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The impact of land use and land cover change on biodiversity within and adjacent to Kibasira Swamp in Kilombero Valley, Tanzania

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Abstract

Wetlands are crucial ecosystems with multiple values and functions to a range of different stakeholders. The future of wetlands depends both on the legacy of the past and how they are currently used. Using 48 vegetation survey plots (0.08 ha) combined with Landsat 5 and 7 TM imagery, we assessed the influence of long-term (1990–2011) land use and land cover change on the biodiversity of the Kibasira Swamp. Information on perceptions of adjacent communities on historical changes and drivers for the changes were also collected. Results showed an increase in the area covered by open water by 1% and forest by 4% between 1990 and 1998 whilst *Cyperus papyrus* L and cultivated land area decreased by 8% and 3%, respectively on the same period. Between 1998 and 2011, there was a decrease in areas covered by water by 35% and forest by 9% whereas *C. papyrus* L increased by 40% and cultivated land increased by 8%. These changes have affected the biodiversity of the swamp and adjacent to it as numbers of mammals have declined. However, the Swamp still provides extensive habitat for plants and bird species despite the ongoing human pressure. Interventions may be necessary to maintain biodiversity in Kibasira Swamp to ensure sustainable ecosystem services.

Résumé

Les zones humides sont des écosystèmes essentiels avec de multiples valeurs et fonctions à une gamme de parties prenantes différentes. L'avenir des zones humides dépend de l'héritage du passé et de la façon dont ils sont actuellement utilisés. En utilisant 48 parcelles d'enquête sur la végétation (0,08ha) et les images acquises par les satellites Landsat 5 et 7 TM, nous avons évalué l'influence à long terme (1990-2011) de la modification de l'utilisation des terres et du couvert végétal sur la biodiversité du marécage de Kibasira. Des informations sur les perceptions des communautés adjacentes sur les changements historiques et les facteurs stimulant les changements ont également été recueillies et incluses dans l'évaluation. Les résultats démontrent une augmentation des surfaces couvertes par les eaux libres de 1% et de la forêt de 4% entre 1990 et 1998, tandis que *Cyperus papyrus* et les terres cultivées ont diminué de 8% et 3%, respectivement, durant la même période. Entre 1998 et 2011, les zones couvertes par l'eau ont diminué de 35% et les forêts de 9%, tandis que *C. papyrus* a augmenté de 40% et les terres cultivées ont augmenté

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de 8%. Ces changements ont affecté la biodiversité et la qualité des services écosystémiques du marécage en convertissant une partie du marécage en terres agricoles. Cependant, le marécage est encore un habitat sauvage potentiel pour les plantes et les espèces d'oiseaux malgré la pression humaine continue. Des interventions peuvent être nécessaires pour maintenir la biodiversité du marécage de Kibasira afin d'assurer des services écosystémiques durables.

KEYWORDS
anthropogenic degradation, ecosystem services, land cover, livelihoods, wetlands

1 | INTRODUCTION

Wetlands cover an area of 1.2 million km^2 and support the livelihoods of more than one billion people worldwide (CBD, 2016; IWMI, 2014; Millennium Ecosystem Assessment, 2005; Ramsar, 2016). Almost a billion households depend on wetlands for rice growing, over 600 million people rely on fishing and aquaculture, nearly half of international tourists go to wetland areas for recreation and supporting over 266 million jobs worldwide (Ramsar, 2016). In Africa, wetlands are estimated to cover from 220,000 km^2 to 1,250,000 km^2 (Tooth & McCarthy, 2007; Bullock et al., 1998), where about 5% of this coverage is in Tanzania (Crafter & Kamukala, 1993). Wetlands also contain exceptional levels of biodiversity and support many unique ecosystems and a variety of threatened species, yet threatened by current global and local degradation trends (Dudgeon et al., 2006; MEA, 2005; Sala et al., 2000; Barbier, 1993). Land use changes associated with increasing demand for agriculture, livestock grazing and settlement have been identified as main causes of wetland degradation (Jenkins, Corti, Fanning, & Roettcher, 2002; Rebelo, McCartney, & Finlayson, 2010; Samora, Moe, Totland, & Munishi, 2012).

Wetlands in East Africa are rapidly changing at a range of timescales (MEMR, 2012; Rucina, Muiruri, Downton, & Marchant, 2010) resulting in rapid declining of wetland-dependent species from niche habitat degradation and loss (Dudgeon et al., 2006; Millennium Ecosystem Assessment, 2005). For example, the main cause of decline in Puku antelope (*Kobus vardonii*) population in Kilombero Valley Ramsar Site (KVRS) of Tanzania is due to high rates of land use changes (Bonnington, Steer, Lamontagne, Owen, & Grainger, 2010; Bonnington, Weaver, & Fanning, 2007); according to Birdlife International (2014), the population of Kilombero Weaver (*Ploceus burnieri* [VU]) has declined due to the continued conversion of the Swamps in the Kilombero river floodplain to cultivation and pasturelands. Moreover, increasing competition for the pasture between livestock and wildlife in Kilombero Valley is threatening the survival of wild animal populations and other biodiversity (Bonnington et al., 2007; Jenkins et al., 2002).

