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Navigating through Complexity by Profiling the Main Threats to Sustainable Tropical Wetlands Management and Governance: A Case Study of Mityana District, Uganda

Baker Matovu[1] · Isaac Sarfo[2] · Yasin Bbira[3] · Emmanuel Yeboah[4] · Yosia Muhoozi[5] · Isaac Lukambagire[1]

Received: 11 September 2023 / Accepted: 23 February 2024
Published online: 12 March 2024

Abstract

Wetlands are crucial ecosystems that promote sustainable livelihood and biodiversity conservation, especially in tropical regions. However, recent studies have reported increasing threats to wetlands both environmental and human which threaten the provision and acquisition of several wetland benefits. Though there is recognition of the value of wetlands, in most local communities in Uganda; especially around the Lake Wamala region in Mityana district, there is still limited knowledge and research on the benefits of wetlands and the level of threat thus affecting wetland governance. This research addresses this gap by using participatory research to create a baseline inventory that could be used by wetland managers to identify the main wetlands threats to inform policy on how to develop participatory actions and local area-based management practices. The study was conducted in 14 sub-counties and a sample of 105 wetlands along the wetlands of Lake Wamala and River Mayanja wetlands system in Mityana District was captured. Study findings revealed increased human threats to wetlands especially in the River Mayanja seasonal wetlands zone. The increased effects of environmental threats such as climate change are also altering permanent wetlands along Lake Wamala. Our developed inventory based on local participants' perspectives revealed that since the level of damage to wetlands in Mityana especially the permanent wetlands is relatively low, a focus on developing new mapping, and a decentralized approach to wetland management that focuses on capacity building, development of wetlands action plans, increased support to local wetland authorities, and a system thinking approach in wetland threat identification and management could help in the regeneration of most wetlands zones.

Keywords Wetland · Wetland resources and ecosystems · Wetland threats · Wetland action plans · Mityana district · Uganda

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s44274-024-00041-5.

✉ Baker Matovu, amiddids20002@am.students.amrita.edu; Isaac Sarfo, isaacsarfo@163.com; Yasin Bbira, bbirayasin@yahoo.com; Emmanuel Yeboah, emmanuelyeboah@nuist.edu.cn; Yosia Muhoozi, yosiamuhoozi18@gmail.com; Isaac Lukambagire, amiddids20030@am.students.amrita.edu | [1]Amrita School for Sustainable Futures, Amrita Vishwa Vidyapeetham, Amritapuri Campus, Kollam, Kerala, India. [2]College of Geography and Environmental Science, Henan University, Kaifeng 475004, Henan, China. [3]District Natural Resources Officer (DNRO), Mityana District Local Government, Mityana, Uganda. [4]School of Remote Sensing and Geomatics Engineering, Nanjing University of Information Science and Technology, Nanjing 210044, Jiangsu, China. [5]College of Agricultural and Environmental Sciences (CAES), Makerere University, Kampala, Uganda.

1 Introduction

Wetlands are crucial biodiversity hotspots that avail myriad ecological, social, and economic functions and values to threshold communities [1–4]. In sub-Saharan Africa, wetlands and wetland resources are a catchment to inland water bodies that provide water, food, and non-food resources that sustain livelihoods [5, 6] thus creating positive synergies and nexuses that serve ecological and human livelihood benefits [7, 8]. Though wetlands cover a paltry 6 percent of the earth's terrestrial landscape such as the dambos wetlands, they are one of the leading ecosystem hotspots in the world that avail a paucity of ecological functions and services [7, 9, 10]. Though the global quantum of the total value of wetlands is largely unknown, an economic assessment of 63 million hectares of global wetlands estimated the annual value of wetlands at 3.4 billion USD; with the leading benefactors being Asia profiting with an annual value of 1.8 billion USD [11]. Unfortunately, despite the immense value of wetlands, there is unsustainable degradation and exploitation of global wetlands; partly due to limited enforcement, limited understanding and knowledge of wetland ecosystems, and perception of wetlands as 'free wastelands' [2, 12] or communal land such as in Zimbabwe, that limits effective governance [13]. For instance, it is estimated that whilst Africa has the largest amount of wetland area (estimated at 131 million hectares), it is experiencing one of the highest losses of wetland cover loss thence affecting the environmentally reliant communities in threshold zones [9, 14]. A case study research in Zimbabwe, Sierra Leone, and Ethiopia documents the mindboggling negative trends in African wetland losses [7, 10, 15]. To develop sustainable synergies for wetland management, there is a need to develop both institutional and decentralized management practices that incorporate new developments [7, 13, 15]; such as on databases for forecasting and modeling wetland losses, monitoring, management and policy, restoration, development of knowledge base, and funding of wetland management avenues [9, 12, 15].

In Uganda, wetlands form a crucial part of the national livelihood and ecological resource base that is envisioned to help the country achieve Vision 2040; hence directly contributing to the National Development Plan (NDP) III and the attainment of Agenda 2030 of the United Nations Sustainable Development Goals [16]. It is estimated that Uganda has a wetland zone covering about 30,105 km^2 [17]; that supports about 80 percent of riparian communities, especially around the Lake Victoria basin [3]. To sustain the immense ecological and livelihood benefits of wetlands, the government has enacted myriad legal instruments to safeguard wetlands [18]. These include inter alia, The Wetland Policy 1995, The Land Act 1998, The National Environment (Environmental and Social Assessment) Regulations 2020, The NEMA Act 2019, and The National Environmental Act 2019 [16, 19]. This has been supplemented by the ratification of global conventions on wetlands such as the Ramsar Convention and the setting up of government Ministries, Departments, and Agencies (MDAs) to sustainably manage wetlands such as the Ministry of Water and Environment, the Wetland Management Department (WMD), National Environment Management Authority (NEMA), and Wetland Inspection Division (WID); that are aided by local government environment management and natural resources departments [16].

However, despite the immense legislations and effort to promote wetland management in Uganda, results show a sporadic decline in wetland cover since the 1990s, especially in urban and suburban areas [18]. It is estimated that wetland cover in Uganda has receded from about 15.5 percent in 1994 to 13 percent in 2017; of which 4.1 percent is under increasing degradation [18, 20]. At the local and district level, there is an overt lack of baseline information on wetland loss and livelihoods therein to guide policy and data quantification for wetland analyses, governance, and management decisions [2, 3, 12]. This has ruined efforts to design local Wetland Action Plans (WAPs) that could guide local government planning and inclusive wetland governance [16]. In scenarios where data from national environmental databases is existent, values are less localized to determine temporal and spatial wetland threats and livelihood changes [21, 22]. Several studies have documented that to guide feasible decisions on local wetland planning, it is crucial to understand the local wetland systems' interactions with livelihoods of riparian communities, their perceptions, and threats at a spatial and temporal dimension [7, 12]. A baseline understanding of the nature of wetlands at a local level and the community livelihoods in threshold zones could help inform policy and decisions in the drafting of inclusive and integrated Village, Sub-County, and District Wetlands Action Plans and address the main drivers of the continued wetland loss in vast tracts of wetland zones at different scales-local, regional, and national [7, 13, 15].

Our study contributes to scholarship; especially about the understanding of systemic challenges threatening inland wetland zones in the tropics, by using a participatory approach to create a wetland inventory of both seasonal and permanent wetlands through the formulation of a situational profile and generation of baseline data on the state of wetlands using the case study of Mityana district with a focus on the type of wetland, location of the wetlands in Mityana, main livelihood activities, and emerging threats on ecosystems, to suggest sustainable wetland management and governance options. This new paradigm is crucial and novel as most wetlands; especially in Uganda, are facing sporadic encroachment and destruction; yet participatory research to understand the systemic causes and effects of this destruction from the participatory perspective of local communities has been largely under-researched. The study further brings to the fore the human-centered perspectives from local communities and local participants on how wetlands could be managed which could be a basis for developing National Wetland Action Plans. The developed inventory could further serve as a guiding tool for the Wetland Inspection Division (WID) of Uganda to develop new locally feasible management measures for wetland resource management and integrated governance; especially along threatened wetland zones of the Lake Wamala system and Lake Victoria basin; a conduit to the attainment of environmental, social, and economic sustainability targets.

2 Materials and methods

2.1 Study area

The study was conducted in Mityana district across fourteen (14) sub-counties/Town Councils that are crossed by the River Mayanja wetlands and Lake Wamala wetlands systems; which are a part of the broader Lake Victoria drainage system [20]. The wetlands in the three (3) divisions of Mityana Municipality (Ttamu, Busimbi, and Central) were not considered in the study as most parts of the municipality are not covered with major wetlands but with minor streams that lead to major wetlands such as in Busimbi [2]. The wetlands considered in the study were in the following Sub-Counties or Town Councils: Bbanda Sub-County, Bbanda Town Council, Maanyi Sub-County, Butayunja Sub-County, Kakindu Sub-County, Malangala Sub-County, Zigoti Town Council, Busunju Town Council, Bulera Sub-County, Kikandwa Sub-County, Kalangaalo Sub-County, Ssekanyonyi Town Council, Namungo Sub-County, and Ssekanyonyi Sub-County (See Fig. 1). The wetlands in the rural Sub-Counties/Town Councils of Mityana district were selected in this study as they form an important livelihood and hydrological resource for the rural populations [20]. In addition, livelihood resources such as fish in the threshold zones especially around Lake Wamala Wetland System are dwindling, and natural resource user conflicts/contestations have proliferated, thus creating the need for evidence-based research to minimize future human-ecological risks that might crop up in such zones [2, 23].

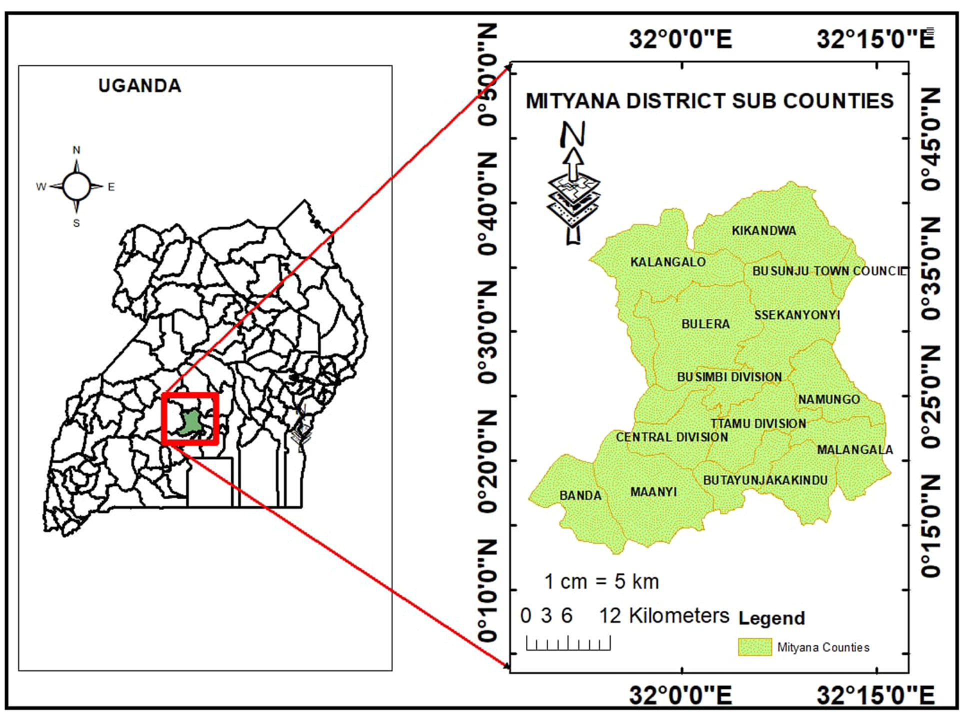


Fig. 1 Map of Mityana District with the main sub-counties/divisions (Developed by the Authors)

2.1.1 Sampled wetland zones and wetland sites

The sampled wetland sites are under two wetland systems: the Lake Wamala and River Mayanja wetland systems (Fig. 2) that drain into Lake Victoria [20].

