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Land Cover and Land Use Dynamics of Semi Arid Wetlands: A Case of Rumuruti (Kenya) and Malinda (Tanzania)

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Abstract

In Sub-Saharan Africa, wetlands particularly those located in dry areas are intensively used and have caused significant loss of the wetlands and their riparian areas. The uses are intensified because of climate variability and the demand to feed the ever growing population. This paper presents results of assessment of land cover and use change in semi arid floodplains of Rumuruti and Malinda in Kenya and Tanzania respectively. Field survey, unsupervised classification and change vector analysis were used to map the uses and assess the changes. Results show that the wetlands are diversely used, agriculture is one of the main land uses (24-35%); other uses and cover include grazing and shrubs (11-39%), built up area (14%, in Rumuruti), burnt area (7%, in Malinda), forest and natural wetland vegetation (5%) and open water (3%). Significant part of natural vegetation (47.76% in Malinda and 72.60% in Rumuruti) has been converted into farms and other uses and as a consequence some parts of the wetlands have been abandoned due to over use. Anthropogenic factors are the main drivers of the changes. The data generated in this study is seen to contribute in monitoring and management of the particular wetlands.

Keywords: Change vector analysis; Wetland use intensity; Wetland monitoring; Wetland loss

Introduction

Wetlands contain numerous goods and services that have social, economic and aesthetic value to local populations as well as surrounding communities where they exist. Since ancient time, wetlands have been used for different human activities due to their diverse ecological richness. Activities such as farming, grazing, fishing and settlement development are common in wetlands particularly in sub-Saharan Africa. In some areas communities depend exclusively on wetlands for their survival. A good example is Yala Swamp in Western Kenya, where it was found that communities rely 100% on water extracted from the wetland for drinking, cooking and washing, while 86% of the population relies on building materials gathered in the wetland, such as clay, sand, wood and papyrus [1].

In East Africa, wetlands have been widely used to generate income and satisfy other human needs. The use of wetlands has been largely necessitated by increased population and climate change. The population has increased pressure on upland areas that have been traditionally used for agriculture. In addition climate change (high rainfall variations) has led to poor harvests. These dominant drivers have led to the search for supplementary food production and income generating opportunities by the poor as a survival strategy, especially by using wetlands to produce crops in the dry season for food security. According to [2] there has been a strong trend towards settlement along riverine and wetland areas due to their suitability for farming and easy availability of water for cultivation.

Lack of efficient markets for crops and capital to invest in agriculture has led to failure in agriculture. In the highlands of East Africa like Kilimanjaro, coffee for instance, was the main cash crop, which people relied on for income generation [3]. Price failure in the world market has caused people to turn their focus to horticultural crops, since they take shorter time to mature and are on high demand [4,5] thus increasing pressure on wetlands. The increasing pressure and uncoordinated wetlands use in Kenya and Tanzania are also a consequence of unclear policies on wetlands management [2]. The use of wetlands has however, caused significant loss of wetlands and their riparian areas [6]. The majority of wetlands lost historically (more than 80% of all 3 wetland conversions since 1980) were drained or filled to create agricultural land [7]. Hydrological disturbance through drainage and vegetation clearance alters wetlands functionality leading to their loss and degradation.

Wetlands located in semi arid or sub humid areas like Rumuruti in Kenya and Malinda in Tanzania are at higher risk of being highly utilised because of their potential location and diverse communities which depend on them for their

survival. Such wetlands normally serve farmers, pastoralists and domestic users [8]. Apart from over exploitation in these kinds of wetlands, conflicts may arise and contribute to their further degradation. A study of wetland use and change is thus important in order to document the use dynamics for their proper monitoring and management.

In order to monitor and manage wetlands cover/ use change, remote sensing is an important tool because many wetlands are located in remote or un accessible areas thus in situ measurements may not be possible. Remote sensors regularly pass over a locality thus land information in the form of multi-date and multi-spectral images can be obtained within a constant period of time [9]. The multi-date images facilitate detection of changes in wetlands and other environmental resources [4]. Remote sensing further helps in monitoring wetland ecosystems and in the long run, determines their resilience to human interference.

This paper presents results of a research carried out in semi arid highland floodplain (Rumuruti) and sub humid lowland flood plain (Malinda) in Kenya and Tanzania respectively to i) map out their land cover/use and ii) quantify the changes in order to generate

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information, which will guide decision makers on the best way to manage the wetlands without compromising their future existence. It is hypothesized that land use change in wetlands can be detected by multi temporal remote sensing and ancillary data.

Site description

The study took place in Rumuruti wetland in Laikipia West District, Rift Valley Province, Kenya and Malinda wetland in Korogwe District, Tanga Region, Tanzania. Both sites are floodplains in 4 semi arid areas but differentiated by altitude, Rumuruti is a highland floodplain while Malinda is a lowland floodplain. Detailed description of each site is provided below.

The Rumuruti site is located between Longitude 36°12'17" to 36°45'16" E and Latitude 0°28'51" N and 0°7'28"S with altitude ranging from 1780 to 1835 m above sea level (Figure 1). It is on the lee ward side of Mount Kenya and Aberdares, which strongly influence the climate of the area. Rainfall ranges between 400 and 1000 mm. High rainfall occurs on the southern and western parts with Rumuruti receiving less than 500 mm.

A few permanent streams exist and most of them are seasonal; usually they dry up during the dry season. The Ewaso Ngiro is the major permanent river, receiving all the tributaries in the drainage basin. Vegetation distribution is strongly influenced by altitudinal pattern, with dry forest occurring on the highest elevations and a gradient of Acacia–Themeda bush on the plains [10]. As an exception to the overall regional ecological gradient, however, are edaphic communities of Acacia drepanolobium Skpestedt in the central plains, escarpment vegetation and secondary communities induced by historical management factors. The gentle warping in the south has contributed to ponding in valleys leading to the formation of swamps, which are mainly dominated by Poaceae (Cynodon dactylon), Cyperaceae (Cyperus rotundus, Cyperus papyrus, and Cyperus exaltatus) and Asteraceae (Galinsoga parviflora). The main economic activities in the area are agriculture, ranching, livestock keeping and small scale business (Figure 1a).

