Journal of Water Resources, Engineering, Management and Policy
DOI: https://doi.org/10.56542/wi.jwempo.v1.i2.a3.2024

Original Article

Mapping and Assessing the Ecological Status of Water Sources in Mbarali River Sub catchment

Nyemo Chilagane[1*], Papilon Mkome[2], Elius Chundu[2], George Wandelage[3], Winfred Mbungu[4], Festo Silungwe[4], Japhet Kashaigili[5]

[1]Tanzania Research and Conservation Organization, P.O. Box 6873, Jumbe Mtoto Street, Morogoro, Tanzania.

[2]National Environment Management Council, Southern Highlands Zone, P.O. Box 1562, Mbeya, Tanzania

[3]Rufiji River Basin, Water User Association of MBUMTILU, P.O. Box 1562, Mdandu, Njombe, Tanzania.

[4]Department of Civil and Water Resource Engineering, Sokoine University of Agriculture, P.O. Box 3003, Morogoro, Tanzania

[5]Department of Forest Resources Assessment and Management, Sokoine University of Agriculture, P.O. Box 3013, Morogoro, Tanzania.

***Corresponding Author**: nchilagane@yahoo.com

Received: 04 March 2024 / Accepted: 28 October 2024 / Published: 21 December 2024
© Water Institute

Abstract

Mbarali river subcatchment (MRS) is an important waterway that faces ongoing degradation due to climate change, land use change and poor institutional management which affected river flows in both quantity and quality. This study presents the findings of the cross-sectional survey conducted to identify, map and assess the ecological status of water sources in MRS. The overall objectives of this study are to provide a general understanding on the number of water sources and their spatial distribution, level of human induced pressure that detrimentally affect the quality of water sources and to propose conservation strategies to be taken onboard at a specific water source to ensure its sustainability. Literature review, field survey and stakeholder consultation were used to accomplish this study. Ecological Management Classes (EMC) adopted from Sood (2017), were used to assess the ecological status of identified water sources. Results revealed that, there are about 200 water sources within MBUMTILU WUA. From identified water sources, only 35% were found to be in good quality and the remaining 65% were degraded from anthropogenic activities. The analysis discloses that, Bottom valley cultivation found to be the leading and deadliest threats to water source. Site specific nature-based interventions were suggested to each identified water source depending on the level of degradation.

Key words: Conservation, ecological management class, river flow

1 Introduction

Freshwater availability is a fundamental resource for natural ecosystems, human livelihoods, and vital to sustainable development. The access to it is considered by United Nation as a universal human right (Spijkers, 2020; Langford., 2005). Regardless to its ecological and social economic importance, its availability is constantly fluctuating and under extensive pressure to meet near future demand (Famiglietti, 2014). United Nation World Water Development report estimated that by 2050, nearly 6 billion people could suffer from water shortage as the global water is demand projected to increase by 55% (Boretti, 2019; Greve, 2018). Various stressors including climate change, population growth, deforestation and unsustainable agricultural practices are the leading causes for freshwater resources degradation. Inadequate management of river basins has resulted into degradation of water sources worldwide. Consequently, it has affected river flows

in both quantity and quality with devastating impacts on the river ecosystems through increased inflow of nutrients, sediment deposits, and variation of flow regimes.

Mbarali river sub-catchment is one of sub-catchments within Rufiji basin in the Southern Highland of Tanzania challenged by climate change, land use change and poor institutional management (Mutayoba, 2018, Kashaigili, 2008). Degradation and poor management of water sources have affected river flows in both quantity and quality with devastating impacts on the downstream including the coastal and marine ecosystems through increased inflow of nutrients, sediment deposits, and variation of flow regimes (Kashaigili, 2008). The exponential growth of water demand catalysed by the increase of anthropogenic activities and population growth, increase the pace of water sources degradation.