2.2 Data collection procedure and tools used

The field data was collected along wetland zones in 14 sub-counties/Town Councils out of the 17 Divisions/Town Councils/Sub-Counties that form Mityana District; a distance covering 100 Kilometers. The data collection phase was done for three (3) months from October 2021 to December 2021. A Community participatory approach was used to collect data involving local community people (Key Informant Interviews (KIIs)) giving insights about the state of wetlands in a given wetland zone/system (Fig. 2). The focus of the participatory interactions was to gain information/baseline data on the location of a given wetland, wetland system, main uses, threats, tenancy status, and co-develop possible pathways to manage the wetlands. To interact with the local community, transect walks were conducted following major and minor routes that cross/along wetland zones in the selected Sub-Counties/Town Councils. A Transect Walk is a participatory field data collection method that involves the systematic cross-sectional walk along a pre-determined route or area to collect information on the study area relating to community assets, goods, services, infrastructure, and natural environment and their interactions over space [24]. Transect Walks helped in the critical observation and obtaining of intricate community information on social systems, wetland ecosystem goods and services, socially feasible management solutions, and people that could have been missed using participatory methods such as Focus Group Discussions (FGDs) and KIIs [25].

To understand and assess the level of threats and livelihood opportunities provided by wetlands in the Mityana district, the focus was made to seek out the local village focal persons and community leaders via pre-planned interview schedules before going to the field and snowballing with historical and much information on local wetlands, their flow, resources therein, and observed changes over time. To identify the wetland zones or areas to be considered, we liaised with the Mityana District Statistics Department and District Natural Resources Office to provide us with the list of villages, contacts of key village persons, and the 2000 wetlands map of Mubende district (Mityana District was curved out of Mubende) respectively. In the mapped-out list of key village persons, the targeted sample was 230 key informants. In

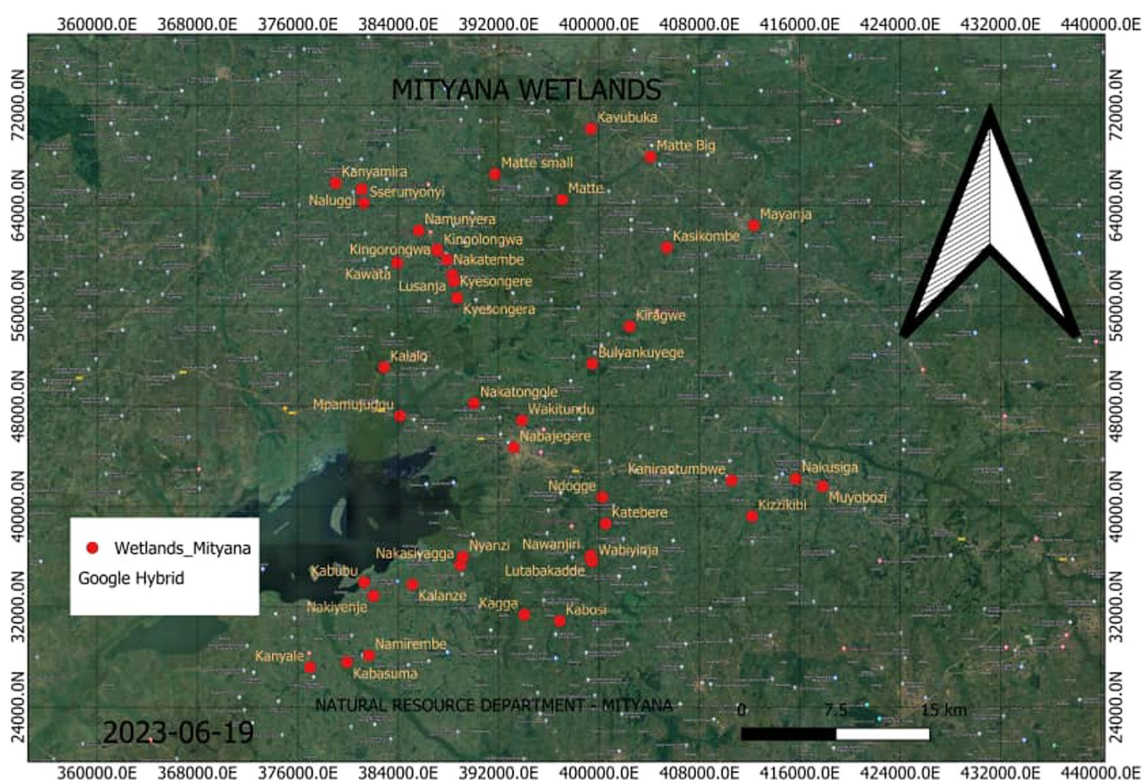


Fig. 2 Main sampled wetland zones in the study (Field Data)

scenarios where the local focal persons were not identified, local wetland users were interviewed to give information on the state of a given wetland that lies in proximity to their household(s). To access the identified wetland zones and key informants mapped out for the study, we conducted transect walks along the main routes in Mityana district leading to the targeted wetlands. The main aim was to use local knowledge perspectives to obtain the local name of the wetland, geographical location, general location, wetland type, wetland system, altitude, ecological features, land tenure, current land use, threats, and possible solutions. For each of the identified wetlands, a local wetland name was recorded in notebooks, and a Global Positioning System (GPS) coordinate(s) was taken to mark out the exact location of the wetland.

2.2.1 Sample size

The study employed convenient sampling where respondents who were willing and able to be interviewed/interact with were considered. Convenient sampling was employed to access and interact with the key village persons identified and contacted for interview. During the field data collection stage, only 100 out of 230 key village persons were accessible. Thus, to obtain more local participation and gain local factual information, during the field, we employed snowballing and simple random sampling to interview local people engaged in local wetland environment management groups or living along a given wetland or found conducting a given livelihood activity along a given wetland. Using this method, we interviewed 50 persons. Thus, a total of 150 respondents along the various wetland zones in the 14 sub-counties/ Town Councils agreed to interact and participate in the study. 70 percent of respondents were male and 30 percent of respondents were female. The discrepancy in the gender dimension during the interview was because most of the people found and local village leaders were males and only females were accessed after consent or finding them in wetland zones. A total of 105 wetlands were identified during the transect walk and field interactions and thus included in the study (See Table 1). Even though we had planned to interview more participants, logistical constraints (financial) and access to some wetlands that are not linked to local road infrastructure; especially in the permanent wetland zones around Lake Wamala such as in Butayunja limited local participation and data saturation.

2.2.2 Data collection tools

The geographical location of wetlands considered in the study was done using Garmin GPSMAP 64. The responses of the interviewees were recorded on the phone to be transcribed from *Luganda* (a local dialect) to English and in notebooks based on a pre-planned survey questionnaire that focused on four (4) main objectives (i) Identifying the main wetlands, wetland resources, and wetlands types in Mityana district (based on permanency or seasonality), (ii) identification of the main livelihood activities carried out (either along or within) wetland zones, (iii) identify the main

Table 1 Distribution of the number of sampled wetlands per county and sub-county (SC)/Town Council (TC) in Mityana District

County	Sub-county/TC	Number of sampled wetlands	Total/percentage
Busujju	Bbanda TC	8	57 (54%)
	Bbanda	5	
	Butayunja	5	
	Kakindu	8	
	Maanyi	22	
	Malangala	6	
	Zigoti TC	3	
Mityana North	Bulera	8	28 (27%)
	Kalangaalo	15	
	Kikandwa	5	
Mityana South	Busunju TC	2	20 (19%)
	Namungo	8	
	Ssekanyonyi TC	5	
	Ssekanyonyi	5	

Field Data

*TC Town Council

changes to wetland cover and the main drivers of such changes and (iv) To gain an understanding of the possible pathways for sustainable management of the wetland zones for better livelihoods and environmental management. During the Transect Walks, field photographs and observation were also used to identify main wetland activities, threats, and existing management practices. We directly observed some wetlands; especially along major roads such as in Maanyi sub-county. In the River Mayanja system and some parts of Bbanda sub-county, some wetlands were not along the road or were accessed by seeking permission to pass through the farms/gardens or privately owned property, and thus, local participant(s) (in these cases) helped us in reaching out/tracing the wetland.

According to Neumann [25], observation and field photography are some of the best qualitative tools for data collection in areas where interviews are not possible. Thus, in wetland areas where we did not find interviewees, we captured field photos and observed wetland features (See *Supplementary materials*).

2.3 Data analysis

The initial process involved the entering and conversion of field data to Excel (.csv) format and exporting it to the visual software ArcMap 10.8 for mapping the various wetland locations, wetland systems, wetland type, site land tenure, and the main land-use systems in the wetlands sampled zones. The various locations of the wetlands obtained during the field data collection were visualized and overlaid on imagery in ArcMap based on their easting and northing coordinates, with the majority points of the wetlands falling on the Uganda landscape (within the boundaries of Uganda) (Fig. 2). The various wetlands were grouped into systems based on their proximity to the lake or river of on different landscapes. This facilitated the identification of the origin and flow of the various wetlands in the Mityana district. The wetlands were categorized based on seasonal and permanent criteria. This was necessary to identify the various wetlands that are permanent irrespective of the time of the year or season and the ones that occur seasonally; thus, those that occur during the wet or rainy season (Fig. 3).

The area's land tenure classification was performed using spot or point analysis to identify wetlands under customary, lease, private mailo, and public categories. This is targeted at informing decisions at the various levels on the kind of activities or practices, use, ownership, and administrative systems, being initiated on the various wetlands and their outlying regions (*Supplementary material*). The wetland points were further reclassified based on the various land use activities occurring on the various landscapes. Predominant economic activities, identified in the region encapsulate aquaculture, arts and crafts, brick making, and crop cultivation, among others (Fig. 4).

Most of the data obtained from respondents (using both convenient and simple random techniques) was qualitative data. In the analysis of this data, we mainly focused on analyzing the main threats, effects, and co-creating of wetland management strategies using the perspectives of local participants. We employed a Reflexive Thematic Analysis (RTA) as guided by [26] as it allows for the generation of similar codes and patterns or themes in a given data set while also being theoretically flexible. The first step involved the translation and transcription of the field data from Luganda to English and the data was entered in a Microsoft Word file. The translation of survey questions in qualitative research allows for the generation of complementary information which can be merged with specific interview questions to get new interpretations of the phenomena under investigation and strategies [25]. The coded themes in this study related to the words that different participants said relating to a given question such as on the threats to wetlands and the identification of similar codes helped in the creation of 'domain summaries' for a given theme of what participants said about a specific topic or data collection question and their perspectives, and are likely to be considered as existing inside the data in a positivistic sense.