The Malinda site is found between Longitudes 38°18'48" and 38°35'49"E and Latitudes 4°51'32" to 5°6'56"S, with altitude ranging between 280 and 380m above sea level. There are two rainfall seasons; the long rains between March and June, and the short rains between September and November. The study site is on the lee ward side of the Usambara West Mountain and, therefore, receives less rain of between 500 and 800 mm annually, and bears some characteristics of semi arid areas.

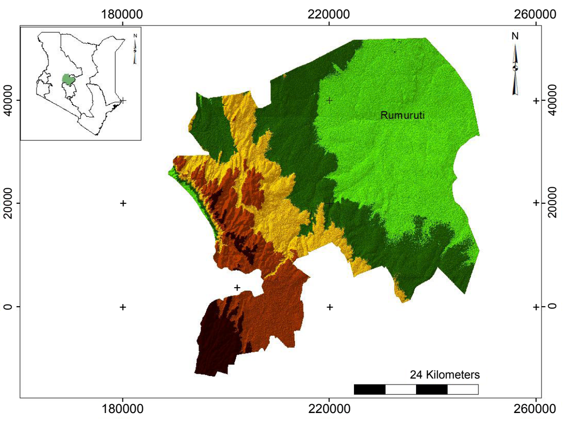

Figure 1a: Location of study sites.

The Pangani River and its tributaries Mbeza, Kizara, and Vuluni are the most important drainage systems. Several seasonal streams exist, which dry quickly as the dry season sets. The dominant vegetation includes grasslands dominated by Penisetum spp, Acacia spp and Cynadon spp. Mangifera spp are also dominant. Within the swamps Cyperaceae (Cyperus papyrus), Commelinaceae (Commelina benghalensis), Asteraceae (Pentodon pentandrus, Ageratum conyzoides) and other various shrub vegetation are the most common. Farming and livestock keeping are the main economic activities in the area (Figure 1b).

Material and Methods

Data types

LANDSAT images were the main data used for change detection with ten year sequence for 30 years time period. It was, however, not possible to acquire images sequentially for all the sites due to either poor data quality like high cloud coverage (>10%) or missing information as was the case of all images collected after July 2003 that are produced with gaps in scan lines due to Landsat 7 sensor failure. Since the wetlands were small in size (500-800 ha) some of the data were missing and efforts to fill in the gaps degraded the quality of the data (Table 1 shows a list of all images used). Historical and recently acquired aerial photographs were used as part of ground truth data for the Landsat images and detailed mapping of the wetlands.

Ground-truth data on spatial location, land cover, agricultural land use and topographic characteristics were collected from field survey, which was conducted in the dry season (January and February, 2009). Data were collected in terms of points using Personal Digital Assistant (PDA) GPS. In total 50 points were collected in the two sites for accuracy assessment. Additionally some qualitative data were collected using focus group discussions on the drivers of land use change since there was insufficient data for spatial analysis. Key informants like village elders, agricultural officers, village government leaders and wetlands users were purposively selected for group discussions. Two meetings were conducted i.e. one meeting in each site.

Data pre processing

The Landsat images were downloaded from GLCF, they were then unzipped and layer stacked to make composite images. Co registration was not important because the images fitted together but they were all re projected to UTM zone 36N for the Rumuruti and 37S for the Malinda

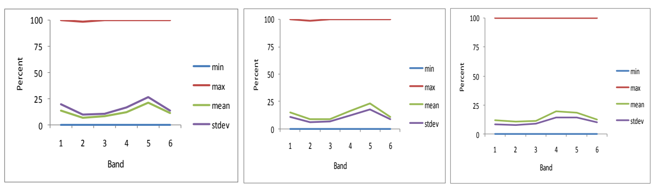

Figure 1b: Location of study sites.

Data type	Rumuruti			Malinda		
LANDSAT	Path/row	Year	Date	Path/row	Year	Date
MSS	181_060	1976	25/01	179_063	1976	10/02
TM	169_060	1986	28/01	167-063	1987	01/01
ETM	169_060	1995	06/02	167-063	1995	07/01
ETM+	169_060	2003	04/02	167-063	2003	06/01
Aerial photos		1961	25/01		1975	10/02
		2008	07/09		2009	04/02

Table 1: Data types.

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sites. The 1976 images were re sampled to 30m with root mean square error of 5. Quick statistics were generated in ENVI 4.3 and converted in percentage then plotted for radiance observation (Figures 2 and 3). The mean values were lower in the 1985 Rumuruti scene and higher 1995 and 2003. In Malinda the mean values were almost similar in 1987 and 1995 but higher in 2003. Since the differences in radiance of the selected scene were significant, they were converted into reflectances. According to [11] it is important to normalise the data when dealing with multi sensor and multi temporal images to reduce noise resulting from sensor differences, sun angle and phenological effects. However care should be taken to make sure that the data quality is not degraded. Subset images were then created by clipping areas of interest.

Multivariate Alteration Detection (MAD) [12] was selected and used for normalization. MAD identifies no-change pixels in bi-temporal images automatically, which are then used for radiometric normalization. For the implementation of MAD analysis spatial subsets were chosen, which were used for the identification of no-change pixels. The statistics of these pixels were then applied to normalize the whole image with an orthogonal regression. The 2003 scenes from both sites were used for normalization. After normalization the images were clipped and a classification scheme was prepared and followed by image classification in ERDAS imagine.