Kibasira Swamp underpins the livelihoods of the people who live adjacent relying on cultivation of rice and harvesting a range of aquatic resources such as fish and weaving materials. Therefore, the degradation of Kibasira Swamp will also affect the livelihoods of people living in the valley who depend on the abundant of natural resources such as fish, game, cropland and grazing fodder (Starkey et al., 2002). Although the Swamp covers a relatively small area, it is enormously important, acting as a source of food and water for people living nearby (Starkey et al., 2002). Previous studies have shown the wetland biodiversity status and drivers of changes in the Kilombero Valley (Samora et al., 2012; TAWIRI, 2011; Bonnington et al., 2010; Jenkins et al., 2002; Starkey et al., 2002), but little has been done to assess the long-term influence of land cover/use change on biodiversity. Here, we present a descriptive study of recent land use/cover changes associated with Kibasira Swamp and examine the socio-ecological interactions with the surrounding communities to understand drivers of change. Specifically, we (i) assessed the land use/cover changes in the Kibasira Swamp between 1990 and 2011, (ii) determine the impacts of land use/cover change on biodiversity, (iii) determine the current baseline plant and bird species composition of Kibasira Swamp, (iv) identified socio-economic and human-induced drivers of wetland degradation and biodiversity losses.

2 | MATERIALS AND METHODS

2.1 | Study site

Kibasira Swamp is located in the southern part of the Mofu village in the Kilombero Valley Ramsar Site (KVRS). KVRS is situated between Udzungwa Mountains and Mahenge Escarpment in Kilombero District and Ulanga District, Morogoro Region, in Tanzania (Figure 1). Kilombero Valley has total catchment area of about 40,000 km^2 (Mombo et al., 2011; Samora et al., 2012) and is the largest low-elevation freshwater wetland in East Africa. The Kilombero Valley has bimodal rainfall distribution with an annual average between 1,200 and 1,400 mm, with periods of short rains between December and February and long rains between March and May (Bonnington et al., 2007). The wetland is estimated to have 7,967 km^2 wet area (Ramsar, 2002) with 6,912 km^2 (86.8%) being designated as Game Controlled Area (TAWIRI, 2011). There is significant seasonal variability in the extent of the wetlands and their connectivity within the valley. The flood plain is dominated by tall *Panicum maximum* Jacq and *Pennisetum* grasses, miombo woodland

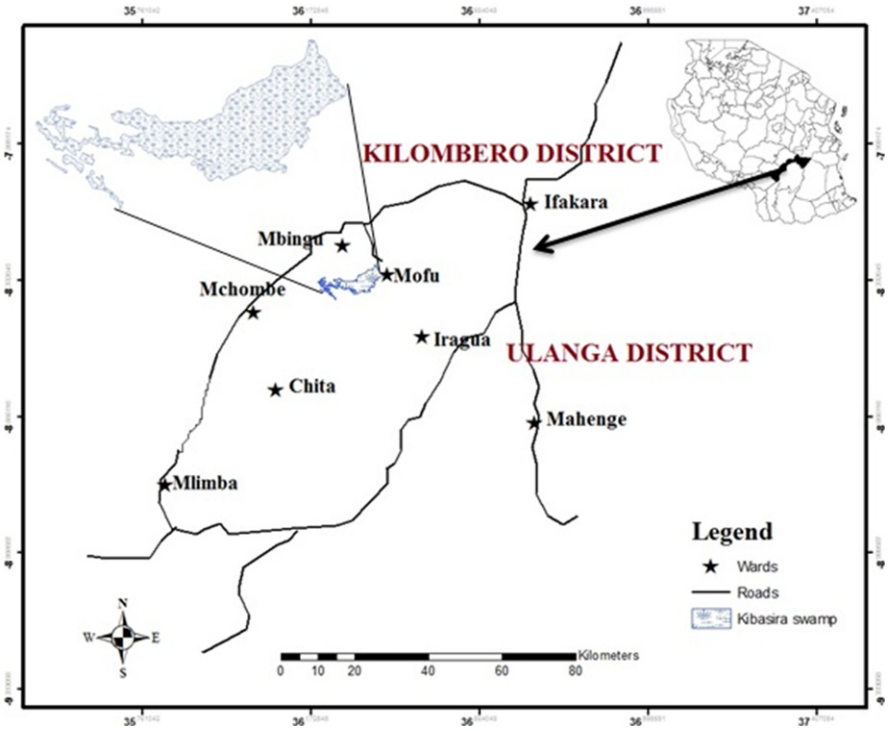


FIGURE 1 Location of Kibasira Swamp in Kilombero Valley Ramsar Site

patches dominated by *Brachystegia* spp., *Julbernardia* spp., *Kigelia africana* (Lam.) Benth, *Lonchocarpus capassa* Rolfe and *Combretum* spp. (Starkey et al., 2002). Based on 2012 census, population of Kilombero District is 407,880 and about 11,722 people in Mofu. The main ethnic groups are Wandamba, Wabena, Wapogoro and several others such as Wasukuma and Maasai who are mainly migrant livestock keepers (URT, 2013).