To generate domain summaries, grounded theory emergent coding, structured coding, and descriptive coding were used to communicate and create a narrative relating to the study topic. For instance, where respondents gave a given similar narrative such as on a given threat, we created a theme for that and summarized the number of times such a narrative was reported. This was followed by the running of the coded data using Word DocTools which facilitated the tabulation and generation of summaries for each coded data for further interpretation, and generation of tables and charts.

To validate the field findings, a further review of the literature was done where ***62*** documents were electronically sourced from Science Direct using the search term 'wetlands in Uganda' and downloaded from Google Scholar to compare the current study findings with existing data on wetlands in Uganda and in the tropics (*Supplementary material: Excel Sheet of reviewed articles*).

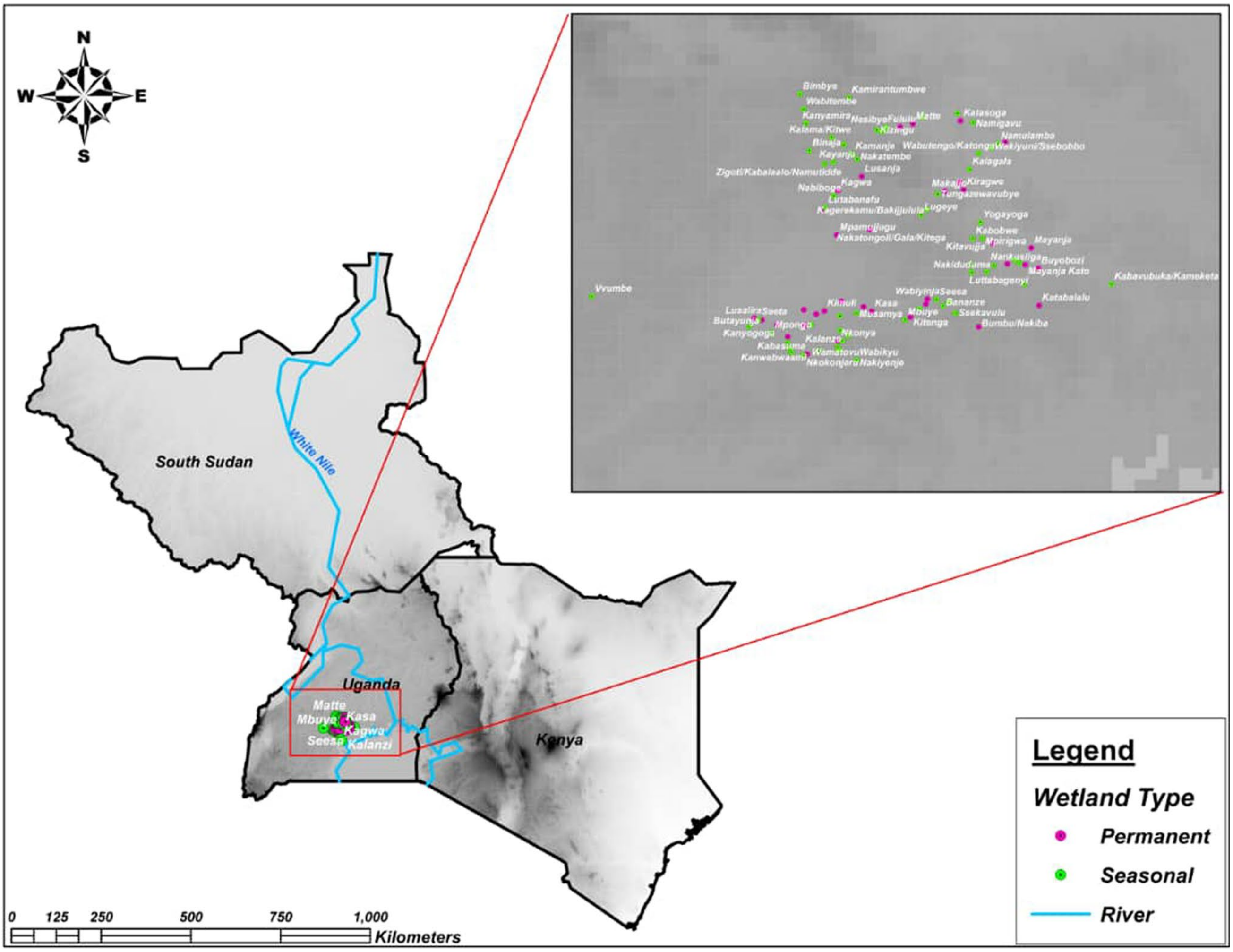


Fig. 3 Types of Wetlands in the Study Area (Field Data)

3 Results and findings

3.1 Types of wetlands

Most of the wetlands observed are either permanent or seasonal (Fig. 3). Permanent wetlands are predominant along the Lake Wamala wetland system-mainly covered with papyrus (See *Field Photos Attachments*) and except for a few areas such as, Matte wetland, the river Mayanja system is mainly dominated by seasonal wetlands. In addition, respondents reported that formerly permanent wetlands (with visible surface water) are also becoming more seasonal wetlands; especially in areas of Kalangaalo, Kikwandwa, and Sekanyonyi Sub-Counties.

3.2 Main wetland resources and functions (ecological and human)

Study findings revealed that wetlands in Mityana have a paucity of biotic and abiotic resources; though these vary depending on the type of wetlands (See *Field Photos Attachments*). For instance, along the Lake Wamala wetland system, the permanency of most wetlands for example, Nyanzi wetland in Maanyi SC that are dotted with lush wetland vegetation such as papyrus and permanent water, and in some sections, with riverine forests, there has been the provision of livelihood resources such as cheap water. Interview results however revealed a decline and in some cases the extinction of some resources such as some bird species; including the crested cranes along wetlands. This

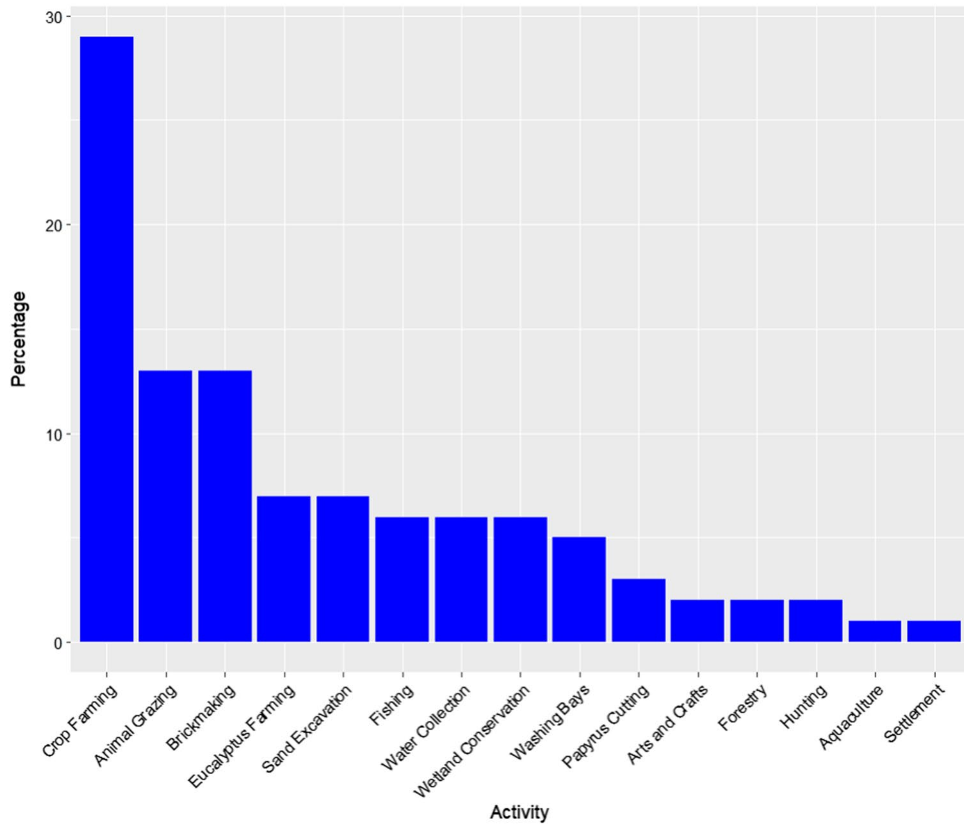


Fig. 4 Distribution of Main Livelihood Activities in Wetland Zones (Author creation from Field Data)

was reported prominently in parts of Lusalira in Banda SC and Lubajja in Maanyi SC. Most seasonal wetlands have dry bushes and greases such as in Kikandwa SC used for thatching and covering dry bricks (*Supplementary Material with field photos*).

3.3 Main livelihood activities

Study findings revealed that a paucity of activities are carried out; both within and along wetland zones of the sampled sites (See *Supplementary material with field photos*).

With a specific focus on activities within the wetlands, 15 activities were identified; of which crop farming is the dominant activity (29%). Animal grazing and brickmaking account for 13%, sand excavation and eucalyptus farming account for 7%, and wetland conservation, fishing, and water collection account for 6%. Low fishing activity was reported due to declining stocks in all wetland systems. 5% of the activities are reported to be washing bays, papyrus cutting accounts for 3%, hunting, arts and crafts and forestry represent 2% and the share of settlement within wetlands is low accounting for 1%. Only 1% of wetlands are used for aquaculture; representing a possible opportunity for livelihood empowerment.

Along the wetland zones, the share of activities also varied and 8 major themes related to these activities were identified. The leading activity is crop farming accounting for 40%, eucalyptus tree farming (16%), animal grazing (15%), settlement (11%), brick making (7%), forestry including, tree nurseries and wetland forest protection (6%), trading (5%), and the least reported activity was quarrying (2%) (Fig. 5).