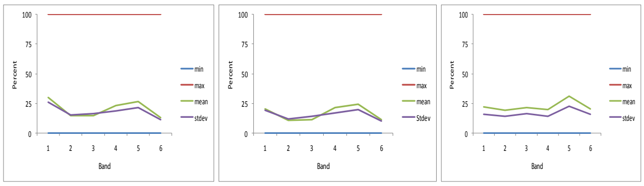

Figure 2: Radiance plots of Rumuruti scene 169_060_1985/1995/2003.

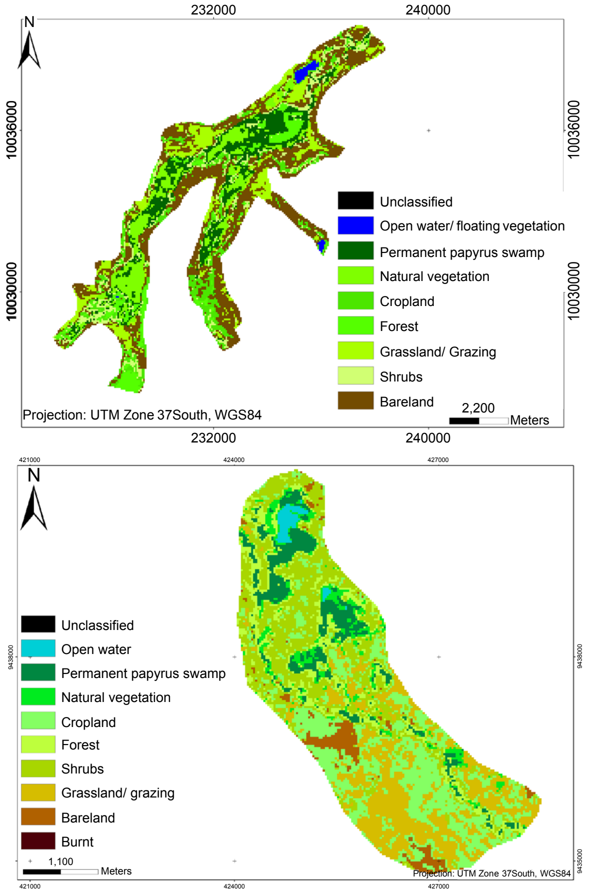

Figure 3: Radiance plots of Malinda scene 167_063_1987/ 1995/ 2003.

Data analysis

In order to determine the main land uses, a classification scheme was prepared (Table 2). According to [13], preparation of a scheme is a prerequisite in the classification process. Even though the wetland types may be adopted from known systems of classification, the detailed land use classification lies in the interest of the scientist. The scheme for this study was prepared after field observation of land uses and covers in the study areas.

Unsupervised classification method was opted for land cover/ use classification using the ISODATA clustering algorithm in ERDAS imagines 9.3. Even though the method is time consuming especially in cluster labelling, normally the analyst has no influence on the resulting clusters i.e. natural clusters are produced automatically [14] it also help to minimize spectral confusion among different classes [15]. Images from 1976, 1986/7, 1995 and 2003 were classified, the convergence value was specified as 0.99 and the maximum iteration was specified at 80, gray scale colour scheme was selected to be able to assign new classes in different colours. Nine clusters were produced per site as shown in figure 3 where two images 1976 and 2003 have been displayed as examples. The clusters were later identified and labelled using maps and aerial photographs. Signatures were generated for field identification of the classes. In the field 100 points were collected using Trimble PDAin UTM coordinate system for cluster labelling (50) and accuracy assessment (50) (Figure 4a and 4b).

Change Vector Analysis was applied for change detection, Interactive Data Language (IDL) program by [16] was used for analysis

Use type	Code	Description
Open water	OP	Areas permanently flooded with standing water for 12months.
Open water floating vegetation	OP/FV	Permanently flooded areas for more than 6 months with floating vegetation like Nile cabbage, which normally dry up during drought.
Permanent papyrus swamp	PS	Areas dominated with apyrus, other wetland vegetation like Typha domingesis exists, may be permanently flooded or with high soil moisture ontent throughout the year.
Natural vegetation	NV	Areas covered with other wetland vegetation like Cyperus species which survives in flooded conditions for 3months and less moisture condition for the rest of the months.
Cropland	CL	Cultivated areas with field crops rice, maize, beans etc or vegetables. Could be easonally flooded with high moisture content for most part of the year.
Forest	FO	Areas covered with either exotic or natural tree stands which are seasonally flooded.
Shrubs	SH	Shrub dominated areas mostly seasonally flooded.
Grassland/grazing	GG	Seasonally flooded areas dominated with Pennisetum or Cynodon that are used for animal grazing.
Burnt	BN	Seasonally flooded areas usually burnt in dry season.
Bare land	BL	Areas without vegetation cover due to prolonged drought or degradation.
Built up	BU	Settlements, roads or any other kind of infrastructure.

Table 2: Land cover/use classification scheme.

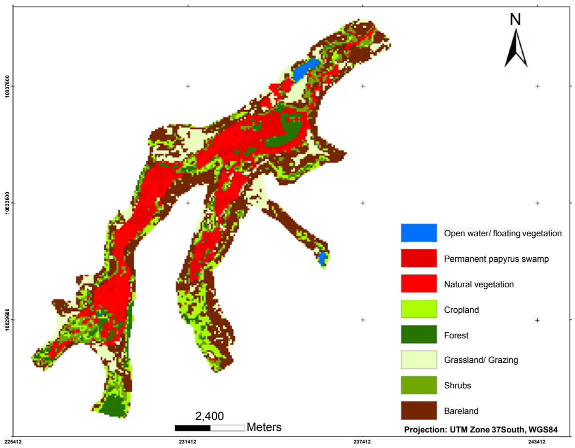

Figure 4a: Error! No text of specified style in document.a: MSS unsupervised (left) and ETM+ unsupervised (Right) LCLU maps of Rumuruti test site, 1976 & 2003.

