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Evaluation of Wetland Loss in Maragua Watershed, Murang'a County, Kenya

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Abstract Wetlands are habitat to a wide range of biodiversity and thus accommodate some of the world's most valuable resources. Unfortunately, their ecosystem services are continuously being lost to destructive anthropogenic activities. Systematic wetland mapping and inventorying to establish wetland status is necessary. A study was therefore done to determine the wellness of wetlands; and the temporal and spatial changes in wetlands in Maragua watershed. Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI) and Topographic Wetness Index (TWI) were used to extract wetlands areas. Additionally, interviews, storytelling events, stakeholder workshop, focus group discussions and personal observations were used to obtain qualitative data on human activities in wetlands and the challenges facing wetlands in the study site. In 1987 the area under wetlands in Maragua was 24.1 ha, in 1999 it was 12.8 ha and by 2018 wetlands covered only 10.1 ha. Further, the wetlands are more concentrated on the downstream side of catchment. Additionally, wetland cultivation, planting of exotic trees and fodder grass farming are the main human activities taking place within the wetlands. It was observed that the local communities are neither aware of the adverse effects of their activities on the wetlands nor the potential benefits of conserved wetlands. With the help of various stakeholders, the County Government of Murang'a has opportunities to create awareness and educate the residents of the study area about the potential benefits of conserving their wetlands.

Keywords awareness, conservation, ecosystem services, small wetlands, stakeholders

1. Introduction

Wetlands are areas on the land that are permanently or seasonally saturated with water such that they have distinct ecosystem characteristics [1], [2]. They occur in diverse ecological zones, soil types and have diverse hydrologic characteristics [3], [4]. Wet areas are estimated to cover 6% of the global land's surface and about 4.7% of the sub-Saharan's continental area [5], [6]. Of all Eastern Africa wetlands, 80% are considered small (less than 500ha), 12 million hectares the small wetlands in the region are in Kenya and Tanzania [7]. In Kenya, wetlands are estimated to cover approximately 14,000 km^2 (2.5%) of the total area [8]. Some limited research

has been done on the wetlands around Lakes Victoria and Naivasha [9].

Wetlands are among the most productive biological ecosystems and are thus recognized as the world's most valuable natural resources [9], [10]. They provide habitats and support a wide range of flora and fauna. Additionally, they remove organic matter, nutrients and toxic wastes thus improve water quality. In watersheds, wetlands form important sinks for sediment transported in runoff as well as damp peak flows. The water stored within the wetlands is slowly released to springs and thus stabilize the dry season flow in rivers and streams. They control floods and soil erosion on the downstream by reducing peak flows. Wetlands also recharge ground water [1], [2], [11], [12].

Because they are rich in biodiversity, wetlands are among the ecosystems most affected by human activities [13], [14]. They are said to have been encroached into when, through human activity, they are completely drained and put into alternative activity [14]. In the Eastern Africa, wetlands were in the past exploited for hunting, gathering, harvesting of thatching material and used as grazing land. This was a relatively sustainable use of these resources. With time, their use dramatically changed into less sustainable forms [15]. Some less sustainable uses of wetlands include farming and food crop cultivation.

Coupled with climate change, human activities have altered the hydrological regimes of wetlands [16]. The pressure to produce enough food for a growing population has resulted in wetland encroachment. Furthermore, poverty and ignorance about the value of biodiversity present a major challenge to wetlands conservation and management. Private land ownership in Kenya also impedes wetland conservation activities. Other factors impeding conservation include the fact that wetlands are used as a source of water for irrigation and domestic use [9], [17], [18].

Wetlands can be identified on the field through land surveying. However, in remote expansive areas this method is labor intensive, time consuming and impractical. Remote sensing and GIS can be used to facilitate identification and delineation of wetlands through analysis of various wetland indicators such as vegetation, hydrology, topographic positions and soil types [16]. In this study, remote sensing was adopted as opposed to field surveying.

