Lake level and area variations 1960 to 2002 in Lake Kyoga, Uganda

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Abstract

Lake Kyoga is a shallow lake in central Uganda of 3 to 5 m depth forming part of the Equatorial lake system. The lake is around 3000 km^2 and the local basin (57,000 km^2) drains large parts of Uganda. However, more than 90 % of the inflow originates from the Victoria Nile. The 1997/98 El Niño flood displaced hundreds of families and dislocated sudds that formed a plug at the outlet which rose the lake level almost 2 meters. Subsequent high flood levels in 2000 destroyed several settlements and led to the drowning of many people. The increase of the lake surface has meant loss of substantial areas of fertile soil, but is also reported by the local communities to have led to higher fish production. In this study, time series of Landsat MSS and (E)TM satellite images has been used to trace recent changes in the area of Lake Kyoga, and compare the flooding data with water levels.

Key words: Lake Kyoga

Introduction

Lake Kyoga is a shallow lake of 3 to 5 m depth forming part of the Equatorial lake system (Figure 1). The lake is around 3000 km^2 and drains large parts of Uganda. The local basin draining directly into Lake Kyoga is 57,000 km^2. However, more than 90 % of the inflow originates from Lake Victoria and the Victoria Nile. The massive swamps at the mouth of the tributary rivers provide a natural regulation of tributary inflows.

The 1997/98 El Niño flood displaced hundreds of families and dislocated sudds (floating mats of papyrus) that formed a plug at the outlet which rose the lake level almost 2 meters. Subsequent high flood levels in 2000 destroyed several settlements and led to the drowning of many people (Bird and Shinyekwa, 2003). The increase of the lake surface has meant loss of substantial areas of fertile soil, but is also reported by the local communities to have led to higher fish production. Bottom dwelling mud or lung fish species (e.g. *Protopterus aethiopicus*) of both commercial and subsistence importance has increased as reported by local fishers.

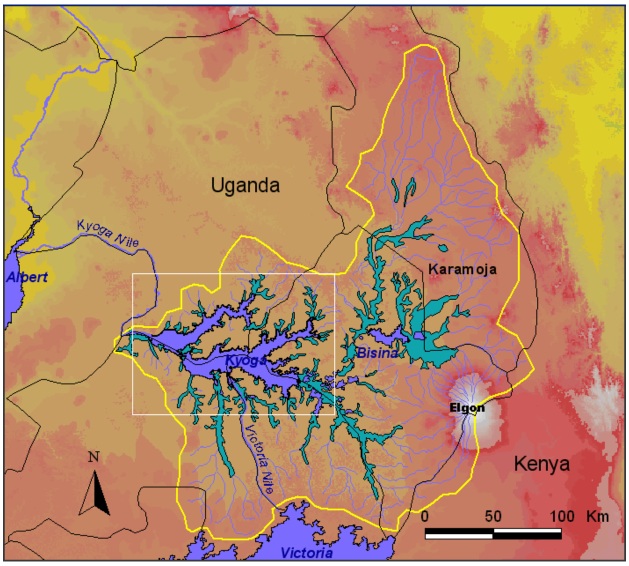

Figure 1. Lake Kyoga and its basin showing the lakes, major streams and wetlands. White box indicate area of Figure 2.

In this study time series of satellite images, mainly Landsat Multi Spectral Scanner (MSS), Themat Mapper (TM) and Enhanced TM (ETM) were used to trace recent changes in the area of Lake Kyoga, and compare this flooding data with historical water levels.

Materials and methods

48 medium to high resolution satellite images from the period 1972 to 2003 were used for mapping the area of Lake Kyoga and its transient changes over this period (table 1) The lion's share of the data are freely available quicklook images from the Landsat

program. These images are available for download as color composites, where water and cloud are easy to detect. This data was complemented with 2 radar composite scenes (JERS) from 1996. Additionally one older Corona ("spy") image was used to confirm the lake area in 1963. No radiometric correction was undertaken. All images were resampled to 250 m resolution and geocorrected to Universal Transverse Mercator (UTM) zone 36. The geocorrection was manually done using ground control points collected by handheld GPS as reference. To create precise geocorrections images were combined to animations, and iteratively adjusted until the animations contained no "jumps".