3.4 Main threats and drivers

3.4.1 The severity of wetland damage from threats

Study findings revealed an increased threat and severity of degradation to wetlands over the years. Out of the 105 sampled wetlands, 38 percent (40 wetlands) are highly degraded, 47 percent are moderately degraded and only 15 percent are less degraded (Fig. 6). Direct field observations revealed that the less degraded wetlands are mainly those that are

Fig. 5 Main land-use/Livelihood Activities along wetland zones (Authors creation from Field data)

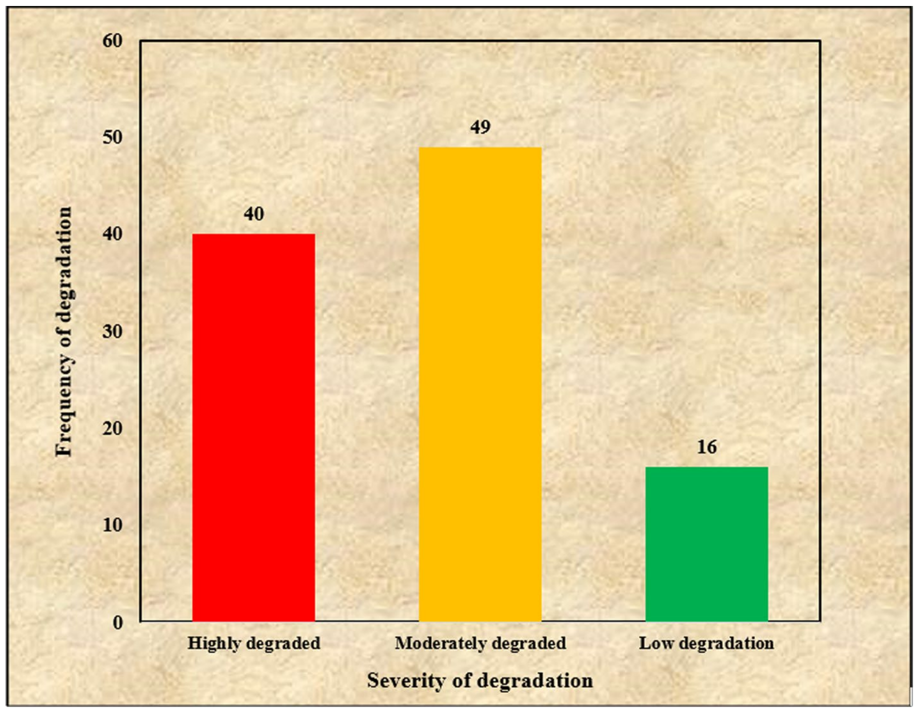


Fig. 6 Severity of wetland degradation (Authors creation from Field Data)

predominantly permanent and have restricted access evidenced by stone marks planted by officials from the Mityana District Local Government and the Wetlands Management Division (WMD). Stone markings are mainly labeled with '*Tokirizibwa kusanyaawo lutobazi luno*' (See Additional files 1, 2) translated as 'you are not allowed to destroy/degrade this wetland' and Wetland support initiatives both from the government and partners such as the Lake Victoria Environment Management Programme II (LVEMP II) as observed around wetlands of the Lake Wamala System for instance along Nakatongoli wetland. Of concern, however, is the increasing threat of degradation to permanent wetlands that are not easily accessible or are in remote areas for instance, in Kikandwa and Kalangaalo.

3.4.2 The main drivers/threats and their impact on livelihoods and ecosystems

In exploring the causation of the increased degradation of wetlands, interview results revealed both anthropogenic and environmental drivers of wetland loss. The key notable finding in most of the field interactions and field observations revealed that a paucity of wetland loss is due to anthropogenic drivers. Most local participants correlated the anthropogenic increase in the threats to wetlands (especially) in wetland zones to the land tenure system where land in most wetland riparian zones is owned by either private mailo or freehold land owners who in most cases expressed ignorance about the statutory legislations and requirement of protecting wetland zones by land owners extending to or sedentary along the wetland areas and where wetland threshold tenure is public, local users think '*it is Freeland to be used*' (See Additional files 1, 2).

In addition, pockets of respondents reported an increase in environmental threats such as climate change-induced effects including hot temperatures that lead to wild natural fires in wetlands and drying of wetlands and wetland resources. In some wetlands for example, in Bbanda and Maanyi SC respondents reported seasonal invasions of locusts and wild animals as degrading factors to wetlands ecosystems. Figure 7 specifically shows the main threats to wetland loss in the sampled zones where anthropogenic drivers account for 93% and environmental drivers account for 7% of the main drivers of wetland loss.

4 Discussion of the results and findings

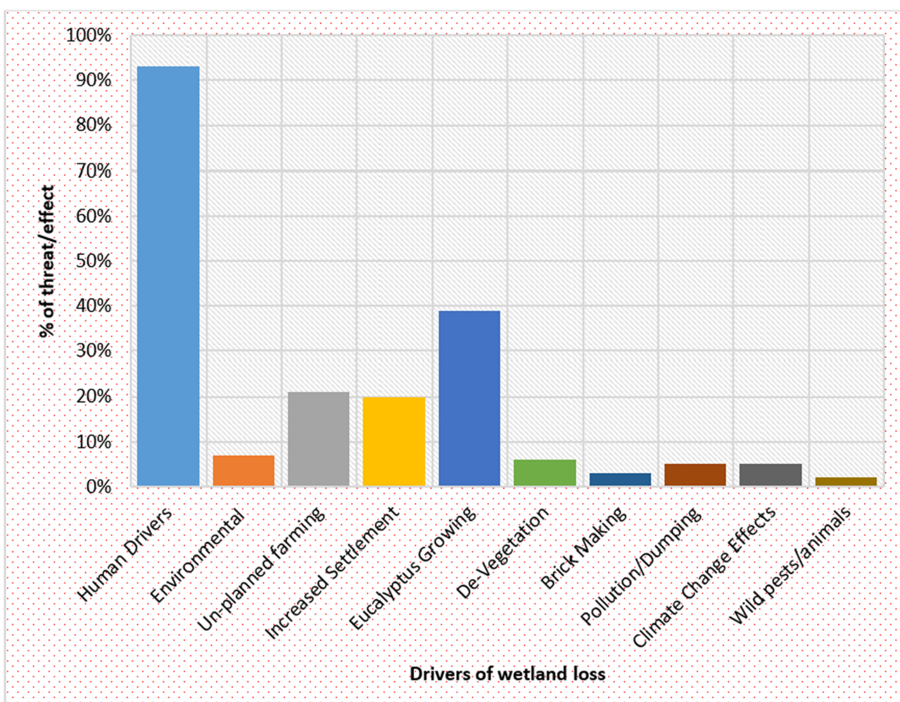
In this section, we discuss the study findings and relate them to the existing literature on wetlands in Uganda. Our current study revealed new insights related to the vulnerability of all wetlands-irrespective of the type as reported in several environmental reports in Uganda [18]. (https://docs.google.com/document/d/1magkpAfb0kcA5y_qQIckyNYEXkNgJ1O0/edit?rtpof=true).

4.1 Types of wetlands

Study findings in *Sect. 3.1* revealed that most of the sampled wetlands are either permanent or seasonal with permanent wetlands being covered with papyrus swamp vegetation. This finding is supported by several literature related to the types, and nature of wetlands, especially in the tropics [27] such as in Zimbabwe, Ethiopia, and Sierra Leone [8, 10]. In Uganda, the varied seasonality of wetlands is evident in the wetland zones of Opeta/Bisina/Awoja, Namatala/Manafwa/Doho, Malaba/Kibimba/Mpologoma wetland systems [28]. According to the 2021 NEMA report, different types of wetlands (both seasonal and permanent) exist in Uganda depending on the regions; with most seasonal wetlands in the northern parts of Uganda [18]; for instance, around the Kyoga plains [29] and along refugee settlement zones such as Palorinya in Moyo, Rhino Camp, and Imvepi in Arua, where several of the minor wetlands are seasonal [30].

Most of the permanent wetlands are located in the Lake Victoria catchment zone [31–33]. These wetlands are observed in the Kampala-Mukono wetlands corridor such as around Namanve [34], Kampala [35], Wakiso [36], Mpigi, Kalungu, and Masaka along Lake Nabugabo satellite wetlands [37, 38]. Further traces of papyrus swamplands exist along the permanent Lubigi and Nakivubo wetlands channel around Kampala and Wakiso [39–43], around parts of the Kirinya wetland zone in Jinja [21]; in the Upper Rwizi catchment zones; and Nyamuriro Western Uganda [22, 44]. Other permanent wetlands are observed around the River Mpologoma catchment area in Eastern Uganda within the Kyoga water management zone [45] and Doho wetlands in Eastern Uganda [46], Namatala wetlands along the R. Mpologoma system [47] in the Lake

Fig. 7 Main drivers/threats to wetlands (Authors creation from Field Data)



Kyoga basin [44]. In Mityana district, a survey around Mityana Municipality validates the dominance of these wetlands as it is reported that most wetlands are permanent [48].

Some studies have further reported that most permanent wetlands in Uganda are broadly spread in eight (8) wetland systems zones located in five various agroecological zones of Uganda. These include the Nangabo, Mabamba, and Mende wetlands in Wakiso District, Rucece in Mbarara, and Lake Nakivale in Isingiro representing Southwestern around the Lake Victoria crescent zone, Limoto and Gogonyo in Pallisa and Kibuku Districts representing the Kyoga plains agroecological zone [3]. This review confirms field findings as most respondents for instance, in Kikandwa and Kalangaalo reported that, most Lake Wamala wetlands are linked to the broader Lake Wamala radial drainage where rivers and wetlands lead to Katonga wetlands and finally drain into the Lake Victoria basin; implying that Lake Wamala wetland system is connected to the Lake Victoria basin zone [27]. Other permanent wetlands zones are found in the Lake Bunyonyi catchment area in Kabale, in South Western Uganda [49] including the Kashambya wetland complex [12], Rushebeya-Kanyabaha wetland [50] and Nyarungu permanent papyrus swamps [51] and the Rwizi-Rufuha wetland system from Bushenyi and parts of Ntungamo districts, through Mbarara and Lake Mburo before entering Lake Victoria [52].

In parts of Maanyi and Banda, most respondents and field observations revealed that permanent wetlands are predominated by papyrus swamp vegetation. This observation is consistent with the literature on permanent wetlands in Uganda [53]; which indicates that such wetlands are covered by papyrus. This was reported in a study around Katiko and Mpongo around the Lake Wamala system [2], and around Lake Kabaleka [54]; where such vegetation is also called *Cyperus papyrus L*. such as around the Kibale National Park wetlands [53, 55] and in papyrus swamps of western Uganda [56]. Studies have also quantified that papyrus vegetation covers most of the 85,000 km^2 of permanent swamps found in Africa [54]. In most wetlands zones such as in southern Uganda [5], guesstimates report that about 30,000 km^2 of the country's wetland area is covered by papyrus vegetation including areas of seasonally flooded grassland, swamp forest, permanently flooded papyrus and grass swamp and upland bog [57]. In southern Uganda alone, the coverage of mixed papyrus wetlands is reported at 5781 km^2 and monotypic papyrus wetlands cover 2169 km^2 [58].

However, other wetlands are dominated by marshlands such as around Lwamunda wetlands around Lake Naubgabo in the Lake Victoria basin [54, 59]; broadly characterized as lacustrine permanent wetlands, for instance, around Lakes [60] such as wetlands around Katonga, Zinga and Nsonga Bays of Lake Victoria [61] and in the River Kafu system [17]. Others comprise swamps and bogs [17] and woody vegetation including the *Cyperus* papyrus-*Vossia* swamps such as in the Lake Albert Delta Ramsar wetland system [62] in the Albert rift area, especially between Lake Albert and Lake Edward [63]. This represents an increasing presence of seasonal ephemeral wetland areas observed in formerly permanent wetlands of Kampala, Wakiso, and Mukono which are now covered by either marshes or modified papyrus including wetland grasses and sedges, for instance, around the River Sezibwa system [20, 64] or completely drying wetlands such as around Nakivubo channel wetlands [42], indicating a decline in permanent wetlands [20, 65] as reported in the field interviews; especially in Kikandwa and Kalangaalo. The worrisomely increasingly seasonality of inland permanent wetlands is further reported in several sub-Saharan African countries with devastating impacts [7].

