Land Cover Change Analysis for the Kingwal Swamp Area, 1967 to 2013

Summary report (March 2015)

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1. Overview

This report is an extended and translated summary of a student project by Marietta Bloch in winter semester 2013/14. Her report, *Veränderung des Kingwal Sumpfgebiets in Kenia von 1986 bis 2013 auf Grundlage von Landsat-Satellitenbildern* [Change of the Kingwal Swamp area in Kenya from 1986 to 2013 on the basis of Landsat satellite imagery], documents the changes in the Kingwal wetland, in Nandi county Kenya, from 1986 to 2013. The changes in Kingwal's footprint were determined by using remote sensing techniques to identify change in land cover and thus the area covered by wetland. In addition to summarizing the findings of Bloch's report, this document extends the change detection by including a third time step of 1967 based on 1:50k topographic map sheets of 1970.

The study area, as originally created, was defined by the topographic map and contour lines. The topographic map sheets with their delineated swamp areas for 1967 were used to define the general area of the Kingwal Swamp study. Contour lines generated from SRTM[1] data were then selected, choosing those that surrounded the historic footprint of the Kingwal Swamp. Elevations of 1950 m and 1980 m were used to define the general boundary connecting them when necessary. This area was buffered by 30 m to define the final study area (Figure 1).

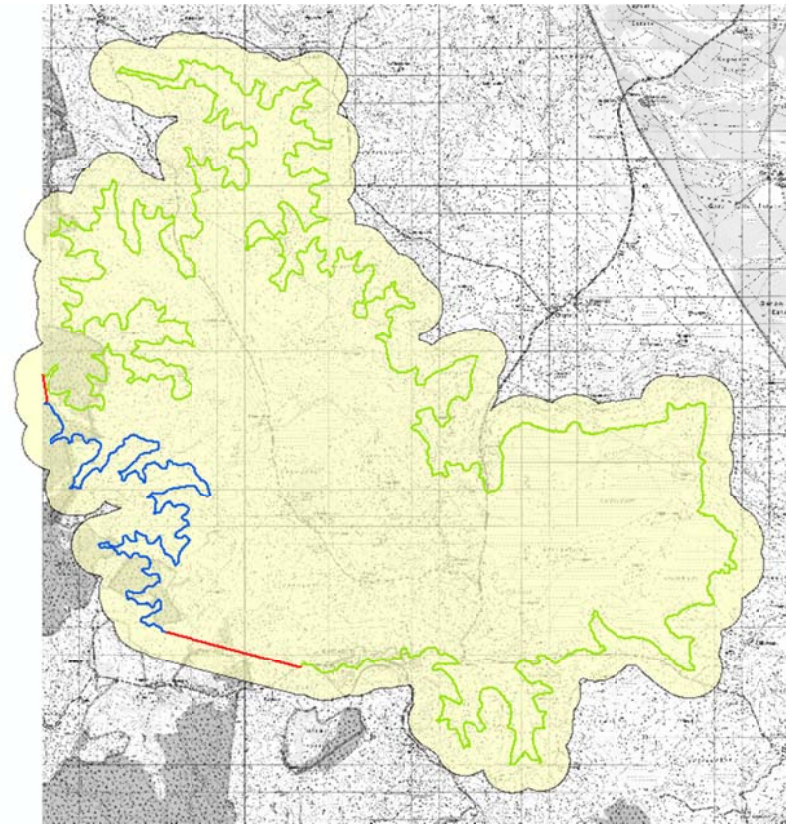

Figure 1: the Kingwal Swamp study area. Buffered contour lines: green 1980 m, blue 1950 m, and red connection lines. Background of 1:50 k topographic map (Bloch, 2014, Fig. 1).

[1] Shuttle Radar Topography Mission

2. Kingwal Swamp area in 1967

The area of swamp for 1967 was derived from 1:50 k topographic map sheets[2,3]. Unlike the other time steps, which used remote sensing to identify areas of swamp, the data for 1967 was digitized from area fills on the topographic survey maps. The map sheets indicate two types of swamp in the area, seasonal swamp and permanent swamp (Table 1).The resulting data indicates 6.7% of the study area to be permanent swamp and 10.8% to be seasonal swamp vegetation (Figure 2).

Table 1: 1:50k topographic map swamp symbology.