2.2 | Study design and data collection

For flora and fauna survey, the Swamp and surrounding areas were classified into five habitat types (Swamps, farmland, grassland, wooded grassland and woodland) based on land use and vegetation types (Jenkins et al., 2002). Systematic sampling was employed with the first plot being established by simple random sampling technique. Transects were established across different habitats along anthropogenic disturbance gradients.

The Swamp was considered as the central core habitat where eight transects of 3 km length were established radiating from the Swamp outward. Along these transects, 48 nested plots of 20 by 40 m for tree species, 5 by 5 m for shrubs and 2 by 2 m for herbs and grasses were established at a distance of 500 m apart. Within each plot, all plant structural forms were enumerated and identified as trees, shrubs, herbs, grasses and sedges (Starkey et al., 2002; Sutherland, 2006). Each plot was georeferenced using GPS map 60CSx with 3–4 m spatial error that should be considered for future monitoring.

Sixteen transects were established from the core habitat for avifauna survey in comparison with eight vegetation transects due to evening and morning surveys. Point counts were adopted for bird survey, whereby 10 minutes was used to count individual birds in a fixed station of 50 m radius. Interpoint distance of 500 m was employed following a 3-km transect (Sutherland, 2006).

Very little historical biodiversity data for Kibasira exist; thus, interviews were conducted to understand the recent conditions and changes at the Swamp. The selection of respondents for interviews was based on a simple random sampling technique. A semi-structured questionnaire with both open-ended and close-ended questions was administered to villagers, key contacts, and village officials, who have lived in the area for more than 20 years (n = 90) to get information ascertaining the historical features, fauna and degradation events of the Swamp. The information collected was used to understand the past perceptions on biodiversity and drivers of change.

The shapefile digitized from the toposheet (Series Y742, Edition 1—TSD) published by Surveys and Mapping Division, Ministry of Lands, Housing and Urban Development, Tanzania, in 1983 was used to clip the area of interest (AoI: Kibasira Swamp) from the acquired satellite imagery. Landsat 5 and 7 TM images for the years 1990, 1998 and 2011 were acquired in July to enhance spectral separability and used to quantify the dynamics of land use and cover in 21 years of time. Trial supervised classification gave poor results when classification includes 3 km buffer from the centre of the Swamp by including its adjacent areas. Therefore, only the Swamp boundary was considered for change detection analysis. Ground truthing was conducted during the field survey between 7 December 2013 and 28 December 2013 with the aid of GPSmap 60CSx to

validate the five major land cover classes: open water, forest, *Cyperus papyrus* L (sedge), *Phragmites* (reeds) and cultivated land. The identified land cover was mapped and used to perform supervised classification.

MODIS fire hotspots were downloaded from Fire Information for Resource Management System (FIRMS) for the available period from 2001 to 2013 as shp files with 1-km resolution (source: https://firms.modaps.eosdis.nasa.gov/download/). These data were used to determine fire events occurred in Kibasira Swamp.

2.3 | Data analysis

Bird and plant species richness (*S*), Shannon (*H*) and Simpson index as measure of diversity were analysed using Biodiversity R package in R 3.2.1 software (R Development Core Team, 2015). The abundance of fauna (birds) and richness of flora were compared across different habitat types along disturbance gradients. Bird abundance was computed in different habitat basing on formulae in Sutherland (2006).

$$D = \frac{(n_i + n_2)}{(\pi r^2 m)} \log_e \frac{(n_1 + n_2)}{n_2} \quad (1)$$

where

r = radius of the first zone
n_1 = number of birds counted within r
n_2 = number of birds beyond r
m = number of replicate plots in the set

Data obtained through interviews were processed and analysed using IBM SPSS version 20. Descriptive statistics were summarized and tabulated to report all quantitative information. Percentage was computed to enhance inferences related to socio-economic findings.

Supervised classification was performed using ERDAS IMAGINE software version 2011. Ground truthing data were used to train image fields in different classes, and where necessary, different classes were identified by inspecting an enhanced colour composite imagery. Spectral differentiation of *C. papyrus* L and other emergent aquatic plants is possible in certain cases (Adam & Mutanga, 2009); however, differentiation between *C. Papyrus* L sedges and *Phragmites* was not resolved. Thus, the two classes were combined into one, resulting in four major classes: open water, emergent aquatic plants (papyrus sedges and reeds) that was termed as *Papyrus* due to its dominance, cultivated land and forest. Areas with similar spectral characteristics were trained and classified. Postchange detection analysis was performed to determine the dynamics of land use and land cover between different time periods. The error matrices were prepared and used in computation of kappa coefficient for the classification accuracy assessment. Attribute tables resulted from the change detection analysis through overlay of classified maps were exported to Microsoft Excel to compute area change and rate of change for 1990 up to 2011. The estimation of the rate of change for the different covers was computed based on the following formulars (Kashaigili & Majaliwa, 2013).