Murang'a County has many small wetlands, some of which have been affected by human activities. The objective of this study was therefore to establish the state and conservation status of wetlands in Maragua watershed.

2. Methodology

2.1 Study area

Maragua watershed, of Murang'a County (Fig. 1), covers an area of 420 Km^2 and extends from 0° 37' 12" to 0° 50' 0" S and 36° 42' 0" to 37° 9' 0"E. The altitude of Maragua watershed ranges from 1191m to 3769m above sea level. The watershed slopes from west to east and receives bimodal rainfall, with long rains between March and June; and short rains between October and December. The average annual rainfall is 700mm-1300mm. The upper areas of the catchment have expansive tea plantations and a gazetted Aberdare forest. The mid-section of the catchment has coffee plantations and subsistence farms, while the lower section is mainly dominated by subsistence crops. The dominant soils in the area include humic nitisols (NTu) and umbric andosols (Fig. 3).

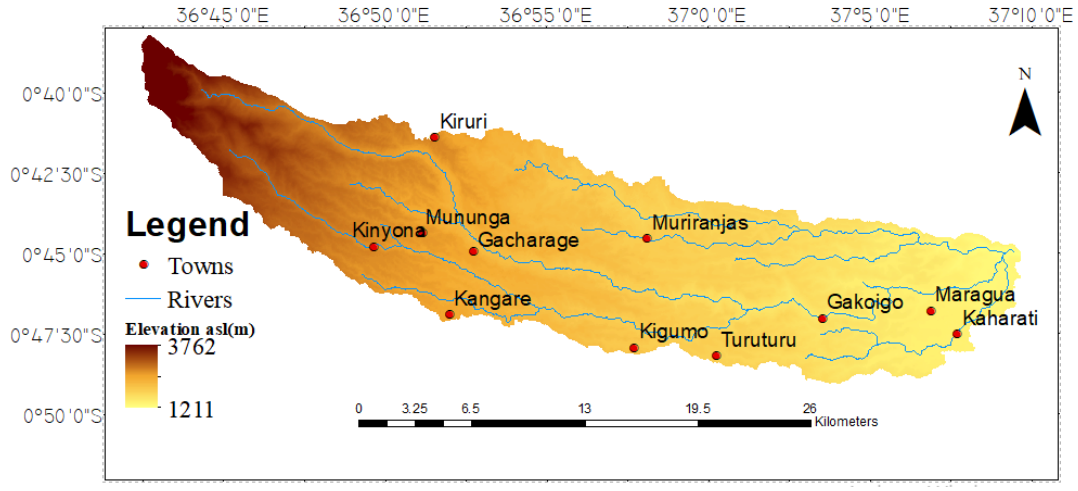

Fig. 1. Map of Maragua watershed

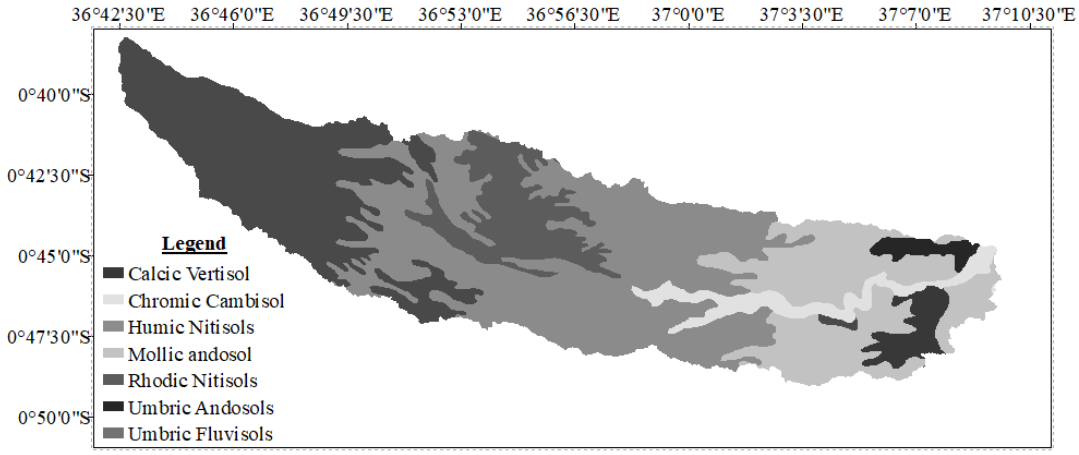

Fig. 2. Maragua watershed soil classes

2.2 Materials

Wetland status in the Maragua watershed of Murang'a County was studied using Landsat 5 (TM) for 1987, Landsat 7 (ETM+) for 1999 and Landsat 8 (Operational Land Imager OLI) for 2018 and a 30m resolution digital elevation model (DEM) (Table 1) downloaded from https://earthexplorer.usgs.gov/. The satellite images collected were path/row 168/060. Cloud free, radiometric and geometrically corrected dry season Landsat scenes were downloaded. Images used included those of February 1987, February 2018 and September 1999

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Table 1: Geospatial datasets used in the study

S/No	Data type	Date	Scale	Source
1	Landsat image (TM)	25/02/1987	30m	USGS
2	Landsat (ETM+)	14/09/1999		https://earthexplorer.usgs.gov/
3	Landsat (Operational Land Imager OLI)	29/1/2018		
4	Digital elevation model		30m	SRTM

2.3 Methods

A reconnaissance survey was conducted to obtain geo-referencing data on a few wetlands in the watershed. The georeferencing data was used to calculate the accuracy of wetland identification.

2.3.1 Wetland identification and mapping

Wetland mapping in the watershed was performed using rule-based index classification. Three indices were used. They were the Normalized Vegetation Difference Index (NDVI), Normalized Difference Water Index (NDWI) and Topographic Wetness Index (TWI). The NDVI and NDWI were used to classify vegetation and water bodies while TWI identified the tendency of water to accumulate at a place. Equations (1)-(3) give the formula for calculating these indices.