Permanent swamp	Seasonal swamp

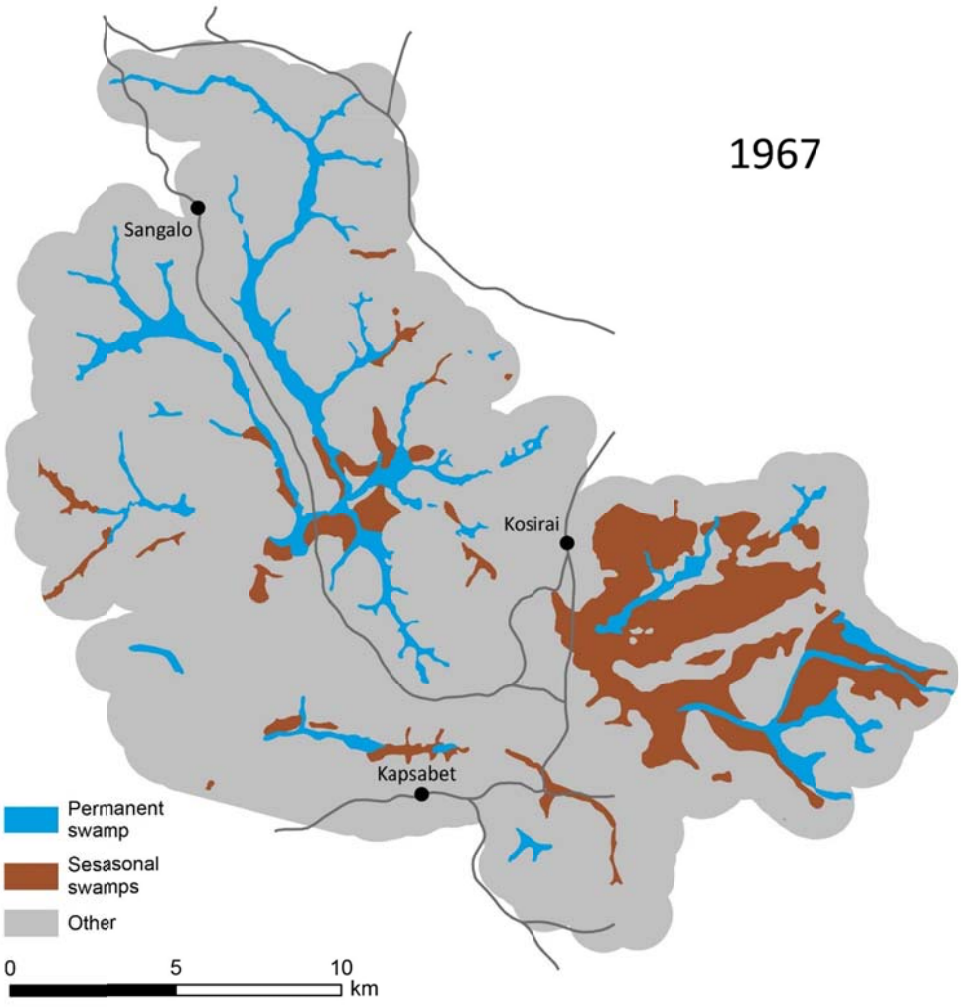

Figure 2: Kingwal Swamp extent 1967, based on 1:50k topographic map.

[2] "Kapsabet 103/3", East Africa 1:50,000 (Kenya), Series Y731 (D.O.S. 423), Edition 6 (1970)
[3] "Kabiyet 103/1", East Africa 1:50,000 (Kenya), Series Y731 (D.O.S. 423), Edition 6 (1970)

3. Kingwal Swamp area, 1986 & 2013

For the latter two time steps Bloch (2014) used Landsat data and remote sensing techniques to determine land cover and thus the area covered by wetland in the study area. For each time step, images from both the dry and rainy season were used to allow for a consideration of wetland dynamics. For 1986 Landsat 5 TM[4] images were used, while Landsat 8 OLI[5] images were used for 2013, both with a spatial resolution of 30 m for the applied multispectral bands (VIS to MIR). The images for the different seasons were combined using a layer stacking technique. Due to cloud cover and image extents, two image stacks are needed for each time step to cover the entire study area. These stacks will later be referred to as the left (western part) and right (eastern part) layer stacks. In total eight images were used (Table 2). Prior to analysis, relative atmospheric corrections were performed.

Table 2: Landsat imagery used for the land cover change analysis of the Kingwal Swamp area.