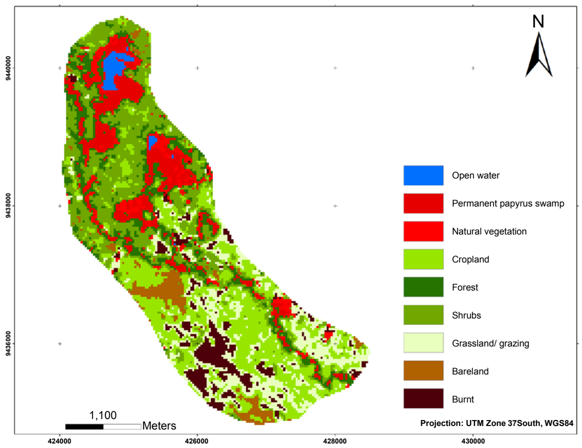

Figure 4b: MSS unsupervised (left) and ETM+ unsupervised (Right) LCLU maps of Malinda test site 1976 & 2003.

in ENVI software 4.3. Data sets of between 1976-1986, 1986/7-1995, and 1995-2003 were used for each site as inputs for analysis. Initially 1986/7 images were used as initial state images and 1995 images as final state, later 1995 images served as initial state and 2003 as final state in the second sequence of change detection. Two output images namely change magnitude and change direction, were generated per single analysis for each site.

Change thresholds were established in an iterative process using analysts' expert knowledge of the study areas. The thresholds of above 25 and 30 digital number values were used to identify areas with significant changes. This meant that change areas constituted between 75 and 79.2% of the wetlands and between 20.8 and 25% remained unchanged in the two time sequence. Figure 5 shows thresholds applied to the two study sites for images of between 1986/7 and 1995.

More information on the changes was obtained in change direction images. There were 23 output directions that equated eight different change types (Table 3). The change directions were the combinations of increase and decrease of reflectance in the three bands used in the study. Change vector analysis (CVA) is a robust approach for

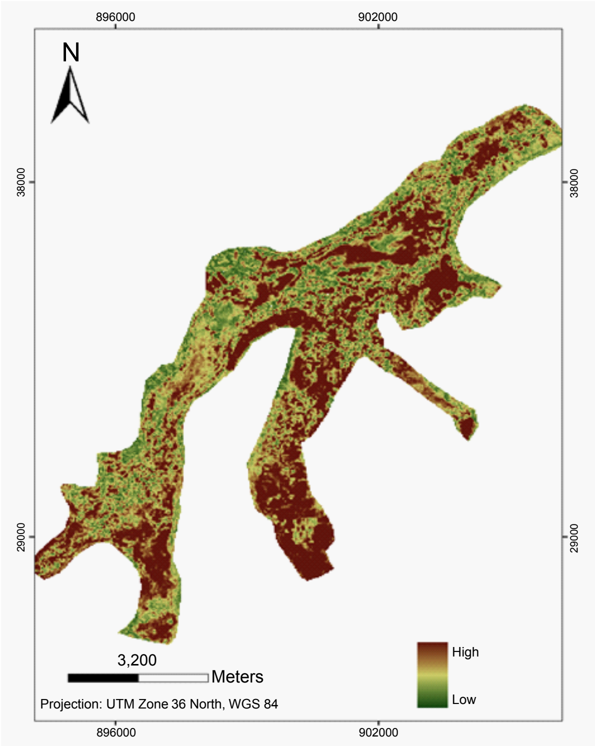

Figure 5a: Error! No text of specified style in document.: CVA magnitude threshold images for site a) Rumuruti b) Malinda presented with colour intensity, the brown colour represents high magnitude i.e. high LCLU, green colour represents low magnitude hence low LULC change 5a) Rumurthi.

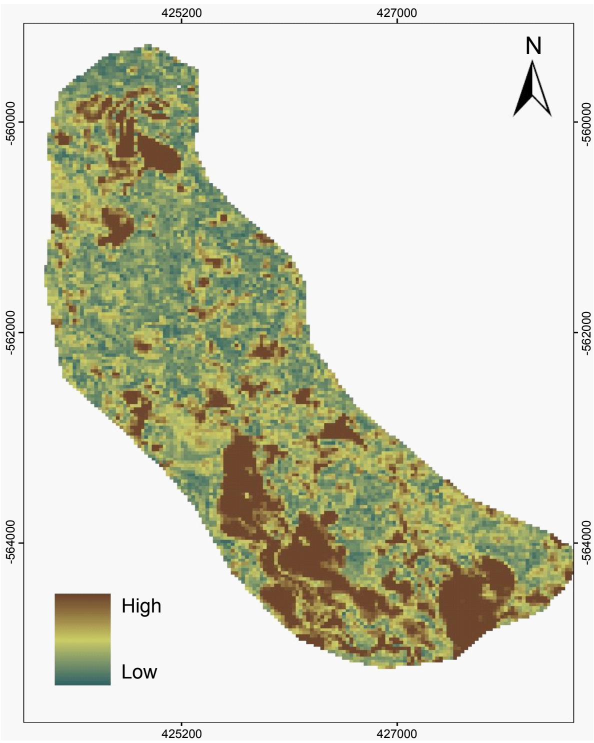

Figure 5b: Malinda.

	Code								
Band		1	2	3	4	5	6	7	8
	1	-	+	-	+	-	+	-	+
	2	-	-	+	+	-	-	+	+
	3	-	-	-	-	+	+	+	+

1-band 3, 2-band 4, 3-band 5

Table 3: CVA codes for LANDSAT-TM and ETM+.