Fire hotspots were classed as higher accuracy (≥50% detection confidence; (Pfeifer, Truman, & Rubin, 2012), which may underestimate detections, and <50% confidence, which was included to examine all detections as MODIS active fire detections are generally underestimate fire activity due to sampling intervals, detectability thresholds and resolution. Fires were plotted within the Swamp surface and a 1 km buffer from the margin and their annual and monthly (seasonal) temporal frequencies plotted in histograms.

$$\%\,\text{Cover change} = \frac{\text{Area}_{\text{iyear}x} - \text{Area}_{\text{iyear}x+1}}{\sum_{i=1}^{n} \text{Area}_{\text{iyear}x}} \times 100\% \quad (2)$$

$$\text{Annual rate of change} = \frac{\text{Area}_{\text{iyear}x} - \text{Area}_{\text{iyear}x+1}}{t_{\text{years}}} \quad (3)$$

$$\%\,\text{Annual rate of change} = \frac{\text{Area}_{\text{iyear}x} - \text{Area}_{\text{iyear}x+1}}{\text{Area}_{\text{iyear}x} x t_{\text{years}}} \times 100\% \quad (4)$$

where

$\text{Area}_{\text{iyear}x}$ = area of cover i at the first date.
$\text{Area}_{\text{iyear}x+1}$ = area of cover i at the second date.
$\sum_{i=1}^{n} \text{Area}_{\text{iyear}x}$ = total cover area at the first.
t_{years} = period in years between the first and second scene acquisition dates.

3 | RESULTS

3.1 | Flora and fauna of Kibasira Swamp

A total of 117 different plant species from 40 different families and 126 bird species in 55 different families were observed in and adjacent Kibasira Swamp. Mean plant species richness was higher in miombo woodlands than in other habitat types (Table 1). Farmlands appeared to have higher bird mean species richness as compared to other habitats despite having lower mean plant species richness (Table 1). The Swamp had substantial abundance of aquatic bird species with higher mean bird abundance per km^2 as compared to all other habitat types (Table 1). It also hosts IUCN Red-Listed bird species such as Kilombero weaver (*P. burnieri*), which is vulnerable and endemic in Kilombero Valley, Martial Eagle (*Polemaetus bellicosus* [VU]) and Southern Banded Snake-Eagle (*Circaetus fasciolatus* [NT]).

3.2 | Socio-economic information on the past biodiversity and drivers of changes

Majority of respondents indicated overgrazing (98%), agriculture (95%) and fire (93%) to be the main drivers for the land cover changes in the area (Table 2). The main factors mentioned as contributing to overgrazing were individual livestock keepers owning large herds of livestocks (over 300 cattle), and other contributing drivers of change include fire which is used to open up the Swamp by burning the floating vegetation for fishing and crop cultivation while increasing in population has contributed much to agriculture expansion. Other identified drivers for the changes include deforestation (81%),

TABLE 1 Average bird abundance, species richness, species diversity plant species richness and diversity of the Kibasira Swamp in Kilombero Valley, Tanzania

	Birds (n = 83)				Plants (n = 48)		
Vegetation type	Abundance (Bird/km^2)	Richness	Diversity Shannon	Diversity Simpson	Richness	Diversity Shannon	Diversity Simpson
All	161 ± 10	8.3 ± 3	1.73 ± 0.5	0.74 ± 0.2	8 ± 5	1.2 ± 0.6	0.63 ± 0.2
Swampy (Water area)	296 ± 41	14 ± 4	1.4 ± 0.4	0.56 ± 0.2	5 ± 3	0.76 ± 0.9	0.58 ± 0.3
Farmland	24 ± 5	19 ± 5	2.5 ± 0.3	0.87 ± 0.04	3 ± 2	0.57 ± 0.2	0.42 ± 0.5
Grasslands	18 ± 4	15 ± 3	2.1 ± 0.5	0.8 ± 0.1	5 ± 3	0.78 ± 0.7	0.57 ± 0.3
Wooded grassland	15 ± 7	11 ± 7	1.7 ± 1	0.89 ± 0.2	4 ± 2	0.92 ± 0.2	0.60 ± 0.4
Woodland	9 ± 6	18 ± 6	0.7 ± 0.8	0.42 ± 0.8	6 ± 3	1.1 ± 0.5	0.63 ± 0.3

TABLE 2 Local people's perception on the drivers of land use/cover dynamics for Kibasira Swamp in Kilombero Valley, Tanzania