Year	Date	Sensor	Season	Image Stack
1986	24th August	Landsat 5 TM	Rainy season	Right
1986	2nd October	Landsat 5 TM	Rainy season	Left
1986	19th January	Landsat 5 TM	Dry season	Left
1986	28th January	Landsat 5 TM	Dry season	Right
2013	22nd June	Landsat 8 OLI	Rainy season	Left
2013	17th July	Landsat 8 OLI	Rainy season	Right
2013	19th April	Landsat 8 OLI	Dry season	Left
2013	28th April	Landsat 8 OLI	Dry season	Right

Land cover for each time step was determined by using a maximum likelihood supervised classification. For a thorough image interpretation and classification first unsupervised classification was applied. As an additional artificial band, the NDVI[6] proved to be beneficial for an enhanced separation of land cover classes in the wetland, as well as in the surrounding area. When selecting training samples contrast-enhanced false colour composites of the bands 5/4/3[7] for the swamp types, but also NDVI/5/4 and NDVI/4/3 were mostly used. The result of picking 50 to 130 training samples per scene subset, was the distinction between 17 different types of land cover that were used in the subsequent supervised classification:

- Agriculture
- Tea
- Bush 1-2
- Forest & Tree groups
- Grassland
- Settlement & Infrastructure
- Bare soil
- “Wet ground”
- Swamp 1-7
- Water

[4] Thematic Mapper
[5] Operational Land Imager
[6] Normalized Difference Vegetation Index
[7] As named for TM and assigned to R/G/B

Of these groups there are several important points to note. The swamp land was determined to have seven distinct spectral signatures. Each of these identifies a different type or vegetation composition of swamp. Although distinct from each other, it was not possible to determine what makes each of these swamp classes distinct from each other. Ground truthing would be needed to make these distinctions. In 1986 only swamp classes 2, 4, 5, and 7 could be distinguished. More classes were distinguished in 2013 because better differentiation was possible with the introduction of Landsat 8.

Similar to the different swamp classes, there are two different types of bush. They represent two different types of land cover, but what is unique about them was not determined in the scope of the research as it would require ground truth, too. It should be noted, that tea is only present in the images from 2013. Tea was not one of the possible classes used in 1986, because there seems to be no extensive growing of tea in the study area at this time.

Finally, the class originally called “Wet ground” needs to be addressed. At the time of the original report, it was not clear exactly what this class represents. This area was determined not to necessarily represent swamp, but did not match any other signatures. It has now been determined that this class is the same as the seasonal swamp delineated on the 1970 topographic map sheets. This determination was made because the classes share a distinctly similar shape and location between the 1967 and 1986 time steps. This area will therefore be referred to as seasonal swamp from this point onward.

In total four classifications were performed, two for each time step (for both the left and right layer stacks independently). Afterwards these had to be mosaicked. For the 1986 time step about three quarters of the area is covered by the classification of the right image stack, while the left stack contributes only about one quarter to the very west. For the time step of 2013 almost the entire area is using the result of the left stack apart from some areas along the margin and even smaller areas within due to single clouds in the original imagery. The classifications for the two time steps are presented in Figure 3.

Following the classification, the overall accuracies were calculated along with other measures of accuracy. The overall accuracies for the four classifications can be found in Table 3. The improved quality for the 2013 result is ascribed to the further evolved sensor of Landsat 8, as compared to Landsat 7, allowing for a better distinction between various swamp types. It should be pointed out that the 1986 classification is likely to contain too many pixels classified as Swamp 7.

Table 3: Overall classification accuracy for the time steps 1986 & 2013 of the Kingwal Swamp area (Bloch, 2014).