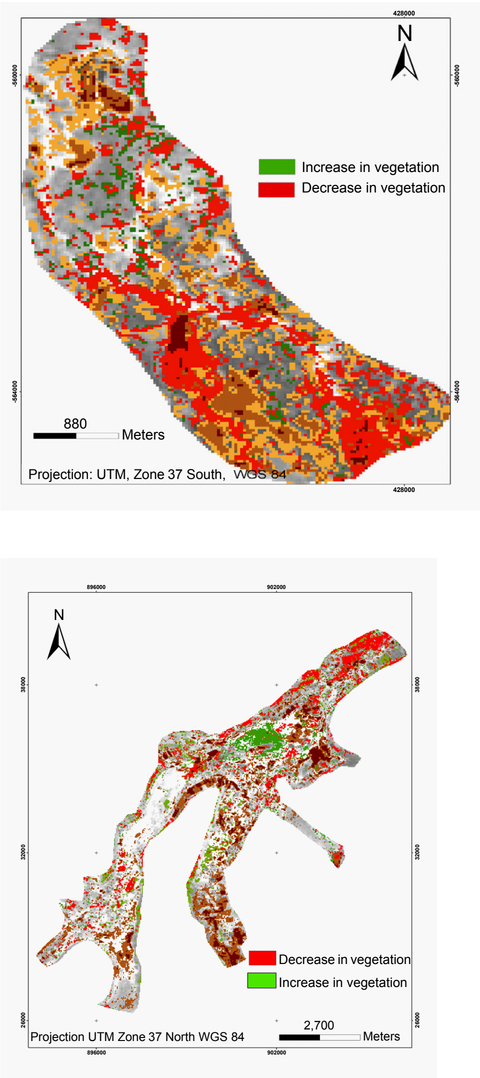

Figure 6: Change direction of interest overlaid on a grey scale LANDSAT image channel 4 and magnitude image of a) Rumuruti b) Malinda.

detecting and characterizing radiometric change in multispectral remote sensing data sets. CVA is reviewed as a useful technique to: (1) Process the full dimensionality of multispectral/multi-layer data so as to ensure detection of all change present in the data; (2) Extract and exploit the 'components' of change in multispectral data; and (3) facilitate composition and analysis of change images. Examples drawn from various projects are included throughout this methodological discussion, in order to illustrate the CVA approach and suggest its potential utility [17]. Suggest that, given the potentially large number of possible change vector directions, it is often desirable to implement some type of simplification in the characterization of change direction. This has been accomplished in a number of ways that vary in complexity and ease of implementation.

In some CVA applications, general characterization of change directions by virtue of the change space `sectors' in which they occur can be useful and sufficient. An arbitrary `sector code' may be assigned and used to distinguish these sectors, which represent general change directions. All codes with increase in all bands were selected, followed by decrease in all bands, codes with increase in vegetation (band -3&+4) and decrease in vegetation (band +3 and -4), then the remaining codes, which represent complex changes were combined. Percentages of change direction were calculated and, density slices were created for change directions with decreasing intensities, and decreasing values of magnitude. They were then displayed with bands of LANDSAT ETM+ as gray scale background (Figure 6). For change labelling, earlier classified images were used. Two different changes of interest, which were related to decrease in vegetation and increase in vegetation were selected. A comparison was done using earlier and later images.

Data from group discussions were recorded and qualitatively analysed using content analysis approach.

Accuracy assessment

For classified images accuracy analysis of the results was determined by overlaying 50 points (25 per site) that were collected in the field. Accuracy for CVA was done by comparing the LANDSAT scenes, which were used for analysis with relevant change direction codes that were more significant for wetland change i.e. code 3 and 4. The results where overlaid in ArcGIS with classified images.

Results and Discussion

Eleven main types of land use and cover were identified and classified. These included open water, floating vegetation, permanent papyrus swamps, natural wetland vegetation (mixed vegetation), cropland, forest (natural and exotic), shrubs, grassland or grazing, burnt areas, bare land and built up/settlements. Examples of the cover/uses are displayed in figure 5a and 5b. The uses were not uniform in both sites except open water, floating vegetation, papyrus swamps; grazing and burnt areas were common in both sites. The percentage of each LCLU is shown in figure 7. Cropland covered 35 and 24% in Rumuruti and Malinda, respectively, followed by grassland/ grazing combined with shrubs (11 and 39%) and bare land (17 and 4%). Natural vegetation covered the same percentage of 5% in both sites and open water covers 3%. Rumuruti is settled and the built up area covers 14%, no settlements were found in Malinda but seasonal burning was very common and covered 7%.

In Malinda there was no any settlement within or close to the wetland, people are settled far away from the wetland and mainly

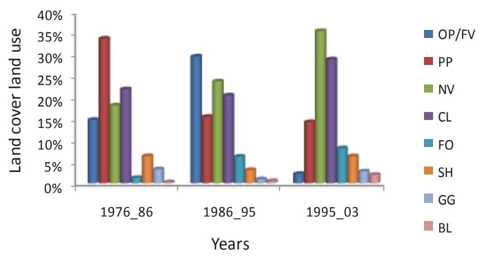

Figure 7: Area Coverage of different LCLU types in Rumuruti and Malinda sites 2003. BL-bareland; BU-built up; CL-crop land; FO-forest; FV-floating vegetation; GG grassland/grazing; NV-natural vegetation; OW-open water; PS-papyrus swamp; SH-shrubs.

come to the wetland for cultivation, fishing or harvesting macrophytes. The wetland is located in remote area and far from social services in addition during wet season floods cover the whole wetland thus making it a risky area to settle in. In contrast the fringes of Rumuruti wetland are settled mainly by squatters who cannot afford to buy land in better areas. Floods do not affect the settlements much as the fringes are a bit raised as compared to Malinda which is mostly a lowland area. Due to intense cultivation and the fact that there are so many wildlife around which feeds on crops, farmers are thus forced to stay nearby in order to guard their produce.