$$\mathbf{NDWI} = \frac{\mathbf{Green - NIR}}{\mathbf{Green + NIR}} \quad (1)$$

$$\mathbf{NDVI} = \frac{\mathbf{NIR - Red}}{\mathbf{NIR + Red}} \quad (2)$$

$$\mathbf{TWI} = \mathbf{Ln}\left(\frac{\mathbf{A}}{\mathbf{Tan(\beta)}}\right) \quad (3)$$

Letter A represents the upslope contributing area and β is the local angle slope.

The classification process entailed setting a threshold for each index estimated from the georeferencing data. The following thresholds were set: NDVI between -0.15 to 0.4; NDWI values -0.3 to 0.15; and 6 to 15 for TWI. The outputs of each index were added in a layer stack before the script was run for each individual year.

Three rules were generated using the indices. All rules in this study were structured by **IF and THEN syntax** and implemented on ERDAS Imagine decision tree module. The specific rules used to identify the wetlands are as follows:

```
NDVI >-0.15 and <0.3
        ANDIF NDWI >0.15 and <-0.3
                ANDIF TWI >6 and <15
                        THEN WETLAND
```

The decision tree uses a series of binary decisions rules on multispectral data. Each decision divides the pixels in two classes, (yes, no) based on an expression. Accuracy assessment was performed using 45 points.

2.3.2 Socioeconomic survey to establish the human perceptions and challenges facing wetlands

Interviews

A total of 20 farmers bordering selected wetlands, who had been settled in the area for not less than 20 years, were interviewed. They asked questions to confirm (i) their awareness about the importance of wetlands; (ii) the changes in land use and land cover; and (iii) the ownership of wetland areas;

Stakeholder workshop

A stakeholder workshop with 42 participants, including key players in wetland conservation and management, was held to discuss the role of the different stakeholders and document the challenges facing wetland conservation in the study area. The stakeholders filled questionnaires outlining their roles in wetland management and conservation. Depending on their roles, the stakeholders were divided into four groups sitting around four tables. Each table had a facilitator who took notes and reported the key findings of the group in a plenary session. Seven categories of challenges were identified and using pairwise ranking [19] the challenges were ranked from the one raising most concern to the least concerning.