	Left Layer Stack	Right Layer Stack
1986	81.47%	82.71%
2013	94.28%	95.88%

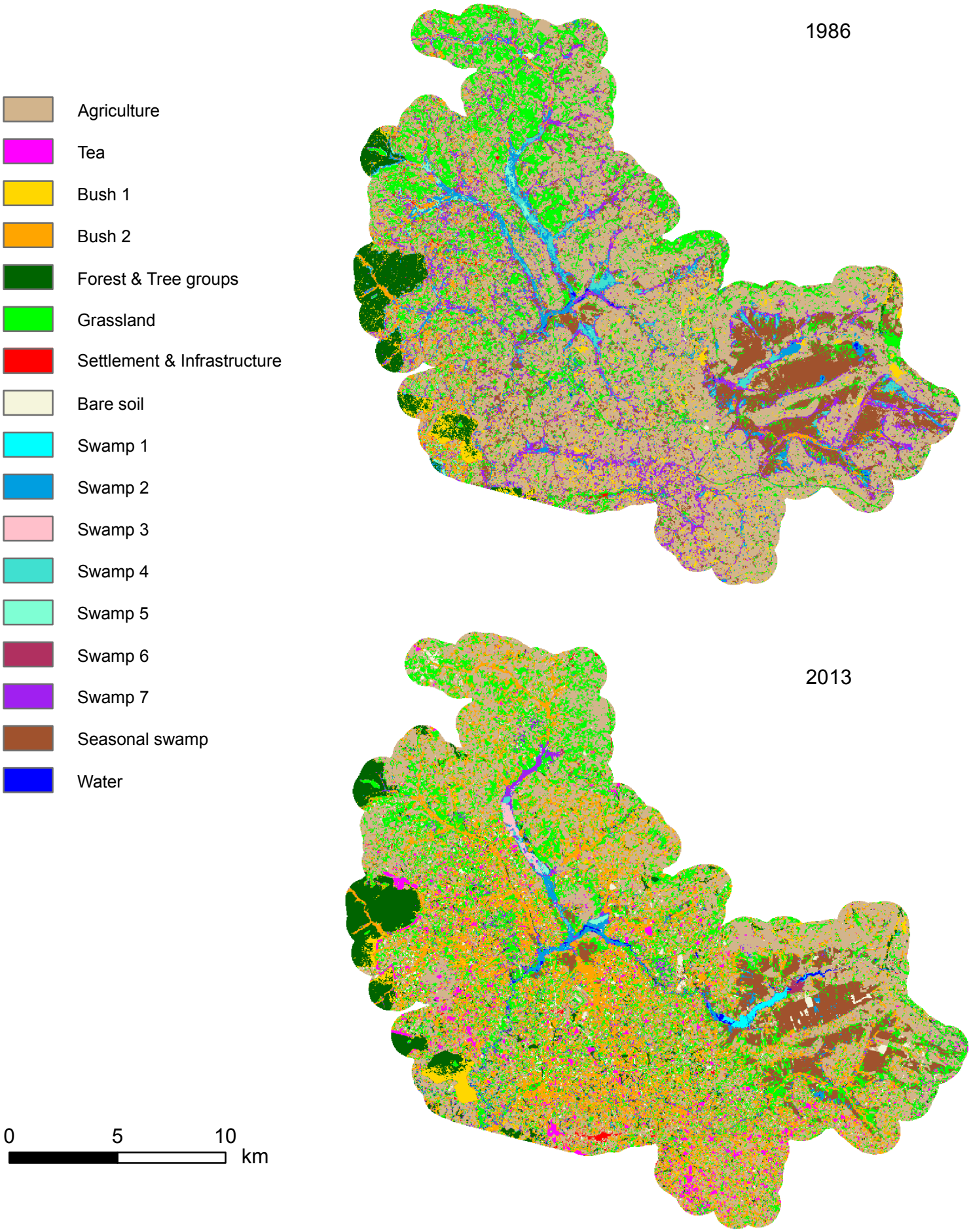

Figure 3: Kingwal Swamp land cover 1986 & 2013, based on multi-temporal Landsat satellite imagery (Bloch, 2014, Abb. 3 translated)

4. Kingwal Swamp's Changing Footprint

The final step in the research process was to identify the change in Kingwal Swamp's footprint in the different time steps. For each time step, the areas of swamp were isolated for analysis (Figure 4). It should also be noted that the original change detection was performed only with regard to the different swamp classes (Swamp 1-7). It did not include what was later determined to be seasonal swamp, thus the seasonal swamp was removed from the 1967 dataset for the change detection. Change in seasonal swamp can still be visualized in the percentage distributions of land cover in Figure 5. When comparing the resulting maps one needs to be aware that for the earliest time step, the swamp area was not determined from satellite imagery, but by digitizing the area marked by an area-fill on a 1:50k topographic map. It represents the outcome of aerial photo interpretation by photogrammetric means and therefore represents a generalization for the map scale of 1:50,000. The classifications of the satellite imagery visualizes every pixel of 30 m by 30 m ground area having been classified as one of the seven swamp classes.