In some other tropical areas, permanent wetlands are called swamp forest wetlands mainly covered by Tropical peatland swamp forests such as in Sumatra in Indonesia [66] or tropical papyrus wetlands, notably in Uganda [50]. In some parts of the Nile Basin zone; for instance, along the R. Kagera [67] well as in parts of South Sudan; Machar Marshes and Sudd Wetlands dominate the Nile Catchment Area [6]. Permanent wetlands occupy an area of approximately 40,000 km^2 in central and eastern Africa [58]. This implies that most of the wetlands in the interlacustrine zone of East Africa; especially along the Nile River are both seasonal and permanent depending on the location [68] and are covered by different vegetation types though there is increasing evidence of wetland cover change [18].

Globally, wetlands cover approximately 7% of the earth's land surface [34] and about 7% of Africa, and many of these wetlands; including permanent wetlands are covered by emergent sedge papyrus [21]. In Uganda, the land cover of wetland areas is 11%: seasonal wetlands (7.7%), permanent (3.4%), and swamp forests < 0.1% [69]. At least 69% of the total area under wetlands comprises impeded drainage, while swamps constitute 30% and swamp forests, 1% [17]. Wetlands cover approximately 15% of Uganda's surface area [70–72]. Uganda has 3.1 million hectares (ha) of wetland representing 7.8% of Uganda's total area respectively [18, 55]. In 2008 wetlands covered approximately 10.9% (26,308 km^2) of the country's land surface area compared to 15.6% (37,575 km^2) in 1994. Permanent: 5867.1 km2 and seasonal 20440.7 km2 by 2008 [20]. According to the Uganda Wetland Atlas II, wetland coverage has reduced from 15.5% in 1994 to 13% in 2017. Of the remaining wetland, 8.9% is still intact while 4.1% is degraded; further representing an increasing decline of wetlands as reported in our study. Considering the cover at the drainage basin level, wetland degradation was highest in the Lake Kyoga and Edward basins (42% and 34% respectively) and lowest in the Kidepo and Aswa basins (1% each). Further analysis showed that Mbale district had the most degraded wetlands with 99% of its wetlands under threat while

Ntoroko had the lowest percentage of degraded wetlands (2%). Currently, wetlands cover 3.2% of the total land area (from 716,721 ha in 2015 to 785,703 ha in 2017) [27, 65].

According to the Wetland classification system for East Africa (Agreed by the Regional Wetland Biodiversity Group at Mbale, Uganda, in May 1996), the wetlands are further broadly categorized as lacustrine; including permanent and seasonal. Other categories include (i) Palustrine (permanent) herbaceous such as Permanent swamps, marshes, dambos, Seasonal/occasional swamps, marshes, dambos, (ii) Peatlands, fens Montane wetlands (including bogs), (iii) Springs, soaks, and woody such as Shrub swamps, thicket wetlands, Swamp forests. Riverine (seasonal and permanent), and artificial wetlands are increasingly being converted or created for fish farming respectively (MWE, 2016). These broad categories of wetlands are evident in areas that are associated with lakes (lacustrine) and rivers (riverine) all over [15, 27]. For instance, in Uganda, the lacustrine includes the Kyoga/Kwania Complex; Lakes George, Edward, and Albert; Bunyonyi Lake/Swamp Complex; Bisina and Opeta; Wamala; and other minor lakes. The riverine swamps include the Okele, and Kafu Systems [17]. These wetlands are further categorized into four (4) types, and these include, (i) Permanent (Soil is inundated for over eight (8) months of the year) such as around Kazinga Channel, Lake George, and Lake Edward wetlands [73], (ii) Seasonal (Surface water present up to eight (8) months of the year, except in the height of the dry season 0.667). (iii) Temporary Surface water is present only during the (two) 2 months of the wet season 0.167, (iv) Dry Wetlands are no longer wet for prolonged periods [12]. These observations reveal that most wetlands in Uganda are under change and have been modified; becoming less permanent as observed in the River Mayanja wetland zone in Mityana district.

4.2 Main wetland resources and functions

Study findings in *Sect. 3.2* revealed that wetlands in Mityana possess innumerable biotic and abiotic resources that provide several functions to both the environment and surrounding communities (See *Supplementary material*). The presence of different biodiversity has made wetlands crucial in the support of several livelihood activities and provision of wetland services of different types as indicated in *Sect. 3.3* (Also see *Supplementary material*). These findings are supported by a paucity of studies on the value of wetlands in the major wetland zones in Africa [15]. A multi-region study conducted in the eight (8) main wetland systems in Uganda brings into perspective the immense wetland resources in Uganda and their valuation. According to Kakuru et al. [29], wetland products/resources in Uganda can broadly be categorized into food and non-food products provisioning functions. For instance, fishing and fish products generate a per capita value of fish of approximately US$ 0.49 per person, fish spawning values are approximated at US$ 363,815 per year, and the grasses for livestock grazing are valued at US$ 4.24 million, and domestic water use at US$ 34 364 million year.

In addition, environmental functions such as flood control are valued at approximately US$ 1,702,934,880 per hectare, water regulation and recharge at US$ 7,056,360 per hectare, grass for mulching is estimated to contribute to US$ 8.65 million annually [3]. US$ 7.1 million is obtained for water recharge and regulation, US$ 1.7 billion for flood control, and water transport for instance along Nakivale and Gogonyo wetlands [3, 70]. These statistics are further supported by studies conducted in Nyamuriro in Western Uganda and Doho wetlands in Eastern Uganda that reported innumerable values of Important Bird Areas and ecosystem sites as Two hundred and eight (208) species of flora were recorded in 140 genera, 63 families, and 37 orders in Nyamuriro while 184 species, 109 genera, 39 families and 27 orders were recorded in Doho, as well as from resources for housing, water, medicinal plants, papyrus for fuel and thatching [46]. A related study along the Kashambya wetland found that the wetland sequestrates over 3000t of 373 carbon per year [12]. Even in a micro wetland catchment such as of Kashambya wetland, the functions of wetland resources are many, especially on human livelihoods, they can specifically be identified as economic, social, and cultural goods and services [12], and some of these values can hardly be quantified as they are non-market values in nature such as around the Nile River [67, 74].

According to NEMA [18], wetlands in Uganda (both seasonal and permanent) and wetland resources [18] avail three main functions; and these are (i) provisioning services such as for agricultural production and non-food and non-wood wetland products, (ii) regulating/support services including on water flow and quality, and climate regulation, (iii) cultural services such as tourism and recreation, education, biodiversity and conservation and cultural, aesthetic and emblematic values like landscapes and species with spiritual heritage as observed in the Nabugabo wetland ecosystem [60]. These functions correlate with field findings, especially in wetlands along the Lake Wamala catchment zones where most wetlands such *as Nakyegalika* in Maanyi were reported to hold great significance to Buganda cultural heritage. In addition, the performance of several functions and possession of a paucity of resources has made wetlands a mecca for several livelihood activities as reported in the field study; is supported by several studies in Uganda [34, 66] and across Africa [8]. Most studies have revealed that wetlands are habitats to both endemic plants [75] such as in The Bigodi wetland sanctuary in

Kamwenge district in Western Uganda [70], animal species such as crocodiles in the Lake Albert Delta Ramsar wetland system [62] and the 12 unique species of primates, particularly chimpanzee around Kibale National Park zone [53].

The immense value of wetlands to the conservation of biodiversity is further reported in studies conducted in the Albertine Rift in Uganda; where it is estimated that wetlands between Lake Edward and Albert are home to over 7,500 species of animals and plants, including many endemic species [63]. Along the Kazinga channel wetland zone alone, over 57 species around exist; *including Oreochromis niloticus, Bagrus docmac, Protopterus aethiopicus, Clarias spp, and Oreochromis leucostictu*s [73] and in areas around Lake Kabaleka [54]. Several bird species are also habitats in wetlands including the unique birds such as white-winged scrub-warbler and papyrus yellow warblers that occur in papyrus swamps, for instance, Lutembe and Mabamba along Lake Victoria [65, 67] and sitatunga around the Rushebeya-Kanyabaha wetland in Kabale [50]. Studies report that Lake Victoria around Kasa and Mabamba Wetland is a habitat to more than 300 bird species including the globally threatened Shoebill, many Palearctic migrants such as the Blue Swallow, White-winged Tern, and the Gull-billed Tern [20]. This is confirmed by field observations where sightings of the crested crane were common in the Mutetema wetland in Kalangaalo. The overall benefit of these functions has further attracted wetland threshold settlement and developments for instance, around Nyarungu wetlands [51], and boosted industrial establishments for instance in Kyambogo in Kampala; a conduit for employment provision and increased national growth [35, 39].

Urban wetlands such as Nakatongoli in Mityana were reported as crucial in waste treatment and effluent (nutrient) retention from Mityana Municipality and this is further supported by several studies such as along the Nakivubo wetland in Kampala [17, 40], and in Mityana municipality [48]. Furthermore, wetland zones are reported by local participants in Sekanyonyi SC to be crucial farming zones such as around Bakijulula for tea plantation irrigation and this is further reported in several studies that most wetlands aid both subsistence and commercial agrarian practices, especially among refugee communities in West Nile around Palorinya in Moyo near Albert Nile wetlands [11, 30]. In Eastern Uganda around Kibimba and Doho-Namatala rice irrigation schemes in the River Mplogoma catchment, local wetlands sustain rice production thus providing food [45] in the Doho-Namatala wetland zones [44, 47] respectively. Some of the subsistence crops that provide food are also a source of income to sedentary communities in poor urban settlements of Kampala and Wakiso along Lubigi wetlands as crops such as yams, maize, and sugarcane are grown and sold to urbanites [40, 43].

Lacustrine wetlands around Lake Wamala are crucial fishing zones [2]. The fish provisioning values of wetlands are also reported by studies conducted along Lake Nabugabo wetlands in the Lake Victoria catchment that revealed over 30 species habituate wetlands such as Lwamunda [59, 60]. The domination of papyrus in most of these wetlands as reported in studies such as around Katonga Bay [61], further aids crafts making [48, 64]; thus employing women who make local crafts such as papyrus mats as reported in Mityana Municipality [76]. The wetlands have further reduced the water harvesting burden on women for instance, around Lake Victoria as about 55% of the water that drains into the Lake Victoria catchment via several tributaries is used for domestic consumption by riparian communities [61]. The water provisioning value of wetlands to households is documented in a study conducted along the Bigodi wetland sanctuary in Kamwenge district that found that the average amount of water collected from the wetland per 425 households was 63.5 L (± 23.8/day) [70]. In addition, most of the wetlands such as the Rwizi wetlands in western Uganda, have been crucial in groundwater recharge/discharge in the Rwenzori area, and in sediment and toxins retention such as around the Lake George wetlands [17]. These benefits have boosted biomass export in the Lake Victoria wetlands catchment zone thus leading to microclimate stabilization; for instance around Lutoboka along Lake Victoria [3, 41]. These wetlands are natural carbon sinks; for instance around Kirinya in Jinja [21] and pollution controllers; notably, around Murchison Bay [42]. In most of these wetland-protected zones such as around Mabamba, the impact of floods and siltation has been minimal as wetlands are natural buffer zones to surface runoff [41].