Table 1. Quicklook satellite images and radar data used in this study.

Source	Dates	Comments
Corona	1963-10-29	Not used in analysis
Landsat MSS	1972-12-29, 1973-03-03, 1974-01-29, 1976-01-27	All images combined to one estimate
Landsat TM	1984-04-26,1984-06-13,1984-07-31, 1984-09-01, 1985-04-13, 1986-01-10, 1986-11-10, 1986-12-12, 1989-02-11, 1994-10-31, 1994-12-02, 1995-01-19, 1995-03-08, 1995-04-09	
Landsat ETM	1999-10-05, 1999-12-05, 2000-01-25, 2000-04-14, 2000-05-16, 2000-08-04, 2000-10-23, 2000-11-24, 2001-04-17, 2001-05-19, 2001-07-06, 2001-09-08, 2001-11-27, 2002-01-30, 2002-03-19, 2002-04-04, 2002-05-22, 2002-06-07, 2002-07-08, 2002-08-10, 2002-09-27, 2002-10-13, 2003-01-17, 2003-03-22,2003-05-25,2003-08-07	
JERS-SAR	January to March 1996, October to November 1996.	Composites Undisturbed by clouds

For all images a statistical unsupervised classification technique was used to identify clouds, water, wetland and land areas (McCarthy et al., 2003). The derived classes were manually categorized into cloud, water, wetland or land by comparing the classified images with the downloaded color composite images (Figure 2). After identification the clouds were expanded by 2.5 km in all directions to accommodate for both thin clouds and cloud shadows. All images were then stacked and water occurrence in cloud free areas was estimated. If this occurrence was more than 95 % *and* the radar images (which are not disturbed by clouds) showed water, then that picture element (pixel) was considered to always be water. Clouds over those areas thus identified were hence changed into water in all images. Using the stacked information on water occurrence the maximum extent of the Lake and its riparian mixed land-water pixels and adjacent wetlands was estimated by using the identified core water area and a growth routine to identify all "wet" areas directly linked to the core area. For each individual image, the occurrence of water under clouds in the fringe area between the lake core and maximum extent area was resolved by using adjacent dates.

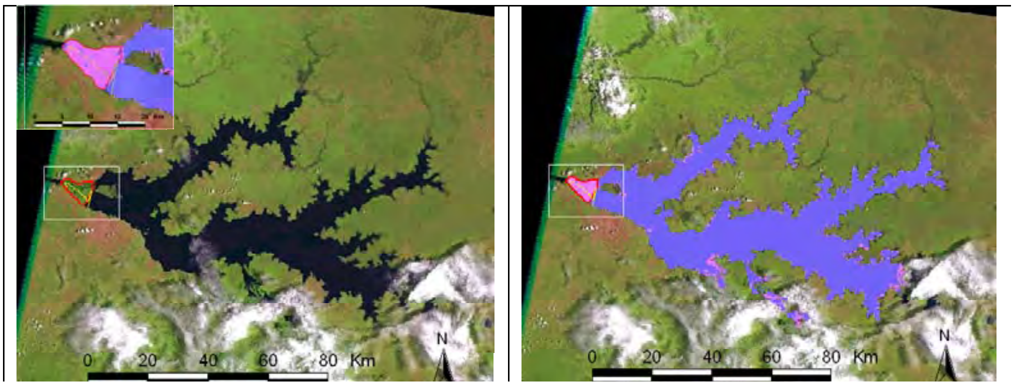

Figure 2. Image classification method exemplified by Landsat ETM from October 2002; the red area indicates the plug that formed after the 1997/98 El Niño. The yellow line is the survey line from November 2002 (see text).

Available "ground truth" data included GPS tracks and waypoints from six field visits in the period November 2002 to May 2004. A boat and flight survey conducted 18-19 November 2002 showed that the accuracy for a 5 km transect along different shorelines was 100 % when compared to water and wetlands classified from the Landsat ETM scene from October 2002 (See Figure 2). Also the tracks and waypoints from other visits indicate a high classification accuracy.