	Percentage response (n = 90)		
Driver of change	Agree	Disagree	Not sure
Agriculture	95	2	3
Deforestation	81	11	8
Livestock grazing	98	2	0
Insufficient knowledge	76	3	21
Fire	93	0	7
Settlement	63	37	0

insufficient knowledge on environmental issues (76%) and settlement (63%). The majority of people adjacent to Kibasira Swamp indicated that before the 1990s areas around Kibasira Swamp used to harbour large population of Puku antelopes (*K. vardoni*), buffalos (*Syncerus caffer*), bushbucks (*Tragelaphus scriptus*) and elephants (*Loxodonta africana*). Currently, these animals are very rare to find around the Swamp; the declining trend in species abundance is suggested to have started in early 1996 after the influx of livestock keepers around the Swamp.

3.3 | Land use/land cover change of the Kibasira Swamp

The developed error matrix using reference data from ground truthing was used to perform overall users and producer's accuracy in combination with the kappa coefficient. The results indicate good and acceptable overall classification result with overall accuracy of 84.21% and a kappa coefficient of 0.73 (Turan & Günlü, 2010).

Land cover maps and the detailed description of the cover area for the year 1990, 1998 and 2011 are presented in Figure 2, and area change for the periods of 1990–1998 and 1998–2011 is shown in Table 3. Generally, land cover maps depict the significant land cover/use change within 21-year period and the overall classification accuracy was 84.21% and a kappa coefficient of 0.73 an indication of good and acceptable overall classification (Turan & Günlü, 2010). The Swamp was covered by 2194 ha (47%) of open water, 505 ha (11%) of forest, 1288 ha (27%) of *Papyrus* sedges (*C. papyrus* L) and 709 ha (15%) of cultivated land in 1990. In 1998, Kibasira Swamp was covered by 2219 ha (47%) of water, 694 ha (15%) of forest, 1206 ha (25%) of *Papyrus* sedges and 586 ha (12%) of cultivated land, and in the year 2011, the Swamp was covered by 553 ha (12%) of water, 262 ha (6%) of forest, 2781 ha (59%) of *Papyrus* and 959 ha (20%) of cultivated land. There was a slight increase of the area covered by water by 1% (25 ha) and forest by 4% (189 ha) for the period 1990–1998. On the other hand, there was a decrease in area covered by *Papyrus* sedges by 8% (398 ha) and cultivated land by 3% (123 ha; Table 1). For the period 1998–2011, there was a decrease in area covered by water by 35% (1665 ha) and forest by 9% (432 ha) while that of *Papyrus* sedges increased by 40% (1891 ha) and cultivated land increased by 8% (333 ha; Table 3). Forests and areas covered by open water increased annually by a rate of 5% and 0.1%, respectively, for the period 1990–1998 while *Papyrus* sedges and cultivated land both decreased by annual rate of 2% for the same period. There was annual decline of areas covered by open water and forest by an annual rate of 6% and 5%, respectively, while areas covered by *Papyrus* and cultivated land increased by annual rate of 21% and 5%, respectively, for the period of 1998–2011.

3.4 | Fire events in Kibasira Swamp

A total of 49 fire detections occurred within the Swamp between 2001 and 2013, with 87.8% (n = 43) of detections ≥50% and 12.2% at <50% confidence. Fires were most frequent in 2010 and occurred in many areas of the Swamp. In 2005, 2007, 2008, 2011 and 2013, few fires were detected. Most fires occurred in October, with fewer fires in November and December; although on occasion fires occurred July–September. In 2006, fires were the most energetic as shown by the high fire radiative power values (Figure 3b). There is a lack of long-term historical information on fire activity in this area (Marlon et al., 2016).