Focus group discussions

A focus group discussion was conducted. It involved four members of the Maragua River Water Resources Users Association (WRUA). This group provided information relating to human activities within the wetlands and their impact on the wetlands. Additionally, they provided information on their views regarding the measures that could be put in place to protect these wetlands.

Story telling events

Story telling approach (STA) was used to collect data on wetlands within Gakoigo, Gikindu, Kagaa and Kaharati villages. Locals living within and around the wetlands were asked to tell stories about perceptions on the wetlands. STA captures information that would otherwise be left out in a formal guided interview survey. From the stories, vital information was synthesized and conclusions drawn.

Observations

In this study, field visits were conducted between February and April 2018 and direct observation was done to enlighten the researchers on the current land use, any conservation measures and general condition of the wetlands.

3. Results and Discussions

3.1 Loss of Wetlands in Maragua Watershed

Some 90% of wetlands in Maragua watershed were located in the middle and lower sections of the watershed. In 1987 the area under wetlands was 24.1 ha; in 1999 the wetland area was 12.8 ha while in 2018, wetlands covered only 10.1 ha. The area covered by wetlands in 2018 was less than 50% of the area covered by wetlands 30 years before (Fig. 3). The overall accuracy of mapping wetlands was 75%.

The wetlands identified in the watershed were generally narrow inland valleys. Using the hydrogeomorphic wetland classification [20], the wetlands were classified as riverine wetlands or depressional wetlands. Riverine wetlands however dominate the available wetlands in the Watershed. Furthermore, land units less than 500 hectares that are characterized by permanent or seasonal flooding or by moisture availability in the soil higher than that of surrounding uplands are classified as small wetlands [7]. In this study, the wetlands identified were less than 10 hectares and thus classified as small wetlands.

The results of this study agree with those of a Ugandan study [21] which established that most riparian wetlands were located at valley bottoms or along streams. In Swaziland, small swamps and flood plains were found to occur along rivers and streams in the Middleveld and Lowveld regions. Although small in size, the wetlands provided important water supply, grazing resources, raw materials for cultural ceremonies and handicrafts and are utilized in dry seasons as farmlands [22].