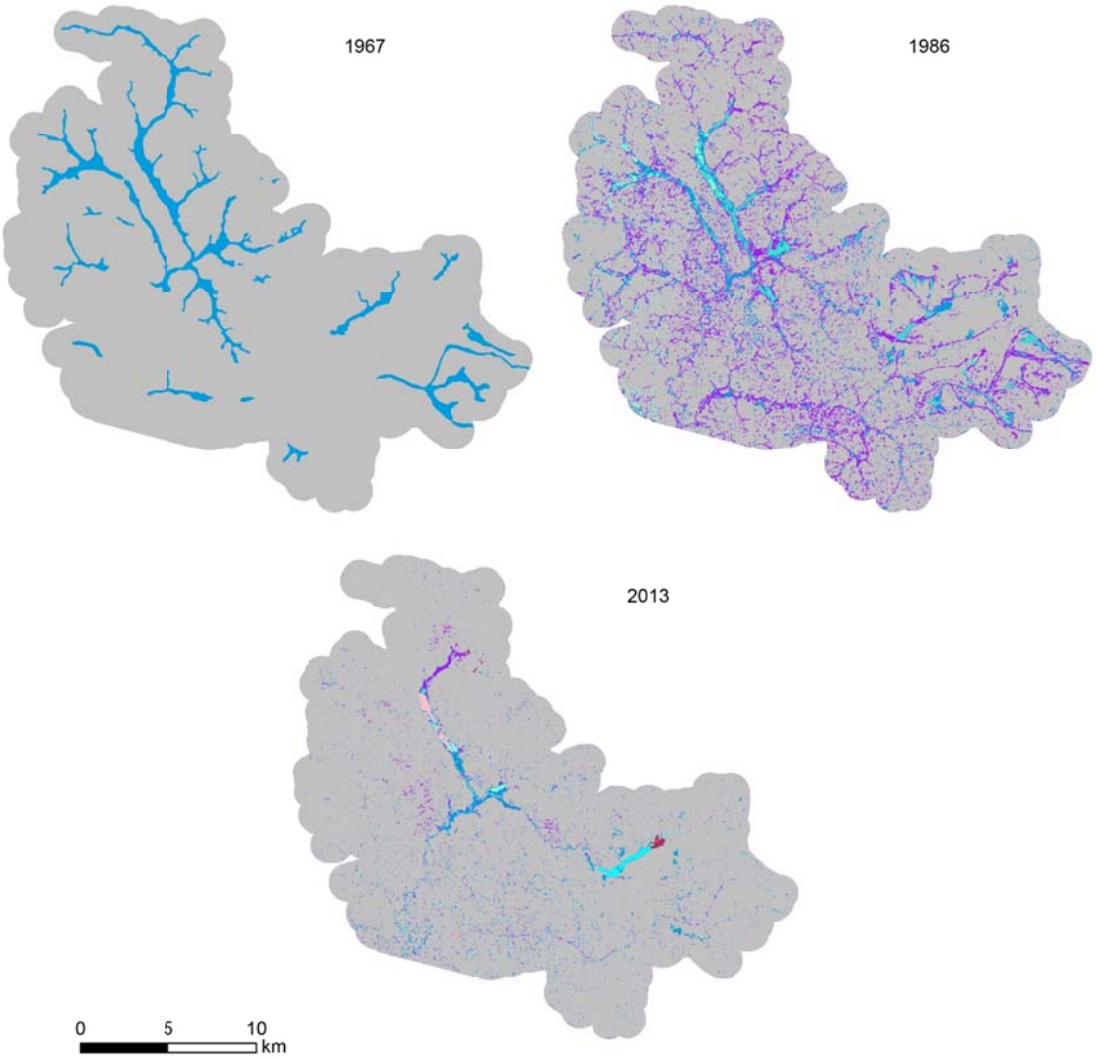

Figure 4: Distribution of permanent swamp in the Kingwal Swamp area in 1967, 1986 & 2013. (Bloch, 2014, Abb. 5 extended; for explanation of colours see Figures 2 and 3).