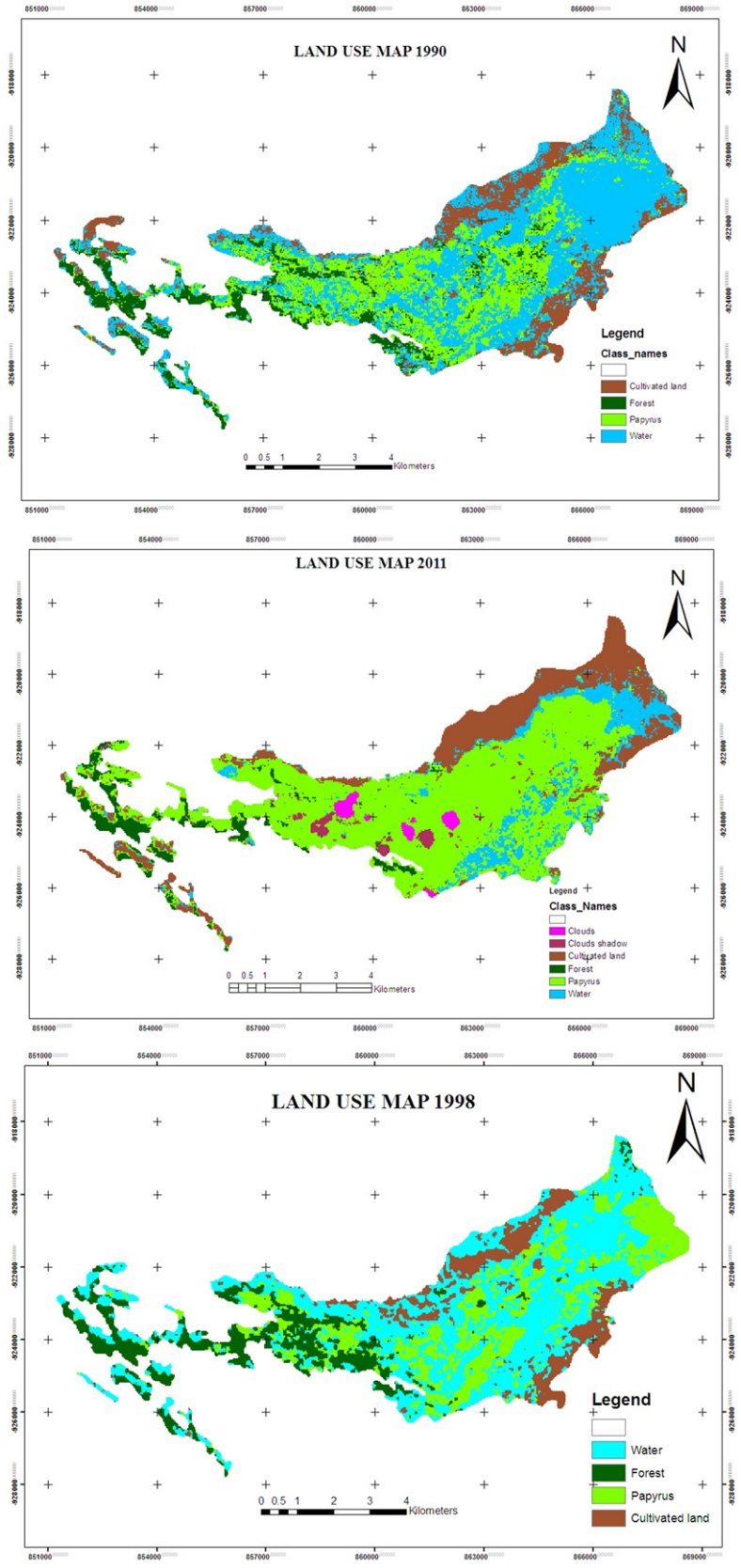


FIGURE 2 Kibasira Swamp land cover map for the years 1990, 1998 and 2011

TABLE 3 Cover area, change area and annual rate of change between 1990 and 2011 for Kibasira Swamp in Kilombero Valley, Tanzania

Cover Class	1990 Cover area (ha)	1990 % Cover coverage	1998 Cover area (ha)	1998 % cover coverage	2011 Cover area	2011 % Cover coverage	Change area (ha) (1990–1998)	Change area (ha) (1998–2011)	% Change (1990–1998)	% Change (1998–2011)	Annual rate of change (ha/year) (1990–1998)	Annual rate of change (ha/year) (1998–2011)
Water	2,194	47	2,219	47	553	12	25	−1,665	1	−35	3	−128
Forest	505	11	694	15	262	6	189	−432	4	−9	24	−33
Papyrus	1,288	27	1,206	25	2,781	59	−398	1,891	−8	40	−50	145
Cultivated land	709	15	586	12	959	20	−123	373	−3	8	−15	29
Total	4,695		4,704		4,555							