In addition, water sources degradation in Mbarali river sub-catchment occurs at variable scales such as in streams and catchments, therefore the restoration must reflect those dimensions of degradation in order to improve conditions and manage flows. Restoration efforts have to start with identifying all water sources and assessing different environmental challenges associated including anthropogenic activities within or nearby the source which will help to provides proper interventions for conservations and protection.

There are initiatives which have been taken for water sources management in the Mbarali River sub-catchment. Establishment of water users' association (WUA) as required by Water Resources Management Act 2009 is among of the commendable efforts where by a total of five active water user association have been established. The WUA's names are JUWAMBA, JUWAMBACHI, MBUMTILU, MPANDO and BALALI. Despite these initiatives, the progress in water sources conservation and management is slow thus hindering the implementation of environmental flow in Mbarali river for sustainability of riverine ecology and downstream users. One of the core reasons is hypothesized to be the lack of a comprehensive assessment of water sources located under each WUA's administrative boundaries for improved restoration.

This study focused on water sources available in MBUMTILU WUA. The reason of choice of this WUA's is because it is the biggest WUA in Mbarali river sub-catchment with most of its administrative area located under village land. It has an approximate area of 453 km^2 covering 20 villages of Wanging'ombe district, having three permanent tributaries drain to Mbarali river namely Mbukwa river, Mtitafu river and Lumbidzi river. Moreover, it has sources that drain to Luhuji river in Kilombero subbasin.

Therefore, this study aimed to conduct a comprehensive assessment of water sources for improved restoration and conservation for MBUMTILU WUA as a strategic approach to enhance environmental flows in the Mbarali river sub-catchment. Specifically, the study mapped the water sources, assessed the current ecological status of water sources and evaluated conservation intervention for specific water source in MBUMTILU WUA.

2 Materials and Methods

2.1 Description of a Study Area

Mbarali river catchment sub-catchment (Figure 1) has an area of 1530 km^2 and is located between latitude 7 °S and 9 °S and between longitude 33.8 °E and 35 °E in the upper part of Great Ruaha subbasin of the Rufiji basin in the Southern Highland of Tanzania. Administratively, Mbarali river sub-catchment extends within three District of Njombe and Mbeya Region namely Wanging'ombe, Makete and Mbarali. The main sources of water which contributes in Mbarali river are located at the upper and mid-part of the sub-catchment, largely in Wanging'ombe District and a small part of Makete district.

Rainfall pattern over the Mbarali river sub-catchment is mainly driven by the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ). This zone moves southwards in October and reach the southern part of the country in January or February.