Most wetlands have served as cultural sites and havens such as the Bigodi wetlands in Kamwenge [70], and Nakyegalika wetlands near Lubajja along Lake Wamala [2], and Kirinya in Jinja along Lake Victoria [21] thus promoting both cultural tourism and conservation and this is common around Kibale National Park [55]. Other human-related benefits of wetlands have included the provision of building materials such as grasses for thatching [55], and grasslands for livestock like in the Kyoga plains [21, 44]. In most of the wetland zones, local communities have tapped wetlands for transport such as along Lake George and Wamala wetlands [2, 3]. Most of these wetland benefits are transboundary and regional as reported in field interviews that wetlands such as River Mayanja have immense benefits in several districts such as Mityana, Wakiso, and Kiboga. The transboundary benefits of wetlands for instance, sudd wetlands along the Nile have been reported at a multi-country level, notably in riparian states such as South Sudan and these are broadly categorized as regulating services valued at about $1.2 billion, biodiversity services at $857 million, provisioning services valued at $209 million, and transportation services estimated at $293,400 per year; with an annual estimated economic value of 2.3 billion USD [6]. This cements the findings in the literature that the integrity of local communities and their welfare is highly dependent on or sustained by wetlands that need to be sustainably managed [65]. However, as reported in the previous section, it is evident that wetlands in Mityana and Uganda, though important in serving human-environmental systems, are in decline [65] and this could immensely affect livelihood welfare.

4.3 Main threats

In *Sect. 4.3*, we break down the main threats to wetlands that affect the provision of both environmental and human goods and services. Field findings as shown in Figs. 6 and 7 highlight that the increasing threat to wetland loss in Mityana district is largely attributed to anthropogenic drivers accounting for 93% of the loss; with environmental drivers accounting for 7%. A review of documents on the main threats to wetland loss both in Uganda and in the tropics conforms with these findings; for instance around wetlands in Zimbabwe, Wakiso and Kampala areas and the Lake Victoria catchment area [3, 13, 34, 65]. For instance, from 1990–2020, 72,828 ha (73%) of the Wakiso-Kampala wetlands were lost mainly to human drivers such as agriculture [64]. Around the Kashambya wetland complex, human-induced disturbance accounts for 15% and 26% of the biomass in papyrus and reed plots degradation [12]. The increased anthropogenic pressure on wetlands has led to increased opportunity costs to wetland management [15]. The opportunity cost of wetlands encroachment is estimated in the range of US$ 1.40–6.61 461 million [3]. We break down the threats in the following sections into both human and environmental threats to holistically comprehend how each threat grossly affects the entire wetland system.

4.3.1 Human threats to wetlands

Section 3.4.2 indicated that human drivers/activities are the main cause of wetland loss in the sampled wetlands. This observation is supported by most of the literature related to the causes of wetland loss in Uganda [18]. Some of these human drivers might not have been a threat per se, but the increased or excessive carrying out of such activities such as subsistence farming compromises the wetland ecosystem health [3] thus leading to long-term wetland loss. The common denominator has been the increase in agriculture around urban and rural wetlands such as the Mpamujugu wetlands in Mityana Municipality is increasingly altering or completely wiping out wetlands [48]. Increased farming has either been subsistence; as reported by a study along Lake Wamala in parts of Buzibazi [2], along Albert Nile in refugee settlement zones such as Palorinya in Moyo [30] or large-scale, for instance, around the Doho and Kibimba commercial rice farming schemes in the River Mpologoma catchment [45]. Around Budongo forest zones, 90% of forests (including swamp forests) have been affected by sugarcane growing and it is estimated that by 2040, subsistence agricultural land is likely to increase; implying that about 647.64 sq. km of wetland will be converted to agricultural land, especially around the Lake Kyoga floodplains; especially around Awoja wetlands [28, 75]. The devastating impacts of both commercial and subsistence farming are put into perspective by a study in the River Mpologoma catchment zone; where the annual rate of wetland loss due to farming is estimated at 5.52% per year [45]. Around Bigodi wetlands, it is estimated that 72% of the wetland buffer zones have been converted into crop farms including tea plantations and gardens of maize (94%), bananas (81%), beans (60%), sweet potatoes (53%), and cassava (47%) [70].

A related study supports these findings as it was observed that about 95% of the local population (mainly Bakiga and Batoro) around Kibale National Park are into agriculture and; tea plantation lands have increased from 39% (27,186 ha) to 45% (31,457 ha) between 1984 and the early 2000s dwindling livelihood resources and assets such as water, land [55]. Around Nakivubo wetlands, it is estimated that about 62% of wetland vegetation has been lost due to crop farming from 2002 to 2014 [41] and in the Kyoga wetland zone, 5,481.1 km^2 have been degraded between 2015 and 2018, partly due to sugarcane cultivation [18]. Recent studies on Kampala and Wakiso wetland buffer zones reported that agrarian land has doubled since the 1990s; of which 16,488 ha (23%) were reclaimed from wetlands. For instance, all agrarian zones in Kampala exist near or in wetlands, while in Wakiso, 73% of crop agriculture is in the wetlands [64]. Currently, it is reported that agricultural practices have led to increased pollution of wetlands as 75% of the riverine nitrogen now entering the Lake Victoria basin comes from agriculture [31]. Small-scale farming is so far the most dominant form of degradation accounting for 95% of the degraded wetland area countrywide [18]. The proliferation of agriculture in such zones has further led to increased emergence of reduced nitrogen content as observed around Nakivubo and Kirinya wetlands with about 4.8% DW and 3.7% DW respectively [5], competition for scarce resources such as grasses for thatching [50], environmental degradation, and reduced groundwater recharge and supply. These threats have increased the risk of gender-based violence such as around *Bidi Bidi* refugee settlement [30] and the loss of resources that women harvest such as fuel wood for their livelihoods as reported in Mityana Municipality [76].

The devastating impacts of large-scale farming have also been reported and put into perspective in several global studies. For instance, in the USA, over 87 million hectares (54%) of original wetlands have been converted into commercial farmlands altering the topography and water resources [11]. In some wetland buffer zones such as in Kibale around Bigodi wetlands, monoculture; due to tea plantation farming [53] has been either dotted with the use of pesticides which has led to the pollution of wetlands and loss of biotic organisms, or increased livestock rearing (as 91% of households own at least 1 or more cattle) threatening primates such as Chimpanzees [53, 70]. These threats have also been increasing around Nyamuriro wetlands [46]. Around the Lake Bunyonyi catchment zone, livestock grazing led to a loss of fertile wetland soils (143 kg ha – 1 year – 1) [49]. It has been estimated that by 2040, about 48,798 Km^2 of wetlands in the cattle corridor such as around the Lake Kyoga catchment are projected to be destroyed by livestock grazing [75]. This is increasingly evident, especially in the Upper Rwizi catchment areas; especially in Mbarara [22]. As observed in the field study, especially around Sekanyonyi sub-county, these threats to wetland encroachment could be due to a lack of awareness about clear wetland boundaries [39]. Similar results were reported in a study conducted in Mityana Municipality which found that areas that lack wetland pillars and demarcations have been over-encroached by brickmakers or subsistence farmers such as around Wakitundu [48]. The impacts of a lack of wetland boundaries have been well reported, for instance around the Lake Albert Delta wetland zones as it has increased human encroachment and habitat destruction of crocodiles [62]. This is increasingly affected by the limited local awareness of wetland zones especially among poor rural communities as reported around Nakivale in Isingiro [3].

In addition, field findings, especially around wetlands of the Mayanja system indicated an increase in pollution mainly due to improper dumping of waste; accounting for 5% of the threats. This impact has been prominent in urban wetland loss; especially around Kampala and Mukono which experience poor solid waste management and increased pollution [34] such as around Murchison Bay [42] and riparian wetlands which is further reinforced by the lack of willingness and ability to pay for waste collection services threaten wetland ecosystems as observed around Kitezi wetlands in Wakiso [39]. Similar effects of wetland pollution due to dumping have been reported along Wakitundu wetland in Mityana Municipality as the municipality has one dumpsite in Namukozi and about 89% of residents in Mityana Municipality lack training on proper solid waste management along wetland zones such as in Katiko along Lake Wamala [48]. Management of waste is further weakened by either the improper wastewater treatment capacity thus increasing eutrophication due to increased nutrient-rich effluents such as around Nakivubo wetlands, especially around the Bugolobi Wastewater Treatment Plant (WWP) [35].

Studies have indicated that the WWPs in Kampala have limited capacity to manage the increasing effluent from urban sprawl thus affecting Nakivubo wetland ecosystems with further consequences on drinking water quality, notably along Nakivubo water treatment plant and increased health risks such as cancer risks [42]. This is partly due to the increased uptake of PFSAs from the soil in yam roots, maize cobs, and sugarcane stems [40] and the increased emergence of blue-green algae blooms such as around Kirinya wetlands [5]. Some studies have warned that due to increased pollution and associated eutrophication in the Lake Victoria wetlands and bays such as Zinga and Nsonga, and small wetlands such as Nakivubo and Wankolokolo wetlands, the current ionic retention capacity has increased beyond normal limits [61]. Studies around Lake George and Edward basin wetlands further revealed that the impacts of pollution have become more localized [77] and are increasingly affecting sedentary species for instance, fishes like *Oreochromis Niloticus* around Hamukungu Bay and wild animals such as Hippopotamus around Kazinga Channel as well as soil macro-invertebrates around Kahendero wetland where heavy metals either accumulate or are re-dissolved leading to bare infertile soils [73]. Localized effects of pollution such as on hypoxia tolerance of many cichlids that use aquatic surface respiration have been also reported around Lake Kabaleka wetlands [54].

Increased pollution has been worsened by a spike in massive industrial developments dotted with the setting up of industrial parks in wetlands, notably around the Kampala region [17]. These have not only increased socio-economic pressures, such as for infrastructural developments such as roads for access but also lead to backfilling of wetlands with gravel [78] as reported around Kyambogo wetlands with devastating effects. For instance, backfilling led to a reduction in 75% of Kinawataka wetland cover by 2011 [39]. In addition, the increased industrial developments have translated into a spike in industrial effluents into critical wetland zones and bays like Murchison Bay along Lake Victoria affecting ecosystems [61]. Devastating effects of industrialization such as the increased release of industrial effluents are reported around Bugolobi wetlands where industrial effluent occurrence and concentrations of 26 per- and polyfluoroalkyl substances (PFASs) were higher (5.6–9.1 ngL – 1) than in the corresponding in fluent (3.4–5.1 ngL – 1) [40]. A related study further reported that 80% of the riverine phosphorus in wetlands around Lake Victoria comes from municipal and industrial sewage, discharged from urban and agricultural drainage channels [31]. The effects of industrial growth were observed along plantation estates in parts of Bulera where large-scale plantations cross wetland zones.