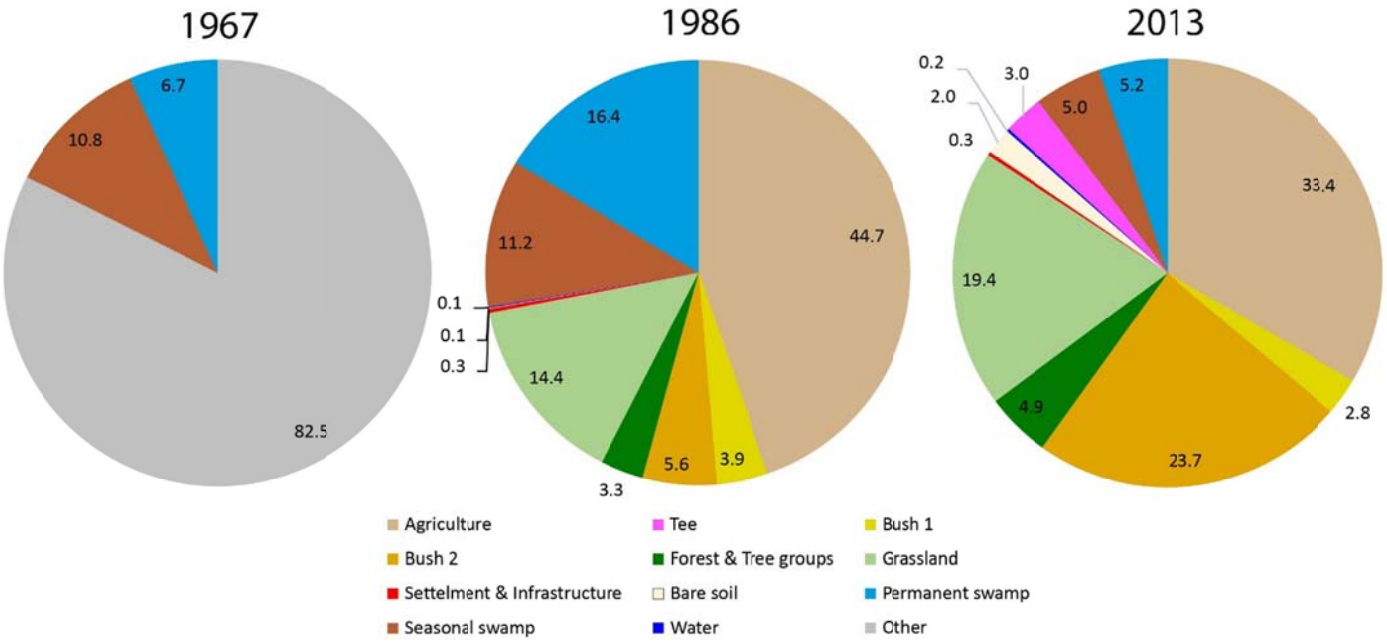

Figure 5: Percent distribution of land cover in the Kingwal Swamp area in 1960, 1986 & 2013 (Bloch, 2014, Abb. 4 extended and translated).

The methods used to derive difference images between two time steps varied based upon the time steps being evaluated. The original report, which used only raster data, used a Matrix Union function to find the land cover changes from 1986 to 2013. When the 1967 data was added, vector overlay methods were used, to determine the change between 1967 to 1986 and 1967 to 2013. The result can be seen in Figure 6. Here the effect of different data sources used becomes even more apparent. In the result for 1967 vs. 2013 one wishes for a generalization of the pattern showing up for swamp gain (in green). However, this would require extensive manual digitizing. Besides, the current presentation is reflecting the data quality as the green pattern has a weaker certainty because smaller swamp areas might have been around in 1967 but were not mapped for inclusion in the 1:50k topographic map sheets.