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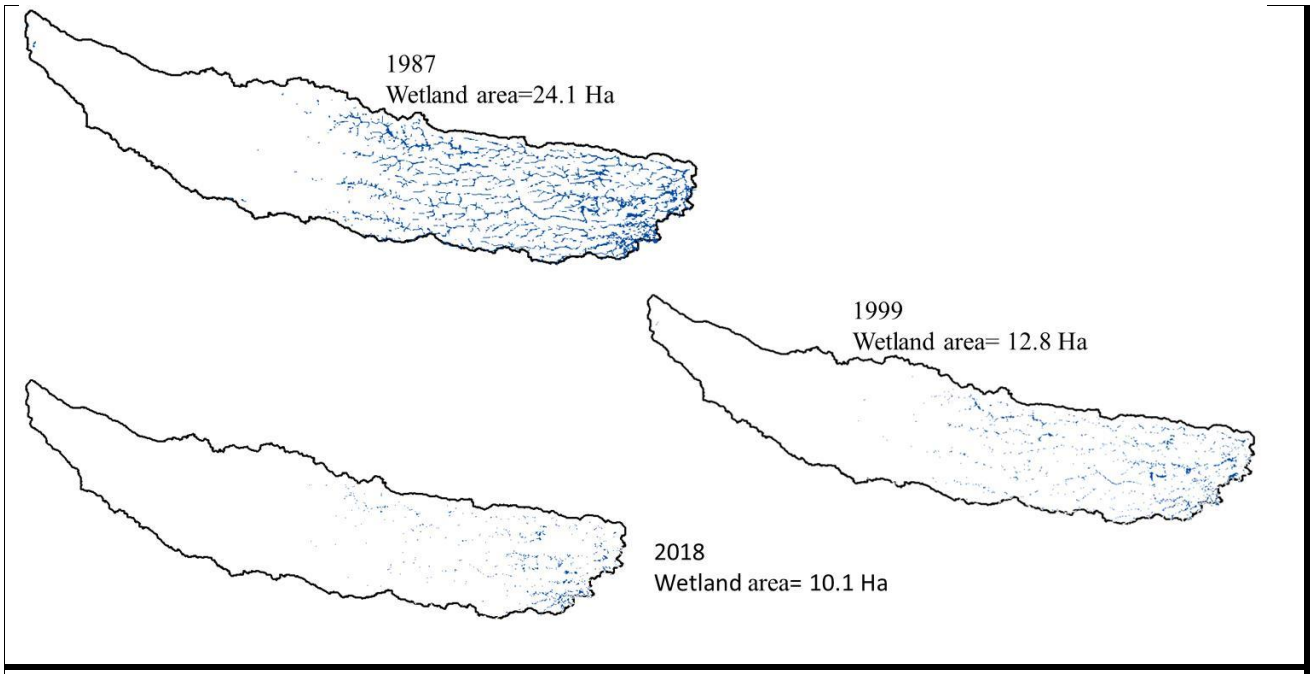

Year	Wetland cover (Ha)	Percent wetland cover	Rate of wetland disappearance (Ha/year)
1987	24.1	0.05	
1999	12.8	0.03	0.94
2018	10.1	0.02	0.30

Fig. 3. Spatial Variation of Maragua Watershed Wetland Area for Years 1987, 1999, and 2018

Land use within the wetlands in the study area was assessed for the periods 1990 and 2018. Based on observations made during field visits and information gathered from interviews, storytelling and focus group discussions, about 20% of the wetlands had exotic trees, mainly the eucalyptus species. Based on observations made in 20 wetlands, about 5% of the wetlands were under natural grass in 2018, while 20% were predominantly under exotic trees (Fig. 4). According to the residents interviewed during the study, in 1990 35% of the wetlands were dominantly under natural grass and there were no exotic trees in the wetlands. Furthermore, while in 1990 only 20% of the wetlands were cultivated, in 2018 some 45% of the wetlands were under cultivation. In 2018 there were buildings in some 5% of the wetlands (Fig. 4).

A study in central Kenya [9] analyzed the changes in land use and noted that increasing human population had resulted in expansion of agriculture into previously uncultivated land in Central Kenya. Based on the findings of this study, farmers grow vegetables, arrow roots, flowers, maize and beans in wetlands. The farmers confessed that they used open ditches to drain the wetlands. Indigenous trees were cleared to create room for human activities within the wetlands.

During interviews respondents provided information that since 1990, human settlement within wetlands has increased. This has been accompanied by increased number of exotic trees and grass which are perceived to be more valuable. Introduction of invasive alien species to wetlands alters their biodiversity and makes them more vulnerable [9].