In Rumuruti the intensity of use is very high compared to Malinda, although they are both located in semi arid areas, Rumuruti serves a number of people, livestock and wildlife. In dry season for example, cultivation in the wetland increases, at the same time all the wild animals in the surroundings and livestock feed in the same area and it is also settled mainly by squatters. Over years the area put under farming have been increasing (Figure 8). The intensity of use is also contributed by the fact that Rumuruti is one of the areas that is used for production of horticultural crops like tomatoes, cabbage, French beans and kales, which feeds major cities of Kenya like Nairobi. During field work a number of trucks were seen carrying horticultural products ready for transportation. Malinda is mainly cultivated in wet season and grazed in dry season. Horticulture is minimally practised mainly for household consumption. Even though in permanently flooded areas of Malinda wetland is year round cultivated with rice there is no rice cultivation in Rumuruti probably because of its location in high altitude and climatic conditions.

The wetlands uses has no clear pattern because farms are scattered all over, in that case spectral signature mix among different land uses was a major classification challenge. In Malinda for example it was not

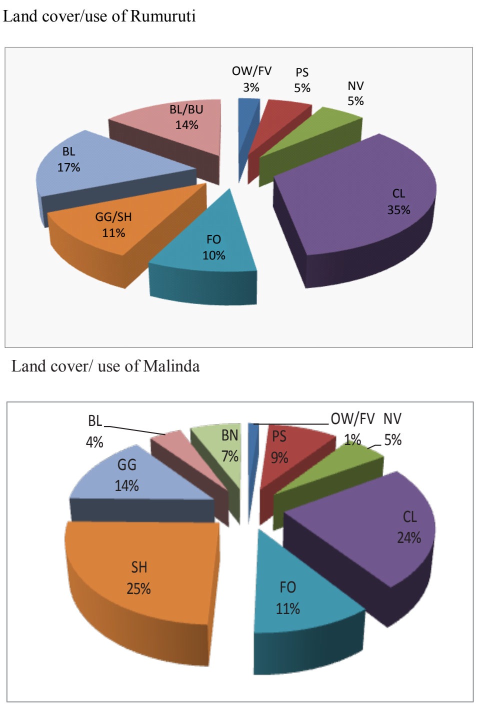

Figure 8: Time series LCLU of the Rumuruti test site. BL-bare land; BU-built up; CL-crop land; FO-forest; FV-floating vegetation; GG- grassland/grazing; NV- natural vegetation; OW-open water; PS-papyrus swamp; SH-shrubs.

possible to distinguish rice from Cyperus species because of similar reflectivity in all bands. Similarly in Rumuruti different vegetation types in the swamp could not be separated from field crops, maize for example were mixed with other wetland vegetation like Typha. It was also hard to distinguish bare surface and mud huts in Rumuruti. In such cases ground truth data assisted much in proper labelling of the classes.

In terms of land use change, in both sites there was decrease in areas covered by vegetation. The decrease in vegetation is related to areas that were converted from either natural vegetation or permanent swamps to cropland. Such areas were related to code 3 (Table 2) in the change direction and accounted for 47.76% in Malinda and 72.60% in Rumuruti. For instance in Rumuruti the area covered by open water/floating vegetation was 10.62 ha in 1986, it increased abruptly in 1995 to 127.69 ha and declined tremendously to 16.29 in 2003. The change was attributed to increased human activities in the wetlands, agriculture in particular, during dry season that requires vegetation clearance. These results corresponds to what [7] found out while using CVA to map changes in Gallatin valley of south west Montana, they observed that decrease in wetland cover accounted for major change in the wetland. The main factor contributing towards the decrease in vegetation is agriculture. Wood and Halsema [17] comment that agriculture in wetlands has double impact; clearing and tillage that lead to both physical and in situ loss. Some studies like [18] which deal with changes in wetlands also report loss of wetland due to agricultural activities worldwide. Most of them rank it as the first and most significant cause of loss of natural vegetation.

Another type of change observed was increase of vegetation which related to areas covered by permanent swamps and other natural wetland vegetation classes, some areas covered by shrubs were also included. A great contribution to this class was conversion from open water areas to permanent swamps or natural vegetation. These accounted for 30.85% in Malinda and Rumuruti 22.72% of the total wetlands. The changes were related to code 4 of change direction. Due to increased anthropogenic influence in the wetlands, there is an increase in nutrients deposition that leads to proliferation of alien vegetation like water hyacinth and Nile cabbage occupying the open water areas thus reducing their size. [19-21] ascertain that wetland uses degrade the quality and quantity of water and in particular un managed use lowers water levels and vegetation diversity.

Significant changes were observed in some parts of the wetlands. These were areas which were heavily drained and permanently converted into croplands or other uses like grazing. Both wetlands had parts, which were completely drained for horticulture or field crops like maize. Those areas were year round cultivated reducing the chances for wetland vegetation re growth or flooding possibilities in wet season. In Rumuruti there were some areas, which were completely degraded and abandoned because of over use. Further more changes in the wetlands were non directional, they were scattered all over the wetlands. This could be explained by the fact that, the two study sites are floodplains with varying wetness conditions. Some parts are permanently flooded while others are completely dry. Wetland conditions also vary with seasons, thus in dry season many parts of the wetlands are cultivated and in wet season some parts are normally abandoned due to increased wetness conditions which may hinder growth of some crops.

Changes were also very dynamic in wetlands in that, areas where the level of conversion is not very high normally vegetation re grow quickly making it difficult to have a clear pattern of change. According to [2] Ewaso Narok Swamp, formed along the Eng'are Narok River, is located in the semi-arid part of the Laikipia District, Kenya. The area, of bushy grassland, is characterised by low rainfall (less than 750 mm annually) and episodic rivers. Before the 1970s, the dominant land use was large scale ranching and nomadic pastoralism. Since 1970, this has slowly been transformed into high density small-scale farming. There has been a strong trend towards settlement along riverine and wetland areas due to their suitability for farming and easy availability of water for cultivation. Ewaso Narok swamp has a rich species diversity of over 170 bird species, resident and migrant, over 100 plant species and it also provides an important dryland refuge for both domestic and wild animals.