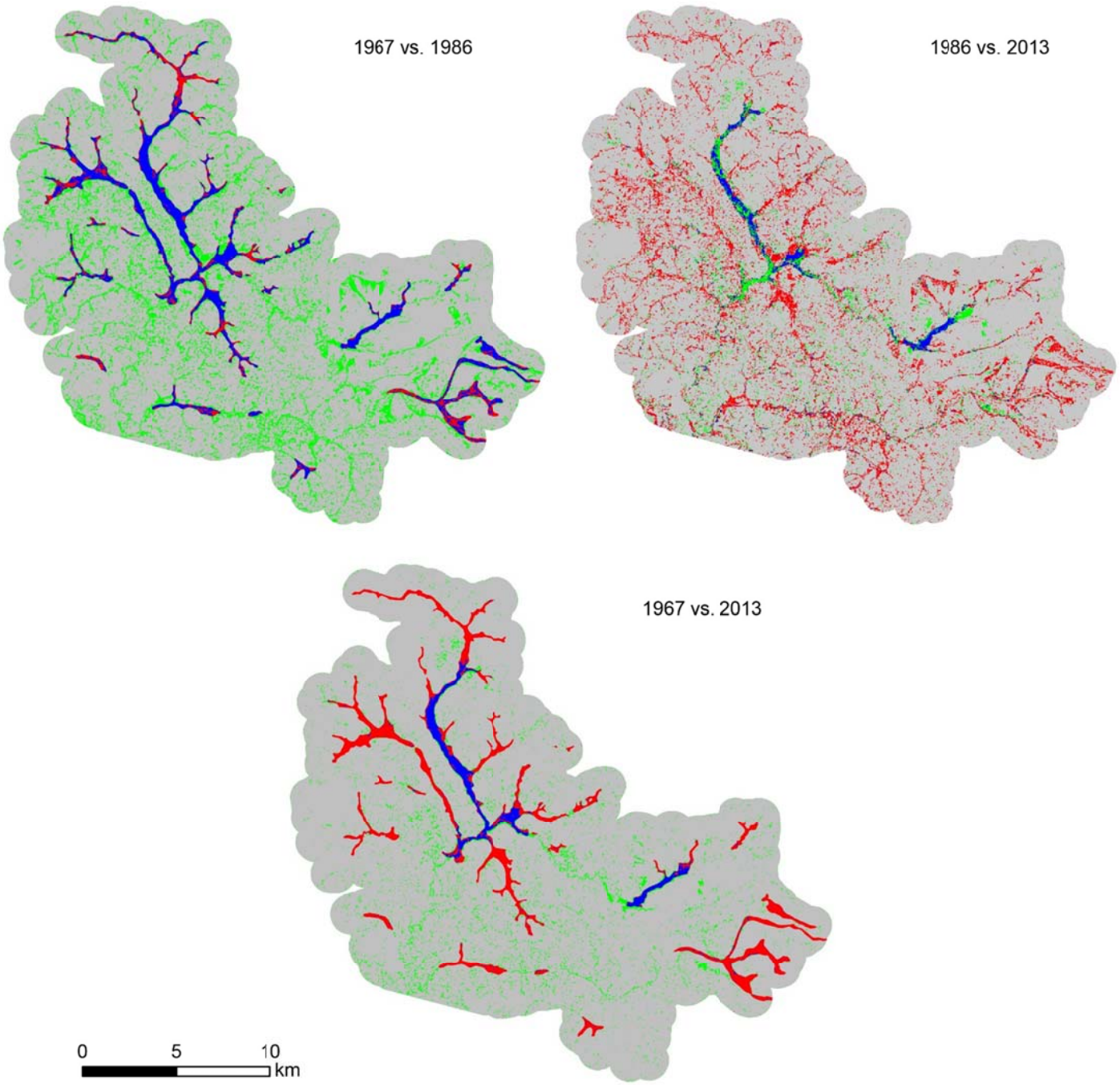

Figure 6: Kingwal Swamp changes comparing all possible combinations of two time steps out of 1967, 1986 & 2013. Blue: sustained swamp, green: swamp gain, red: swamp loss.

5. Conclusions

The results of the land cover change in the Kingwal Swamp area from 1967 to 2013, show a clear and dramatic decrease in wetland, particularly in the second time interval. As revealed by the map depictions, there has been a complete loss of two large areas of swamp, and many smaller areas. These areas include the more westerly of the two north western former swamp arms, and the swamp area to the south east of the study area where also the seasonal swamp area decreased in size. While in 1967 6.7%, 29 km^2 (17.6%, 75.6 km^2 including seasonal swamp) of the study area was covered by swamp, the results point to an increase over the following 19 years with 16.4%, 71 km^2 (27.6%, 119.3 km^2) in 1986. Over the next 27 years the area decreased, now (2013) covering only 5.2%, 22.7 km^2 (10.3%, 44.6 km^2) of the area. Not all of the increase from 1967 to 1986 can be attributed to a growing swamp area. Instead it includes a side effect of the differing methods of data creation for these time steps. These effect can be seen in the amount of dispersed areas of swamp (in parts class Swamp 7) that were detected in 1986, but not mapped in 1967. The major change over the second time interval must be the effect of a change in the water balance in the area.

Besides the overall loss of wetland, the other major difference between the 1986 and 2013 time steps is the dramatic increase in bush land. In total, bush land increased by a factor of 2.8 while swamp land receded by a factor of 2.7. Although these areas are not congruent, it can clearly be seen in the classifications from 1986 and 2013, that much of the lost swamp was replaced by what is here named bush land. For more precise naming ground truthing is necessary. However, class Bush 2 clearly represents a type of agricultural land use.