Two Landsat MSS, two Landsat TM and one Landsat ETM scene were acquired in full resolutions. The classification accuracy of the reduced resolution images from the same scenes was evaluated (table 2).

Table 2. Classification accuracy in 250 m resolution images as compared to full resolution images (30 to 60 m).

Date and sensor	Full resolution Water area (km^2)	Low resolution Water area (km^2)
1973-02-02/1974-01-29 (MSS)	2687	2702
1986 (TM)	2628	2574
1995 (TM)	2491	2492
2001 (ETM)	2744	2655

Data on relative water stages in Lake Kyoga was taken from the Department of Water Development recorder in the Lake. This dataset has large gaps, and in cases where the mismatch between available recorded water stages and dates of satellite images was less than 1 month, the recorded data was interpolated, or in a few cases extrapolated if stable conditions prevailed in the adjacent record.

Results

The area of lake Kyoga has varied between 2400 and 2850 km^2, or almost 20 % over the last 3 decades. From the water level recordings it is evident that the Lake level has varied around 3 meters, and that the lowest recording is from 1961, before the well known rise in the Lake level of Lake Victoria. This rise in 1961 is also clearly reflected in the levels at Lake Kyoga (Figure 3). The Corona satellite image over Lake Kyoga confirms the Lake shore, but large parts of the Lake in covered in clouds in the images.

The recorded changes in Lake levels and the open water area as interpreted from satellite images show a high degree of correlation (Figure 3), with an R^2 of 77 %.

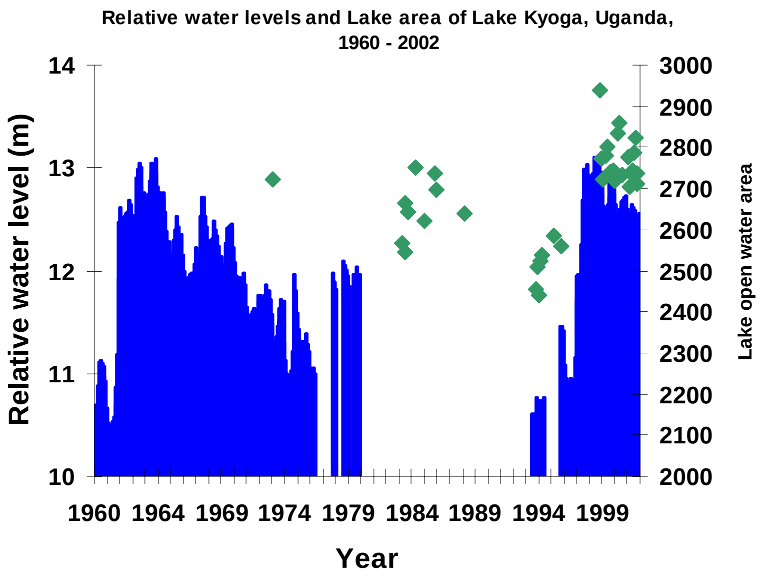

Figure 3, Lake Kyoga recorded water levels 1960 to 2002 (blue columns), and lake open water area (green rectangles) as interpreted from 48 satellite images 1973 to 2003.

Discussion

Lake Kyoga has experienced large variations in water levels as well as in surface water area over the last 40 years. An abrupt rise in 1961 coincides with the well-known rise in Lake Victoria water levels. The 1997/98 rise and prolonged high water level was caused by a plug of papyrus formed following a high precipitation period related to an El Niño event.

Following the rise in water level the local fishermen report improved catches, This increase in yield is, however not reflected in the official statistics (Allison et al., 2003). It has been suggested that a long term decrease in fish yields from Lake Kyoga over the last 20 years is due to over-fishing, wetland conversion and aquatic weed invasion (see Ogutu-Ohwayo, 1990; Allison, 2003). Local fishers tend to favor the latter explanation (weed invasion e.g. entangling and suffocating fish). They also attribute a collapse of fish yield in nearby Lake Bisina (see Figure 1) to invasive submersed weeds (personal communication with officials in several villages).

Conclusion

Lake Kyoga in central Uganda has experienced large variations and a general increasing trend in water levels and water area over the last decades. Compared to the early 1960's the Lake water volume is now almost double.

References

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