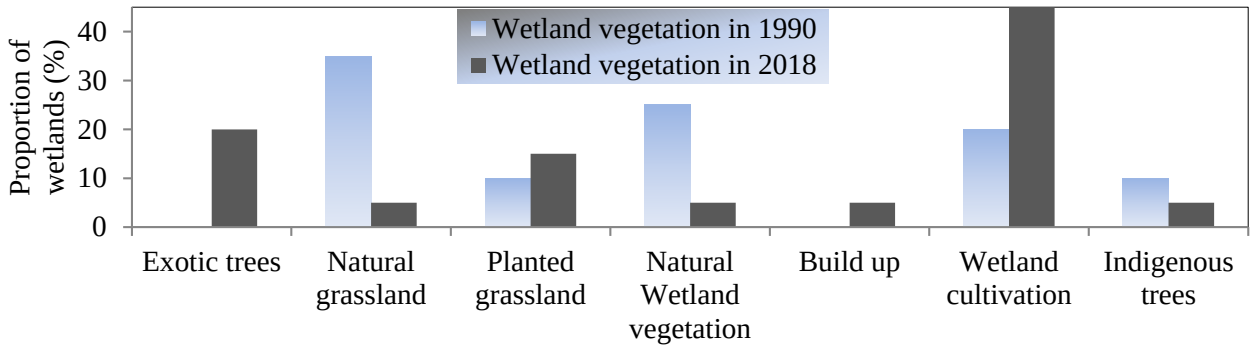

Fig. 4. Comparison of land use within the wetlands for the periods up to 1990 and 2018

3.2 Perceptions about the Value of Wetlands

During the interviews respondents were questioned about what they thought was the value of wetlands. Some 50% of the respondents said wetlands were a source of livelihoods, while 35% viewed wetlands as sources of water for irrigation and domestic use. Only 15% attached aesthetic value to wetlands (Fig. 5). Of all those interviewed, 40% were unaware of the hydrologic value of wetlands. About 45% had a little knowledge and only 15% were aware of the hydrologic benefits of wetlands (Fig. 6). During the study, it was also noted that little effort is made to promote awareness about the importance of these wetlands, thus their continued exploitation.

A study in Chingombe community in Zimbabwe [23], found that the residents of Chingombe attached some value to the ability of wetlands to sustain their livelihoods, provide water and improve the aesthetics of their environment. The residents of Maragua watershed had similar views.

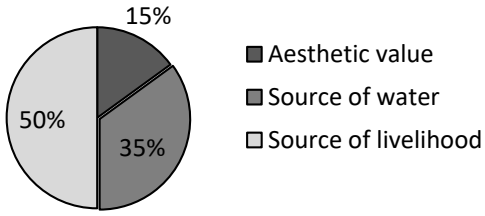

Fig. 5. Community perception about the value of wetlands

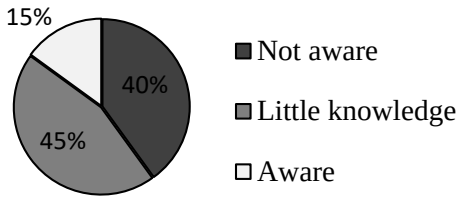

Fig. 6. Awareness about the hydrologic value of wetlands

Although residents viewed wetlands as assets, they were not aware of the adverse effects of their activities on the wetlands. This was attributed to a breakdown of communication between the stakeholders, particularly natural resource managers, policy makers, local communities and law enforcers on one side and researchers on the other side. A population that only sees wetland as potential farming areas will not care to conserve them. This contributes to loss of wetland area. There is therefore need to conduct public awareness campaigns on the potential benefits of conserved wetlands in order to promote sustainable use of wetlands in Maragua watershed.

3.3 Wetland management

There were 42 participants in the stakeholder workshop. One represented the national government (administration); 17 represented the national government ministries (water, agriculture and environment); 9 represented academia; 9 were from the County government; and 3 were from the mainstream media (Figure 7 and Table 3). The stakeholders were put into five categories namely: policy developers; policy implementers; financiers, wetland users and researchers based on their roles.

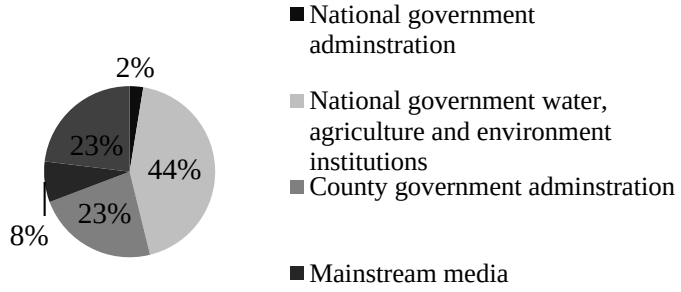

Fig. 7. Proportion of participants from each sector

i. Policy developers

The County Environmental Committee and the County Environmental & Climate Change Department were involved in policy development. Their responsibilities included making laws and policies regarding conservation of wetlands, and ensuring budgetary allocation for the water department. They are also expected to conduct regular inspections to ensure laws on conservation of wetlands are enforced. The Kenya Meteorological Department provides the data necessary for policy formulation.