4 | DISCUSSION

4.1 | Flora and fauna of Kibasira Swamp

We found high plant species richness in woodlands and low plant species richness in grasslands contrary to other reports in Kilombero Valley grasslands (Samora et al., 2012), possibly due to differences in sampling techniques used. Bird species richness was higher in farmlands compared to wetter habitats because they are rich of food, accommodating diverse birds of different feeding habit while wetter areas are restricted mostly to aquatic birds and birds of prey (Baker & Baker, 2002; Mulwa, Böhning-Gaese, & Schleuning, 2012; Starkey et al., 2002). There is a close link between land use/cover change and biodiversity loss (Dudgeon et al., 2006; Millennium Ecosystem Assessment, 2005; Mungo & William, 2003). The trend of biodiversity in the study area was mostly influenced by land use/cover change given the fact that plant species richness was lower in areas that had greater anthropogenic influences such as farmlands and grazing lands (Bonnington et al., 2007, 2010; Jenkins, Maliti, & Graham, 2003; Jenkins et al., 2002; Society for Environmental Exploration, 2009). It is reported that woodland patches within the Kilombero Valley provided a refuge for different wildlife species during the wet season (Bonnington et al., 2007, 2010; Jenkins et al., 2002; Starkey et al., 2002), and thus, the conversion of forest and woodland cover to grazing and cropland is exposing wild animals to illegal hunting and may lead to further increase in agriculture–wildlife conflicts (Jenkins et al., 2002). The declining trend of important species in Kilombero Valley such as the wetland-dependent Puku antelope (*K. vardoni*) due to increased land use/cover change previously reported by Bonnington et al. (2010) and Jenkins et al. (2003) is also supported by villagers in Mofu. It is known that, at least 6,912 km^2 of Kilombero Valley is designated as Game Controlled Area where licenced trophy hunting is carried out, but this has negligible impact on wildlife species as compared to habitat fragmentation and illegal hunting (Jenkins et al., 2003). Kibasira Swamp and Kilombero Valley at large will continue to face habitat loss due to increased anthropogenic pressure resulting from high human population (Ntongani, Munishi, More, & Kashaigili, 2014; Starkey et al., 2002). This will continue to cause the decline in biodiversity of the Swamp and other parts of Kilombero Valley. Although there is continuing anthropogenic degradation that causes lots of habitat fragmentation in Kibasira Swamp and Kilombero Valley at large, most of the biodiversity including flora and fauna goes unquantified. Linking these land use/cover dynamics and the loss of biodiversity is crucial to know how much we lost, and how much we will lose if the trend continues to be the same. Policymakers and management authorities should adopt an approach to provide a "buffer zone" around the main loci of biodiversity concentrations, while at the same time promoting socio-economic and cultural activities to enhance biodiversity conservation in wetlands and local livelihoods improvement (Munishi et al., 2011).

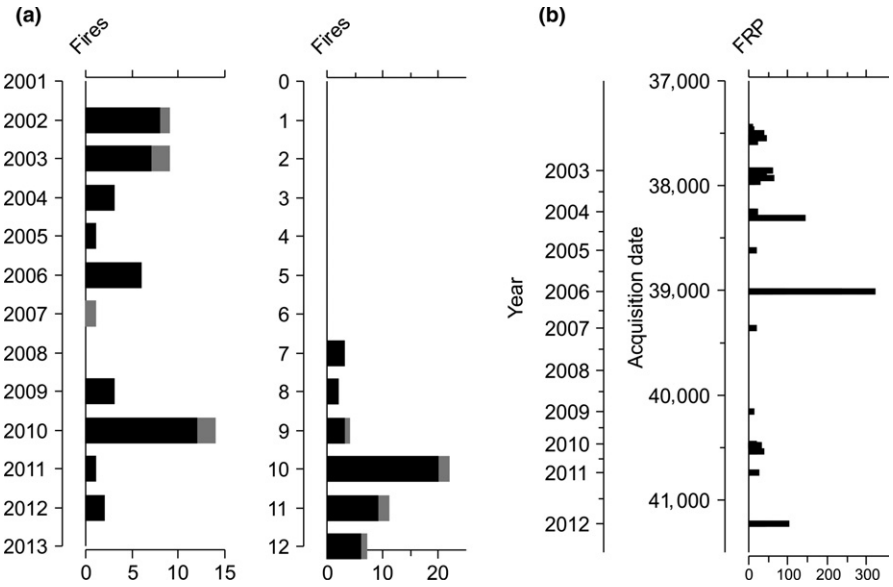


FIGURE 3 (a) Fire hotspots within the Swamp distributed by years (2001–2013) and months (January = 1, December = 12). Grey bars represent fires with <49% confidence, and black are >50%. (b) Fire radiative power (FRP) of all 49 within Swamp MODIS hotspot detections from 2001 to 2013 at Kibasira Swamp. Stratified by acquisition date and time and converted to years for secondary *y*-axis

4.2 | Socio-economic information on the past biodiversity and drivers of changes

It is important to take into account local indigenous knowledge on natural resource dynamics which set a clear identification of the linkage between social activities, natural resources and socio-ecological interactions (Kioboe, Vinding, Salazar, Tuxen, & Munk-Ravnborg, 2005; Ntongani et al., 2014). Majority of respondents indicated livestock grazing (98%), agriculture (95%) and fire (93%) to be the main drivers for the land cover changes in the area, in agreement with observations by Ntongani et al. (2014). The main factors contributing to livestock grazing and fire incidence were large herds of livestocks (over 300 cattle owned by single livestock keeper) and use of fire to open up areas for fishing and crop cultivation coupled with increasing in population (Kangalawe & Liwenga, 2005). Overgrazing of livestock is known to be a threat to biodiversity in many parts of Kilombero Valley as a result of excessive livestock numbers (Bonnington et al., 2007). Other identified drivers for the changes include deforestation (81%), insufficient knowledge on environmental issues (76%) and settlement (63%). Moreover, people around the Swamp showed their concern on the declining trend for Puku antelopes (*K. vardoni*), buffalos (*S. caffer*), bushbucks (*T. scriptus*) and elephants (*L. africana*) after the influx of livestock keepers in most parts around the Swamp. This incidence of declining trend of biodiversity (i.e. Puku antelopes [*K. vardoni*]) due to land use/cover changes also suggested by Bonnington et al. (2010, 2007) and Jenkins et al. (2002).