The swamp also provides socio-economic products such as plant matter for building. The result of its land use transformation has been ecosystem alteration, habitat modification and destruction both for wetland and rangeland species. This change has also been accompanied by escalating human–wildlife conflict. However, although this process is self-destructive, the lack of economic returns from wildlife to some extent justifies the land use transformation since the communities settling here have to satisfy the basic requirements of food and shelter. This poses the challenge of the developing appropriate ways to conserve the dryland wetlands whilst attaining maximum returns for the local community. Thenya [2] observed a quick re growth of cleared vegetation in Ewaso Narok swamp with onset of rainfall. Similar pattern of vegetation re growth was observed in Malinda and Rumuruti during the field survey, particularly in permanent flooded areas wetland vegetation grew very fast and at some points farmers had to stop cultivation because of excessive labour required.

Accuracy assessment

The overall accuracies were high as observed in table 4, they ranged from 88.28 to 95.17% with a Kappa index of 0.85 to 0.94. The MSS data had lower accuracies as compared to other LANDSAT data largely due to the resolution of the images. Producer accuracies for OP/FV in Malinda site for MSS and ETM data were the lowest (33.33%), which means many pixels were confused with other LCLU types. This was a result of spectral mixture between OP/FV and PS or other vegetation. In 1995 much vegetation were observed over the open water area, which didn't appear in the following images. User accuracies were higher, which means many LCLU were labelled correctly. For CVA accuracy assessment images when overlaid in ArcGIS matched well with their respective change classes. This means that CVA was able to distinguish the change areas appropriately. All classified images which were used for change labelling had accuracies above 86% and Kappa indices above 0.83 (Table 4 and 4b).

Drivers of wetland use change

As afore mentioned lack of sufficient ecological, socio-economic and demographic data made it difficult to conduct spatial analysis of land use change drivers. The following factors were described to be the main drivers of the changes:

Climate change is one of the main factors driving people to intensify wetlands use. It was argued that over the past 20 years, seasons have changed dramatically, rainfall is very variable and unreliable that cultivation on upland areas was very uncertain. Since wetlands offer food security options to farmers and livestock keepers because of availability of water or moisture content that support crop production and growth of pasture, most famers and livestock keepers shifted their attention to wetlands particularly in dry seasons. This argument is supported by [9,22] who also noted that drought conditions especially in semi arid areas have increased pressure on the wetlands for cultivation or search for pasture or fodder.

Another driver is rural impoverishment, in rural areas poverty, unemployment and underemployment are very high, and rural population is growing faster than rural employment creation. As other economic options disappear, increasing numbers of rural residents engage in wetland resource utilization to support their livelihood. Currently many people in the study areas engage in horticulture production for income generation as well as field crops for food security. This is because wetland soils are very fertile and can be cultivated with minimum investment in terms of inputs. However in those areas wetlands utilization is undertaken without control and proper management. The consequence of uncontrolled utilization is wetland degradation and loss. [1,17] confirms these arguments by noting that both population increase and poverty are among the major driving force of wetland use and consequent degradation.

Year	Accuracy %	OP/FV	PS	NV	CL	FO	SH	GG	BU	BL	Overall %	Kappa
1976	Producer	33.33	94.12	76.19	92.31	72.73	88.89	81.25	100		88.28	0.86
	User	100	76.19	94.12	80	80	88.89	92.86	93.88			
1986	Producer	50	100	60	100	66.67	97.22	93.33	66.67	75	92.41	0.91
	User	100	93.33	100	96.55	100	87.5	96.55	66.67	75		
1995	Producer	50	90.91	93.75	96.97	100	97.5	87.5	80	90.91	93.1	0.92
	User	100	90.91	88.24	96.97	100	95.12	93.33	88.89	83.33		
2003	Producer	100	100	93.55	100	100	100	100	71.43	25	95.17	0.94
	User	100	90	100	97.96	100	100	100	62.5	33.33		

Table 4a: Accuracy results Rumuruti test site.

Year	Accuracy %	OP/FV	PS	NV	CL	FO	SH	GG	BL	BN	Overall %	Kappa
1976	Producer	33.33	95	50	100	71.43	82.93	87.1	80		88.32	0.85
	User	100	79.17	80	84.62	83.33	91.89	75	80			
1986	Producer	100	84.21	89.47	76.19	93.75	73.33	100	76.92		94.48	0.93
	User	100	84.21	80.95	100	78.95	100	81.48	100			
1995	Producer	66.67	87.5	92.45	84.62	100	81.48	100	100		92.41	0.9
	User	100	82.35	92.45	84.62	86.36	100	71.43	100			
2003	Producer	100	97.92	93.55	70	87.1	90.91	93.75	90.91	91.67	94.48	0.94
	User	100	97.92	63.64	90	90.91	93.75	90.91	91.67	100		

Table 4b: Accuracy results Malinda test site.

Improvement in regional infrastructure like transport, market access and communication was identified to be another important driver to the increased trends of wetland use. Infrastructure facilitated increased wetland uses in rural areas since the linkage between rural and urban areas had also improved a lot. Farmers were able to communicate with their customers in urban areas and were assured of disposing their products to markets timely. Farmers sold their produce in the farms to the brokers who picked up the crops when they were ready for harvest. This was particularly the case for Rumuruti wetland where customers drove to the wetland to pick up the wetland products. Famers were also able to sell their crops at road side markets [17].