ii. Policy implementers

Policy implementers include the Water Resources Authority (WRA); the office of County Commissioner and Water Resource Users Associations (WRUAs) (Table 2). Their roles included implementing and enforcing the set policies.

iii. Financiers

Under this category of stakeholders, Upper Tana Natural Resource Management Project (UTaNRMP) was identified. The financier funded the activities of WRUAs and had the task of building the capacity of different players for water resources protection.

iv. Wetland users

These are stakeholders who carry out human activities within wetlands. In addition to the general citizenry, this category also includes the Water and sanitation companies, the County Irrigation Department and the Fisheries Department which has constructed some fish ponds within the wetlands. The roles of wetland users included ensuring sustainable use of wetlands and creating public awareness on the sustainable use of wetlands.

The majority of wetlands in the study area were on private land. This study found that the owners were not adequately empowered to protect existing wetlands. There is need to develop a strategy for capacity building among identified stakeholders.

Table 2: Roles of policy implementers in wetland management and conservation

Stakeholder	Roles
Water Resource Authority (WRA)	• Formation of WRUAs • Water quality and quantity monitoring • Protection of wetlands from encroachment
The County Commissioner	• Awareness creation • Enforcement of laws and regulations • Coordination of different players
Water Resource Users Association (WRUAs)	• Marking, demarcating and fencing wetlands • Discourage community encroachment into wetlands • Identification and rehabilitation of encroached wetlands

v. Researchers

Academic researchers carry out studies on wetlands in order to inform policy makers on sustainable use of wetlands.

3.4 Challenges facing wetlands

The challenges facing wetland conservation in Maragua were identified and ranked. The challenges identified were grouped into seven categories namely: encroachment, pollution, and conflict in legislation; lack of community empowerment, limited resources, bad governance and inadequate planning. Supplemental information is provided in an attribute table in (Table 4). A pairwise ranking matrix was drawn (Table 5a) and the challenges ranked. The frequency of each challenge was determined (Table 5b). Shortcomings in legislation, planning, and community empowerment policy implementation were identified as top three factors affecting wetland conservation. Other challenges were identified as bad governance, limited resources, encroachment and pollution.

Conflict in legislation was identified as the key challenge facing wetland conservation. Stakeholders highlighted the conflicting aspects of the land ownership policies in the Land Act No. 6 of 2012 (PART V-Administration and Management of Private Land) and WRA regulations on wetlands. Physical boundaries such as rivers are used in cadastral survey as demarcations between land portions. In such cases, the riparian wetlands are allocated to private owners [24]. From the visited wetlands, 95% of the wetlands were on private land whereas only 5% were on public land. Most of the land in Kenya, including riverine wetlands, is privately owned. A recent study found that one of the major impediments to conservation of swamps in Kikuyu Sub-County of Kiambu County was the fact that the land was privately owned [19]. Wetlands allocated to private land owners during land demarcation are difficult to conserve since the rights to use of the land is vested on the owner.

The Environmental Management and Co-ordination Act (EMCA) cap 387, 2017 amendments provides regulations for the conservation and management of wetlands. Section 12 prohibits human activities within the wetlands without a permit and an environmental impact assessment report [25]. This was not found to be the case as wetland cultivation was a dominant activity within the wetlands, and this was done without any permits. When asked whether they would be willing to conserve wetlands, only 30% of the respondents were willing to conserve wetlands while the remaining 70% viewed restoring natural wetlands as a loss of farmland and loss of livelihoods. When it was suggested that farmers cultivating wetland could consider alternative livelihoods, many could not think of any viable alternatives to wetland cultivation. However, since 30% of the private wetland owners were willing to conserve wetlands, this should be

recognized as an opportunity to undertake wetland conservation. Another opportunity also exists to educate the 70% who viewed wetland conservation as a loss of livelihood.