4.3 | Land use/cover change at Kibasira Swamp

Land cover maps (Figure 2) for Kibasira Swamp indicates there is notable variation in land use/cover between periods under consideration. The observed changes in Kibasira Swamp are brought about by many factors and in large part being human induced (Bonnington et al., 2007; Kangalawe & Liwenga, 2005; Kashaigili, Mbilinyi, McCartney, & Mwanuzi, 2006; Kashaigili, McCartney, et al., 2006; Ntongani et al., 2014). Large part of Kibasira Swamp has been converted to cultivated lands, and the use of fire is increasingly pausing a threat to the Swamp. Kibasira Swamp is perennially moist and does not ephemerally dry out during the dry season (Starkey et al., 2002). However, the current trend of anthropogenic pressure is threatening its potential for biodiversity conservation and ecosystem services provisioning. The increase in *C. papyrus* between 1998 and 2011 that covers large area of open water is an evidence of increased sediment loads resulted from livestock grazing and agricultural activities causing a gradual infilling of the Swamp (URT, 2006). This is forcing the community adjacent the Swamp to employ other ways such as the use of fire to open up the inner part of the Swamp for fishing activities which will continue to pause a severe threat to the biodiversity of the Swamp as in many other parts of Kilombero Valley (Ntongani & Samora, 2013; Ntongani et al., 2014). Furthermore, it is important to note that satellite images are able to tell us about the land cover change taking place in between 1998 and 2011, but not plant diversity. Vegetation adjacent to the Swamp particularly miombo has undergone different growth or recruitment stages after disturbance, whereby diversity will differ between earlier succession and climax. It is possible that moderate levels of disturbance will result in high diversity of plant species while high levels of disturbance will result in low diversity (Connel, 1978). Interestingly, Kibasira Swamp used to receive water from Ruipa via the Ngumbingumbi stream, but as revealed by respondents of Mofu village, the stream was intentionally blocked in 1994 by villagers to secure the most flooded land for agriculture, which contributed to the reduction in Swamp size. Contrary to what was reported by Starkey et al. (2002), the Swamp is currently prone to human activities because of high accessibility. The increasing number and distribution of human population will be an important factor in determining the loss of biodiversity of the area in the near future.

Fires occur in Kibasira Swamp primarily due to intentional anthropogenic burning (Figure 3). Parts of the Swamp are slashed and burned to open up space for fish that are trapped and consumed by people. Purposeful opening of the *C. papyrus* L areas of the Swamp by slashing and burning does lead to more open water conditions conducive for catching fish and changing water chemistry primarily by increasing dissolved oxygen content of the water column due to atmosphere–water transfer. Fish are both used as food and for income generation. Future increases in this land use may lead to biogeographic shifts in plants and animals, create more open water habitat, and influence the hydrology, nutrient cycling, and redox conditions within the water column and at the water–sediment interface (Chale, 1985; Okurut, Rijs, & van Bruggen, 1999).

5 | CONCLUSIONS AND RECOMMENDATIONS

There is a strong evidence that land use/cover of Kibasira Swamp has changed substantially over time. These changes were dominated by anthropogenic activities to convert most parts of the Swamp to cultivated land and grazing land as a result large area of the open water is covered by floating sedges due to increased sediments filled into the Swamp. Meanwhile, the impact of land use/cover change on biodiversity was evident. The study demonstrated the shift of one land use to another which is associated with habitat fragmentation. This transformation of land cover types leads to a change in the structure and function of ecosystem services and species loss. Most of the woodland patches that used to harbour variety of plant and animal species have been converted to agricultural land. Future expansion in agriculture, overgrazing and the use of fire to open up the Swamp for fishing may lead to biogeographic shifts in plants and animals, and influence the hydrological cycle of the Swamp. Despite these changes, Kibasira Swamp is still an important habitat for plant and bird species diversity and richness. Woody plant species dominate in areas outside the Swamp creating woodland community as opposed to short derived or secondary grassland maintained by livestock grazing and continuous burning. The Swamp is also important habitat for the endemic species, Kilombero weaver (*P. sburnieri*), and supports a diverse population of water birds.

Although anthropogenic degradation makes wetland dynamics difficult to unscramble, effective assessment, inventory, monitoring and mapping of wetlands can improve our understanding on the ecological and socio-economic factors that have effects on wetlands and also can help to recognize the interlinkage of various wetland composition and that support the adjacent livelihood. The vulnerability of wetland ecosystems should act as a key in promoting monitoring programs to ensure that they are utilized sustainably.

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