Some respondents attributed the loss of wetlands to the tricky land tenure system, especially around small wetland areas such as in Mutetema and cross-boundary wetlands such as Bimbye in Kalangaalo separating Mityana and Kassanda districts. The complex land ownership, notably around Kampala [39], and weak local land management agreements have become a persistent complex issue all over Uganda mainly around major wetlands like Mpologoma which has increased encroachment. A study on complex land ownership systems revealed that weak land management policies have led to an increase in the built-up area in the catchment by 55.5% [45]. This is further worsened by the limited knowledge of legal arrangements governing wetlands, especially among land owners and tenants. Most land owners near wetland zones rely on unwritten policy/ies since the 1950s that encourage communal extraction, less controlled swamp drainage for pasture, and growing of crops and also rely on the 1995 Constitutional provision that land belongs to people [17]. The complexity of land ownership in buffer zones and its effect is resoundingly reported in a study around Bigodi wetland; that found that the increased private ownership of land (estimated at 2.26 hectares/household) is increasing encroachment on conservation zones of Kibale National Park thus increasing wildlife attacks on local households or farms [70]. Complex land ownership has also been common in areas with conflicting land uses; especially around Kibale National Park where the leasehold system to large-scale tea plantation owners has led to the loss of wetland buffer zones [55]. Areas with communal land ownership systems such as around Lake Albert Rift have either increased excessive resource utilization; for instance, where an average holding of only 2.36 ha exists, or increased encroachment in conserved wetlands such as around Lake Albert in Bugungu, as local people have limited access rights to resources, notably around conservation zones; yet the household poverty levels are high [63]. Private land ownership around the Kashambya wetland zone led to the loss of about 40% of papyrus plots due to burning for cultivation and 7% due to excessive cutting for crafts [12]. Smallholding along open water wetland zones has led to the illegal destruction of wetland resources and encroachment such as around Lake Kyoga plains [75] and Lake 580 Wamala zones [2].

In the field study, about 20% of wetlands are lost due to increased settlement both within and in the buffer zones of wetlands such as in emerging urban centers, including Zigoti, Sekanyonyi, and Kikonge. The effect of increased settlement along swamplands has been reported in most studies in urban zones, especially around Kampala where 90% reported people invaded wetlands such as in Lubigi in areas of Bwaise and Nabweru [39] leading to risks such as floods. The incidence of urban flooding in Kampala wetland zones has increased from five floods in a year in 1993 to ten in 2014/year [39] and this has been prominent around Nakivubo wetlands where settlement in the wetland zones has increased from 3 to 15% between 2002 and 2014 [41] and around Kirinya wetlands in Jinja [21]. In the Kampala metropolitan area, the urban population increase is worsened by the acute housing deficit estimated to rise to eight (8) million by 2030 and the annual increase in solid waste (350,975.38 tonnes/year) of which only 1500 tonnes of solid waste is taken to Kitezi landfill daily with the rest dumped in urban wetlands [27]. A study by Wasswa et al. [34] revealed that increased settlements have led to a loss of 17% of papyrus swamps in Mukono alone from 1974 to 2013 such as around the Kasokoso-Namanve wetland zone, partly due to improper waste management and encroachment. A related study in Kampala reported that wetland cover has reduced by about 49.1% from 1995 to 2020, and in Nakivubo wetland, 62% of wetland vegetation has been lost in the past decade [39]. In 2016, a loss of about 6,740 hectares of wetlands was reported in Kampala and Wakiso alone [64]. The effects of the population explosion around the Kampala metropolitan area have in other words added pressure on wetlands and wetland resources such as around Nakivubo [17] and the Murchison Bay area [61].

In addition, with a 15.7% increase in built-up zones in wetlands such as around Doho [45], settlements have partly led to a decline in wetland cover from 15% to 10% from 1994 to 2008 nationally. This is further worsened by the increasing population which has increased the demand for cheap land and resources for survival [45] such as in Eastern Uganda. A study by Bunyangha et al. [45], revealed that the population density in Eastern Uganda is high at 3.55%, and around the Mpologoma wetland zones, it is 567 persons per square kilometer. Around Nyamuriro wetlands, subsistence farmers' density in the wetland zones is estimated at 290 persons/km^2 with an annual growth rate of about 2.17%. Thereby increasing encroachment and digging of channels in the wetlands [46]. For instance, around Jinja, there is overuse/drawing of water to serve two (2) dams; that is Nalubaale and Kiira that cater for the increasing populations [31]. The effects of settlement on the degradation of urban wetlands such as along Katiko and Wakitundu wetlands in Mityana Municipality have also been well documented in a study by Bbira and Nabukonde [48]. Similar incidences have also been observed in rural wetland zones, especially around refugee settlements such as Imvepi in Arua [30].

The increasing encroachment is also attributed to weak regulatory frameworks and low levels of coordination between NEMA and local authorities [19] at district and municipal levels have led to encroachment from various groups of people; most notably, rural–urban migrants and the urban poor who cannot afford decent housing facilities elsewhere [39]. These findings are further reported around agricultural zones such as around Kibale NP where local politics has led to the increased giveaway of wetland buffer lands to Bakiga and Batoro farmers thus increasing the fragmentation and clearing of wetlands. For instance, 3262 patches out of 3631 ha of wetlands in Kibale NP had been fragmented by 2003 [55]. The threat of contested wetland ownership is prominent and has increased around Kampala, Wakiso, and Mukono [34, 65]; with several land ownership barriers as local authorities still have less control over wetland encroachment due to little ownership/access to buffer land (owned by legal landlords such as mailo landowners). This has led to the increased clearing of wetlands by the rich for real estate or industrial development; as wetlands are seen as a cheap option to acquire cheap land near the city [41].

The weak governance systems are documented in a study conducted by Mwanjalolo et al. [75] that reported that weaknesses such as in the Land Sector Strategic Plan in 2001 and a National Land Use Policy in 2013 as well as in the Land Act; do not adequately address wetland management issues and population increase; hovering around a 3.4% annual growth rate and this has partly increased encroachment in wetland zones. For instance, the shift and government preference for industrial developments in the Kampala-Mukono wetland corridor (KMC) has reduced wetland coverage from 7190 hectares in 2006 to 5410 hectares in 2013 representing a − 24.9 decline [34]. This weakness is also demonstrated by a study conducted along Lubigi wetlands that reported improper wetland monitoring mechanisms and political interference; where Central and Local Authorities such as the KCCA leadership have indicated that they converted wetlands for the sake of providing their communities with economic growth opportunities and for fighting poverty as per Government Policy (Poverty Eradication Action Plan) [57]. According to the Uganda Wetlands Atlas I report, population encroachment accounted for a 14% reduction in wetlands in Kampala, Mukono, and Wakiso between 1995 and 2010 [20]. This has increased the loss of revenue for national development. According to MWE [65], Uganda loses about 15% of its GDP through the destruction of natural resources including wetlands, and the annual cost of revenue loss is about 2 billion Uganda Shillings well as the opportunity cost of wetlands water resource pollution (including open water bodies such as Lake Victoria) due to *inter alia*; low buffering capacity, which is more than 38 billion shillings (Additional file 1 and Additional file 2).

Of increasing concern, as reported in the field study findings is the proliferation of commercialized eucalyptus and pine tree planting in both wetland riparian and within wetland zones such as along Rhino camp [30], along River Mpologoma wetlands [45] and along the Lake Bunyonyi wetland catchment zone; where eucalyptus trees led to a loss of fertile wetland soils (reported at 78 kg ha − 1 year − 1) and loss of water [49]. According to the 2019 NEMA report, commercial eucalyptus tree farming is a new driver to wetland loss and currently represents 0.9% of the degraded wetland area such as along the Namavundu wetland zone. A related study around urban wetland zones in Wakiso and Kampala such as along Lubigi further explained that eucalyptus farming is currently one of the main human drivers of the total change in wetland cover which has reduced from 96.3% in 2002 to 80.6% in 2018 [57]. Other related threats include increased charcoal burning and timber collection, for instance, from woodlands along seasonal wetlands such as in the Kyoga Catchment zones [45], and increased mining such as of sand [1], and clay for brick making affecting wetlands; especially at Lutoboka around Lake Victoria [17] and Nyamuriro [46]. Intentional human destruction of papyrus to capture sitatunga or harvest natural honey is also threatening biodiversity such as around Nyarungu swamp, in the Lake Bunyonyi area [51]. Other minor but increasing threats reported include unregulated papyrus cutting [79], unplanned infrastructural developments that are projected to account for 42.7% of the gross KMC (Kampala-Mukono corridor) wetlands damage by 2040 [34], and poverty that increases pressure on wetland resources such as harvesting of young fish to sustain households as reported around the Rwizi-Rufuha wetland system [52]. These threat indicators; though in varying degrees, are significantly related to field results that found that 93% of wetlands are threatened by human drivers.

4.3.2 Environment threats to wetlands

In Fig. 7, it is clearly shown that about 7% of the threats to wetlands are environmental mainly related to climate change (increased drought/temperature), wild animals, and seasonal occurrence of pests. These observations have been consistent with most of the research related to the relationship between wetland loss and environmental drivers, especially in the Lake Victoria region [43, 59, 80] and in most of the inland wetland zones of sub-Sahara Africa [74]. In this section, we further explain the environmental threats that proliferate wetland loss.

In the Lake Victoria catchment, studies have reported the increasing emergence and introduction of invasive species such as the water hyacinth since the 1990s in the Lake Victoria basin, and exotic fish species that have affected biodiversity and species richness [32]. A study in the Lake Nabugabo wetlands reported that the introduction of Nile Perch reduced species richness from thirty (30) endemic species in the 1960s to only sixteen (16) based on the 1992 Fisheries survey statistics by the Fisheries Resources Research Institute of Uganda [59]. In addition, Nile Perch preyed on nine (9) of the eighteen (18) species from the open waters of the Lake Nabugabo satellite wetlands [38]. The emergence of invasive plants has reduced oxygen in the waters thus affecting non-air-breathing fishes that use aquatic surface respiration [59]. Around Lake Victoria, the water hyacinth; such as around Rubondo Island has affected fish diversity and spawning [31]. Similar effects were reported in a related study by Chapman et al. [60] and Schofield and Chapman, [37] which found that 50% of the indigenous fish species (> 99% of the mostly endemic *haplochromine* cichlids) disappeared from the open waters; after the establishment of the introduced predatory Nile perch (*Lates niloticus*) and this had multiplier negative effects as it has increased overfishing; thus causing a loss of ecological habitats and fishes in Lake Victoria basin. By 2000s, most fishers had adopted the "fishing-down" process, focusing on successive smaller, shorter-lived fishes than the lost large fish individuals thus causing changes in fish faunal structure and diversity. Research in Lake Nabugabo satellite wetlands in 1995 revealed that the Catch Per Unit Effort (CPUE) of *haplochromines* in experimental gill nets was very low (with a mean of 6 fish per transect) [59, 60]. Climate change effects such as increased floods around Lake Kabaleka have been reported to affect patterns of hypoxia tolerance among *haplochromine* cichlid species [54]. This indicator could partly explain the concern reported by a key informant among fish communities around Lusalira wetlands that '*tilapia fish catches have increasingly reduced in Lake Wamala since the early 2000s*' (field report).