Table 3: List of institutions and departments represented in the stakeholder workshop

Institution	Departments	Number of attendees
National government administration	County commissioner	1
National government water, agriculture and environment institutions	Fisheries department	2
	Kenya Meteorological Department (KMD)	1
	National Environment Management Authority (NEMA)	1
	Upper Tana Resources	1
	Water and sanitation companies	4
	Water Resources Users Association (WRUA)	11
	Water Resource Authority (WRA)	1
County government administration	County Environmental Committee (CEC)	4
	County climate change committee	3
	Member of county assembly (MCA)	1
Mainstream media		3
Academia		9

Table 4: Supplemental information on Challenges facing wetland conservation

Challenge	Components
Encroachment	Cultivation, draining of wetlands, lack of proper demarcations to wetlands, invasive species.
Conflict in legislation	Non-compliance to laws, conflicting policies within WRA and Land Act of parliament, conflicts of interest in conservation activities, uncoordinated policy implementation.
Lack of community empowerment	Lack of public campaigns on promoting awareness of wetlands, lack of awareness within the farmers, poverty.
Pollution	Disposal of carwash wastes, agricultural chemicals, and sewage in urban centers.
Bad governance	Corruption, delayed justice, non-compliance to laws.
Limited resources	Funding for public awareness creation and implementation conservation activities.
Inadequate planning	Lack of deliberate planning.

Table 5a: Pairwise Ranking Matrix of Challenges facing wetlands

	Lack of proper planning	Encroachment	Conflict in legislation	Pollution	Lack of community empowerment	Limited resources	Bad governance
Lack of proper planning		PL	L	PL	PL	PL	BG
Encroachment			L	E	CE	R	BG
Conflict in legislation				L	L	L	L
Pollution					CE	R	BG
Lack of community empowerment						CE	CE
Limited resources						B	R
Bad governance							

PL-Inadequate planning; E- Encroachment; P-Pollution; L- conflict in legislation; R-limited resources; CE- lack of community empowerment; BG-bad governance

Table 5b: Frequency Summary

Inadequate planning	Encroachment	Conflict in legislation	Pollution	Lack of community empowerment	Limited resources	Bad governance
4	1	6	0	4	3	3

In Kenya, only wetlands of international importance such as Lake Naivasha, Lake Nakuru and Saiwa swamp have management plans and financing [9]. Small wetlands are often neglected in planning and receive limited financing thus continue to suffer degradation. Bad governance also ranks highly. Officers in charge receive bribes from people encroaching wetlands instead of reclaiming them.

Existence of conflicts in current laws and regulations has been identified as a major impediment against wetland conservation. There is need to harmonize the policies and regulations that govern wetlands in EMCA and the Land ownership and demarcation policies and regulations in the Land Act.

4. Conclusions and Recommendations

In the last 30 years, Maragua watershed has experienced loss of wetlands. The area covered by wetlands in 2018 was less than 50% of the area covered by wetlands 30 years before. The present study shows that wetland loss in Maragua has been as a result of land use change from wetland vegetation to exotic wood lots and cultivated farmlands.

The residents of Maragua watershed viewed wetlands as farmlands and were not aware of the adverse effects of their activities to the wetlands. This has contributed to wetland loss. There is therefore need to conduct public awareness campaigns on the potential benefits of conserved wetlands. This will promote sustainable use of wetlands within the study area.

Existence of conflicts in current policies and regulations on wetland ownership and conservation has been identified as a major impediment against wetland conservation. There is need to harmonize the policies and regulations that govern wetlands in EMCA and the Land Act.

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