Wood and Halsema [17] argue that market forces are the major driver of wetland cultivation in Africa. The growing urban centres are a major stimulus for vegetable and some cereal cultivation. Similar observations were noted in this study, increased demand for wetland products in urban areas and neighboring countries contributed to over use of wetlands. Both poor and well off famers were intensifying their activities in the wetlands. There was an extensive use of high yielding seeds and pesticides to intensify wetland cultivation. Water from the wetlands was also used to support irrigation of upland farms. Diesel pumps were being used for water abstraction from wetlands to the uplands. Economic liberalisation in Tanzania (late 1980s'), in particular, has opened more markets within and outside the country for agricultural crops. In the past food crops were only sold in the domestic markets. Market failure for traditional cash crops like coffee, tea and cotton had forced farmers to reduce dependency on these crops as a source of income. Thus in both Kenya and Tanzania such farmers have turned their attention to either horticulture or other means of diversifying their economy. Ponte [5] noted that economic reforms carried out under structural adjustment programs in Tanzania since 1984 have brought a wave of changes in farming practices and rural livelihoods. Agricultural market liberalization and increased commercialization of rural life made farmers to switch from slow to fast growing cash crops. Farmers also switched from cash crops requiring high input use to those requiring low input.

Conclusion

This paper presented the results of land cover/ use classification and change analysis in Rumuruti and Malinda wetlands of Kenya and Tanzania respectively. Remote sensing was an important tool that facilitated mapping land cover/ use and detection of the changes. The results have revealed that the two wetlands are very diverse in terms of cover and use. Agriculture is one of the main land uses where field crops particularly rice in Malinda and horticulture in Rumuruti are cultivated year round, other uses includes grazing, settlements and macrophyte harvest. The intensity of use also vary a lot between the two wetlands, while Rumuruti is intensively used Malinda is extensively used especially for dry season grazing. A number of changes are taking place in the two study sites. The major changes detected were decrease in natural vegetation, shrinking of permanent swamps and increase of vegetation in areas covered by open water due to increased nutrients in the water resulting from human activities within the wetlands and from the upland areas. Some parts of the wetlands have been abandoned completely because of uncontrolled use. Climate change, poverty, infrastructure improvement, economic liberalization and availability of market forces are the main drivers of changes in the wetlands.

There is a need to monitor activities that are taking place in wetlands in order to ensure wise use of these precious resources. Remote sensing is a very important tool in monitoring and management of wetlands. The data generated in this study may assist in the monitoring of the two wetlands. The governments of the two countries should initiate more efforts to reduce poverty and create more livelihood options to rural communities in order to reduce high dependency on wetlands and other natural resource.

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References

1. Schuyt KD (2005) Economic consequences of wetland degradation for local populations in Africa. Ecol Econ 53: 177-190.
2. Thenya T (2001) Challenges of conservation of dryland shallow waters, Ewaso Narok swamp, Laikipia District, Kenya. Hydrobiologia 458: 107-119.
3. Maghimbi S (2007) Recent changes in crop patterns in the Kilimanjaro Region Tanzania: The decline of coffee and the rise of maize and rice. African Study Monographs 35: 73-83.
4. Ozesmi SL, Bauer ME (2002) Satellite remote sensing of wetlands. Wetlands Ecol Managt 10: 381-402.
5. Ponte S (1998) Fast Crops, Fast Cash: Market Liberalization and Rural Livelihoods in Songea and Morogoro Districts, Tanzania. Canadian J African Std 32: 316-348.
6. Haack B (1996) Monitoring wetland changes with remote sensing: An East African example. Environ Magne 20: 411-419.
7. Baker C, Lawrence R, Montagne C, Patten D (2007) Change detection of wetland ecosystems using Landsat imagery and change vector analysis. Wetlands 27: 610-619.
8. Kiai SPM, Mailu GM (1998) Wetland characterization and classification for sustainable agricultural development.
9. Rundquist DC, Narumalani S, Narayanan RM (2001) A review of wetlands remote sensing and defining new considerations. Remote Sens Rev 20: 207-226.
10. Mwita E, Menz G, Misana S, Becker M, Kisanga D, et al. (2013) Mapping small wetlands of Kenya and Tanzania using remote sensing techniques. International Journal of Applied Earth Observation and Geoinformation. 21:173-183.
11. Singh A (1989) Review Article Digital change detection techniques using remotely-sensed data. International Journal of Remote Sensing 10: 989-1003.
12. Canty M, Nilelsen AA (2008) Automatic radiometric normalization of multitemporal satellite imagery with the iteratively re-weighted MAD transformation. Remote Sensing of Environment 112:1025-1036.
13. Lyon JG (2001) Wetland Landscape Characterization: Techniques and Applications for Gis, Mapping, Remote Sensing, and Image Analysis Front Cover. Ann Arbor, pp. 135.
14. Jensen JR (1996) Introductory Digital Image Processing: A Remote Sensing Perspective. Prentice Hall PTR, California, pp. 526.
15. Kindscher K, Fraser A, Jakubauskas ME, Debinski DM (1997) Identifying wetland meadows in Grand Teton National Park using remote sensing and average wetland values. Wetlands Ecology and Management 5: 265-273.
16. Klein D (2001) Vergleich von Change Detection im Mount Kenia Gebiet. Diplomarbeit Geographisches Institut der Universität Bonn, Bonn.
17. Wood A, van Halsema GE (2008) Scoping agriculture – wetland interactions towards a sustainable multiple-response strategy, Food and Agriculture Organisation of the United Nations, Rome.
18. Liu K, Li X, Shi X, Wang S (2008) Monitoring mangrove forest changes using remote sensing and GIS data with decision-tree learning. Wetlands 28: 336-346.
19. Voldseth RA, Johnson WC, Gilmanov T, Guntenspergen GR, Millett BV (2007) Model estimation of land-use effects on water levels of northern prairie wetlands. Ecological applications 17: 527-540.
20. Dixon AB (2002) The hydrological impacts and sustainability of wetland drainage cultivation in Illubabor, Ethiopia. Land Degradation & Development 13: 17-31.

21. Johnston CA (1991) Sediment and nutrient retention by freshwater wetlands: Effects on surface water quality. Critical Reviews in Environmental Control 21: 491-565.

22. Franke J, Becker M, Menz G, Misana S, Mwita E et al. (2009) Aerial imagery for monitoring land use in East African wetland ecosystems. Geoscience and Remote Sensing Symposium, IEEE International, IGARSS 5: 288-291.

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