Field findings further reported an increasing threat of climate change; characterized by the increased drying of wetlands of Kikandwa and this is supported by literature that relates climate change to wetland loss such as in Africa [15]. Instance, a study of the Lake Victoria wetlands around Zinga Bay reported increased temperatures; a component of climate change affecting thermal inversion along the water column and leading to evapotranspiration and wetland shrinking [61]. The threat of climate change on the loss of wetland resources such as organic matter of wetland peat soils has also been reported in many other tropical zones; especially in seasonal wetlands [74, 80] creating a looming food crisis [66]. These threats have been evident around Nakivubo wetlands as heavy rain has increased runoff and silting/flooding, and hot temperatures have led to the drying of *Cyperus* papyrus, cattails (*Typha* sp.) and common reeds (*Phragmites* sp.), and a large area on the northeast side covered by *Miscanthidium violaceum* [41]. Currently, most of the wetlands in the Victoria catchment are increasingly becoming seasonal [18, 41, 65]. For instance, around Rubondo island wetlands along Lake Victoria, global warming has led to an area decrease of 2.5 m between 2000 and 2006 leading to increased loss of wetlands partly due to natural fires, and drying, especially in the dry season [31, 51]. The effects of climate change/hot temperature-induced wetland fires are also evident in the Kashambya wetland complex [12] and around Nyarungu swamp, Lake Bunyonyi in South Western Uganda [51].

The threats of climate change on wetlands are further well reported in several national reports [18, 27, 81, 82] and studies conducted around the Lake Wamala area found that increased droughts accounted for 15% of wetland losses such as in the Buzibazi and Lusalira, thus affecting local communities; especially women who harvest such products for crafts making [2, 76]. In Lubigi wetlands, hot temperatures have led to vapor deficits for papyrus growth leading to drying of young papyrus [43]. Around Lake Nabugabo, hot temperatures have led to low dissolved oxygen for the fish thus partly leading to species decline [38]. In addition, vapor deficits have been reported in recent studies due to climate change [18]. A study conducted around Kirinya wetlands revealed evapotranspiration from the papyrus vegetation was 25% higher than calculated rates of evaporation from open water; affecting water quantity and biodiversity [58]. This observation has also been well-documented along most riparian zones of the Nile Basin [68].

There is also increasing evidence of non-climate change-related environmental stressors to most wetlands zones [7, 15]. In the field study findings, 2% of respondents reported threats due to wild animals and pests. This is supported by pockets of literature that reported that increased seasonal invasion of swamps by wild animals including large herbivores such as elephants and Hippopotami has an important effect on the destruction of Paleotropic ecosystem-especially where populations have increased such as around Nyarungu swamp [51]. The effects of pest; especially locusts have been reported to cause devastating loss of wetland vegetation such as sedges and papyrus that ameliorate micro climatic conditions; notably in the plains of the L. Kyoga wetland zone around Lake Opeta in Pallisa district and Limoto wetland in Kibuku district leading to the emergence of hard wetland pan, aridity shrinkage and limited ability of local communities to conduct smallholder farming thus food insecurity [29].

5 Conclusion

Field findings in our study and review documents prove that wetlands are a crucial ecosystem in promoting sustainable livelihoods and development especially in tropical regions [8, 34]. In most regions; including Uganda however, most wetlands are increasingly under threat mainly due to human-induced threats with devastating impacts to microclimate conditions [65], ecosystems-both biotic and abiotic [20] as well as livelihoods [18]. The proliferation of anthropogenic drivers such as increased cultivation in wetlands such as along the River Mayanja system and the Kyoga plains like Doho-Namatala [44, 47] has not only increased pain points to sedentary communities heavily relying on wetlands resources for their survival but also scupper and compromised national efforts to achieve sustainable development [3, 82]. In the context of Mityana district, especially in the study area, it is evident that the level of threat varies. For instance, in most of the wetlands (seasonal) such as around the River Mayanja system, the level of degradation is higher than in most of the permanent wetlands; especially around Lake Wamala. Field findings related this to several reasons such as cultural values and the increased demarcation and marking of wetlands like around Nakatongoli and Wakitundu by the Wetlands Department and the Mityana District Local Government Natural Resources Office/Department. Though this could be a positive step in the management of wetlands, the partial focus on Lake Wamala wetlands could grossly affect the riparian wetlands of River Mayanja since all the wetlands are interconnected and are part of the entire Lake Victoria catchment [27].

Based on this context, one may wonder what could be done to reverse this trend. A review of documents on wetlands and wetlands management practices reveals pockets of strategies that could be undertaken to promote wetland management for socioeconomic and environmental benefits. These could inter alia involve, the identification of context-specific conditions and rural/urban processes through which the Disaster Management Plans can network or function [39], buffering of peak loads using locally cost-effective technologies to reduce effluents into treatment plants [35], integrated capacity building e.g. on solid waste e.g. using participatory human-centered and compassion driven methods [48], habitat partitioning and seasoning access to wetland resources [62], buffer zones livelihood productive forestry projects including a transition to renewable energies [30], value transfer approach by valuing the socioeconomic benefit of wetlands [11], promotion of green belts and green cities including urban farming [45].

In most studies conducted in sub-Sahara Africa that focused on wetland management strategies, proactive measures on activities that promote wetlands' structural integrity and functionality have been emphasized albeit with few impact-evidence case studies [15, 61, 74]. This among others envisions increased research on the tolerance of indigenous species to environmental stressors [59], increased pollution risk and control research along wetlands [40], wetlands zoning using a sustainable community-centered approach [70] that is also multi-faceted and participatory [41], using of remote sensing and new technologies to monitor wetland riparian zones and land-use threats [55, 83], sustainable utilization of papyrus as a biofuel alternative to fuel wood [21, 31] and papyrus maintenance [78]. In shared wetland zones, calls for continuous wetland ecosystems assessments and inventories using feasible ecosystem assessment tools have been envisioned [12]; with a focus on wetlands restoration [42] and sharing of updated information among local communities [3] including gender mainstreaming as agents of positive change [49]. This perspective brings to the fore the need for decentralization of wetland management approaches as initiated in Zimbabwe [13], Ethiopia, and Sierra Leone [10] via the use of locally feasible institutional arrangements, historical knowledge, and inclusive legislation [74].

5.1 How to navigate through the increasing threats and lessons learned

Even though we acknowledge the increasing scholarship; especially in identifying challenges facing wetlands in tropical regions, mainly in Africa, one key gap in the literature is that most studies have focused on policy and institutional threat identification thus discounting the use of participatory approaches that help co-create new ideas on why and how wetland loss has perpetuated in most regions of Africa. For instance, in Zimbabwe, even though calls for decentralization and institutional frameworks for the management of inland wetlands have been recommended, progress in their implementation is slow [7, 74]. In addition, most of these strategies are still fragmented, and scaling up or translating them into positive outcomes in the context of wetland management options seems debatable [15]. Part of the causal factors for such collaborative management gaps; as reported in Ethiopia has been the use of top-down management policies that are incompatible with local interests, abilities, and knowledge of wetland management [10]. In addition, balancing the intricacies related to stakeholder power and influence in the use and management of wetland resources created more tensions between local users and government or governance institutions [7, 8, 13].

Based on the critical synthesis of the knowledge gaps in the literature, our study adopted a participatory approach; where we engaged with local communities (bottom-up engagement process) to understand systemic risks, their interactions, feedback mechanisms, and synergies to develop locally feasible solutions that could be scaled up after identification of spatial and temporal situational gaps and challenges in a given wetland zone. We do believe that the insights brought to the fore could serve as key strategic policy recommendations that could be scaled up in sustainable micro-wetland management including; increased capacity building and training on wetland laws, regulations, and responsibilities of communities; especially land owners along wetland zones on their responsibilities to manage wetlands. One of the key system gaps that our study brought out is the lack of baseline wetland profiles to inform local communities and authorities about human-environmental needs assessments. Based on the recognition of the variance in the threat levels of wetlands such as in the Lake Wamala and River Mayanja zones, it could be feasible to develop Village Wetland Action Plans (VWAPs) for each area or zone crossed by wetlands to guide local policy on local wetland management. These could further be supplemented by the development of by-laws (both soft and hard) coupled with continuous follow-up to ensure enforcement, a Sub-county, and a district wetlands Action Plan (DWAP) as an inventory to profile wetlands and guide land-use policy and development priorities. The local and district environmental office needs to further be supported in efforts to demarcate and mark wetland zones and boundaries to increase local community knowledge on the extent and limit of their activities. This could be through direct financing of natural resources departments to ensure continuous monitoring of wetland zones. A system-thinking human-centered design is needed to address the systemic causes and risks of wetland degradation in Mityana district and this could be scaled up to other wetland zones; especially in the Lake Victoria basin [71]. This could further be done using new adaptation approaches for shared resources such as the Collaborative Risk Informed Decision Analysis (CRIDA) as a new approach for specific wetland planning and adaptation options for shared wetland resources. Such a local process pathway has been recommended and applied in complex natural resource contexts with increasing pressures (human and environmental) to chart sustainable pathways for sustainable natural resource management, inclusion, and equity [1].

In most of the conflict natural resource zones, ownership issues have derailed management efforts at all levels. Our study revealed that wetland resources and zones in Mityana have been engulfed in this cobweb of land use and land-ownership puzzles. This implies that irrespective of the robustness of institutional mechanisms, scaling up sustainable win–win management and local community user actions might not yield tangible results unless new local pathways are developed [13, 74]. In the context of Mityana and threshold wetland zones in the Lake Victoria region, we could argue that the baseline strategy could revolve around building transparent partnerships among key stakeholders and institutions focused on wetland management. This strategy has been applied with success in parts of Zimbabwe around inland wetland zones and formerly contested communal wetlands [8, 13]. For instance, in our study setting, the Wetlands Management Division of the Ministry of Water and Environment, District Natural Resources Departments, and other Civil Society Organizations could partner with landowners near wetland zones in the integrated management of wetlands. In highly degraded or highly vital wetlands, landowners such as with mailo land titles can be compensated. This could further involve local community sensitization on the meaning of wetlands, on alternative livelihoods to reduce encroachment, and wetland zones and policy needs to be extended to local communities, especially in wetland threshold zones. One key limitation on the key takeaways is that social dynamics are always complex and in highly fragile environmental zones such as wetlands, developing of a collaborative pathway and its implication revolves around several political, socioeconomic, environmental and psychological dimensions. Cognizant of this, further research could involve conducting continuous local area-based focus discussions to constantly update wetland data and situational profiles. This could create transparent decision-making and governance mechanisms as well as help in updating databases that could be mapped and analyzed to guide policy actions.

Author contributions BM: Manuscript preparation, structure, writing, revision, proofreading IS: Data analysis YB: Data collection and proofreading EY: Data analysis YM: Data collection IL: Visualization and proofreading

Data availability The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate The protocol was approved by the Mityana District Natural Resources Department in accordance with the guidelines of Mityana District Local Government.

Informed consent Verbal informed consent was obtained prior to the interview.

Competing interests The authors declare no competing interests.

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