Further enhancement to the results would include ground truthing to identify the bush classes and the differences between the different swamp classes. In order to get a better understanding of the uncertainties related to the use of the different data types (topographic map vs satellite imagery) one could classify an early Landsat scene of the same area (available from 1972/73), although the scenes are of poorer spatial (60 m) and spectral resolution (4 bands). The information now available could be used to update the KWS[8] map of the Kingwal Wetland from 2012 based on various inputs and marking 17.8 km^2 of swamp (Figure 7), because a large section of swamp area along Kingwal River (before joining the Kabutie River) seems not to exist anymore. It would be also interesting to compare our results with statistics on wildlife (e.g. numbers of change in the Sitatunga population) as well as on human population and agricultural activities surrounding the wetland.

[8] Kenya Wildlife Service

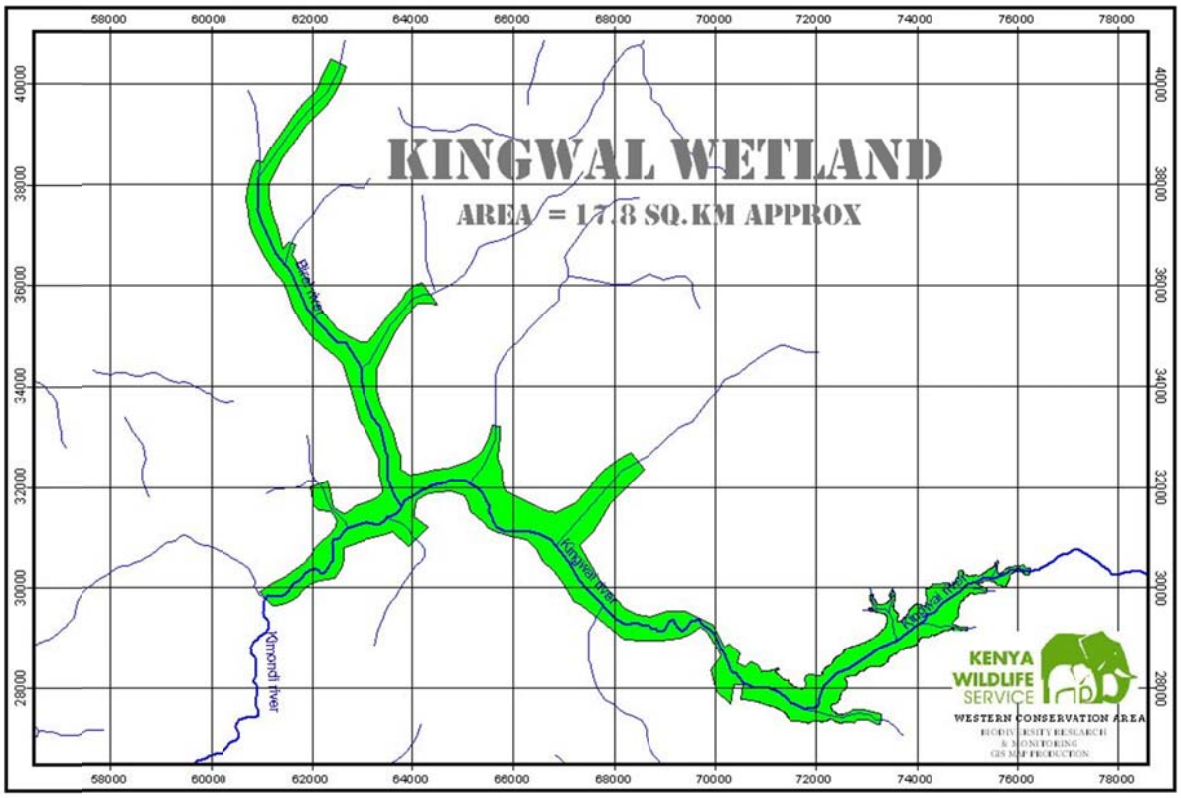

Figure 7: Map of the Kingwal Swamp as prepared by KWS (2012).

6. Reference

Bloch, Marietta (2014): Veränderung des Kingwal Sumpfgebiets in Kenia von 1986 bis 2013 auf Grundlage von Landsat-Satellitenbildern [Change of the Kingwal Swamp area in Kenya from 1986 to 2013 on the basis of Landsat satellite imagery]. Unpublished student project for course Projekt Fernerkundung (winter semester 2013/14), Faculty of Information Management and Media, Karlsruhe University of Applied Sciences, Germany.