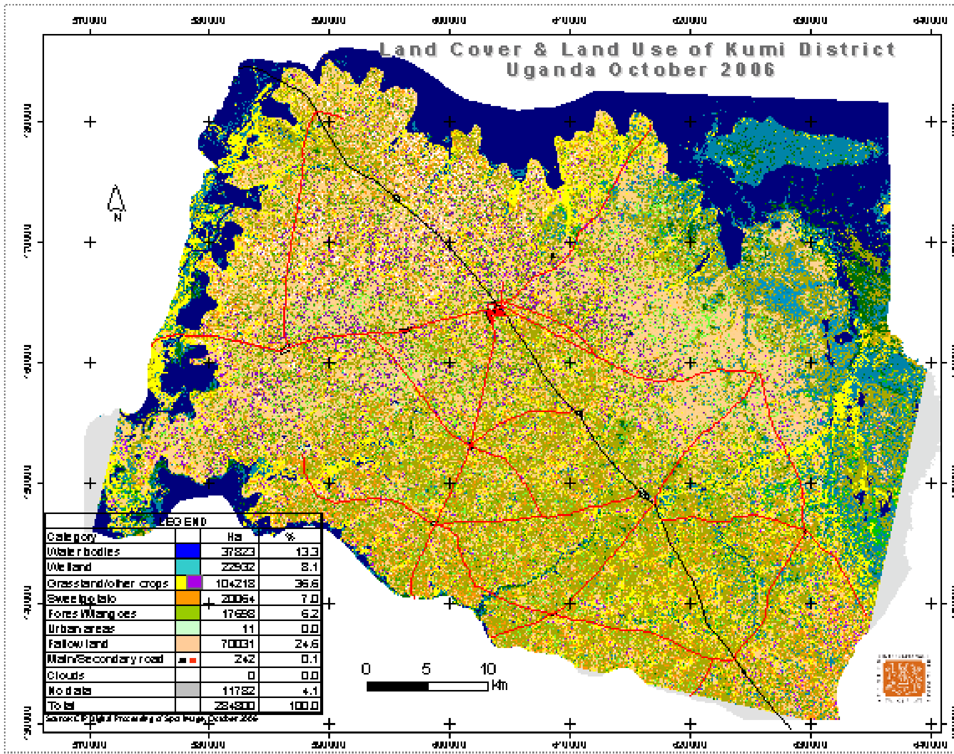
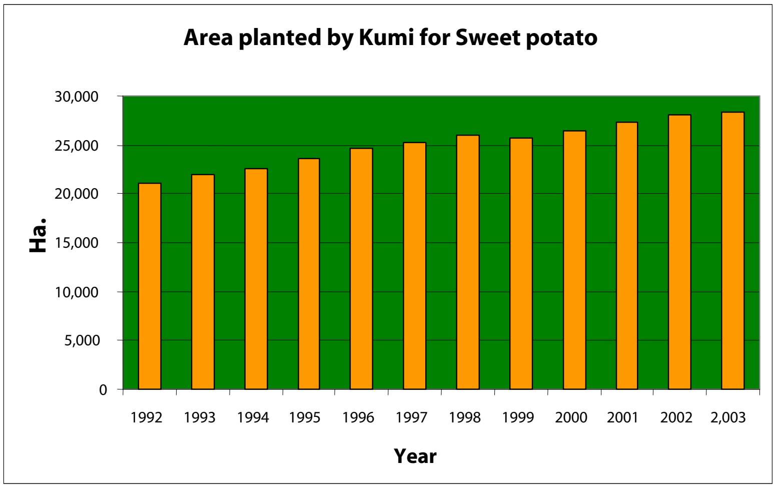


Figure 5. Classified SPOT Image of the Kumi district, October 2006

Table 2. Area covered by different land use and plant cover categories, May and October 2006

LEGEND					
Category		May-06		Oct-06	
		Ha	%	Ha	%
Water bodies		39310	13.8	37823	13.3
Wetland		23858	8.4	22932	8.1
Grassland/other crops		118324	41.5	104218	36.6
Sweetpotato		24556	8.6	20064	7.0
Forest/Mangoes		17710	6.2	17698	6.2
Urban areas		11	0.0	11	0.0
Fallow land		30840	10.8	70031	24.6
Main/Secondary road	.--/—	242	0.1	242	0.1
Clouds		4872	1.7	0	0.0
No data		25078	8.8	11782	4.1
Total		284800	100.0	284800	100.0



Source: Uganda Bureau of Statistics (UBOS)

Figure 6. Sweet potato cropping area en the Kumi District according To official statistics of Uganda

Conclusions

The radiometric evaluation and processing of the SPOT scenes of the district of Kumi in Uganda have made it possible to determine that the sweet potato foliage has a distinct spectral pattern defined by a low reflectance in the visible range of the spectrum and a high reflectance in the near infrared range. This spectral pattern makes it possible to identify the sweet potato crop with a high degree of certainty, which allows defining with precision the cultivated area and the spatial distribution of the crop through the utilization of high-resolution SPOT images. The results suggest that the traditional statistics underestimate the total annual sweet potato cropping area in Kumi. The use of the tested method substantially improves the estimation of cropping areas.

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