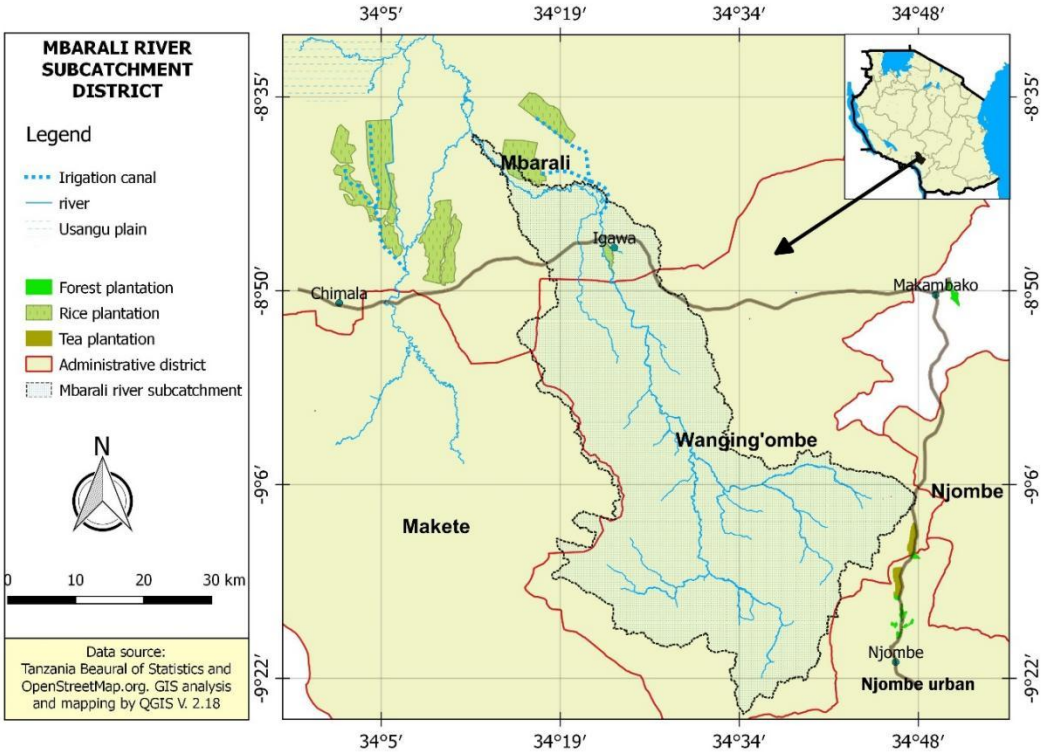


Figure 1. Mbarali river sub-catchment

Again, it reverses northwards in March, April and May. This movements makes Mbarali river sub-catchment to receive a unimodal rainfall pattern that starts in October and continue through April or May. The mean seasonal rainfall and temperature with the sub-catchment ranges between 450 to 650 mm and 25 to 30ºC respectively. The topography of Mbarali sub-catchment is dominated by forest, woodland, bushland, cultivated land and grassland.

2.2 Data Collection

Data were obtained from stakeholder consultations, field observations and literature reviews. The data collection was conducted under the local guidance of MBUMTILU WUA (Figure 2).

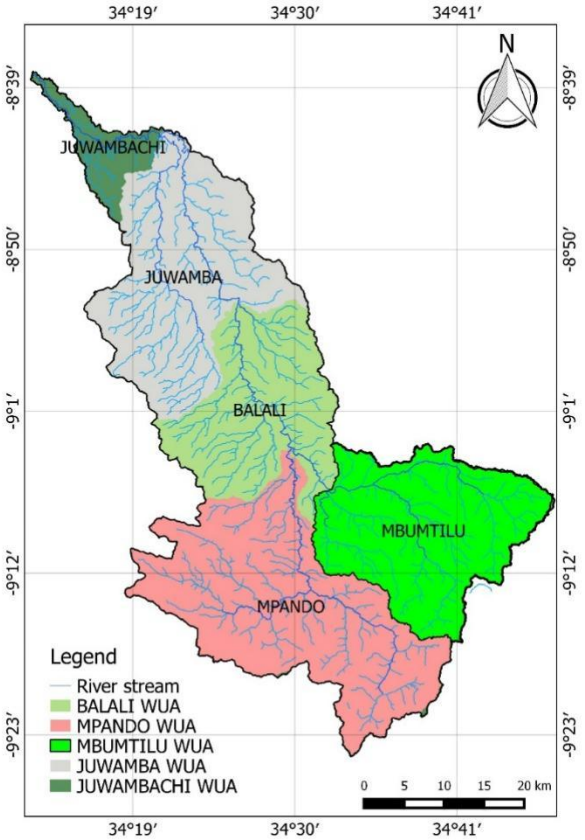


Fig 2. WUAs in Mbarali River Sub-catchment

2.2.1 Field Survey Data Collection for Mapping the Water Sources

The field survey was conducted in 20 villages of MBUMTILU WUA, for identification, assessment and mapping available water sources. Point mapping using hand held GPS were used to map geographical position of each identified water sources. Attribute information including name of water source, current status of the water source, level of human disturbance, water availability, observable threats to water sources, ownership, surrounding ecology were then collected. Ecological Management Classes (EMC) adopted from Sood (2017), were used to assess the status of identified water sources. EMC is ecological condition of an ecosystem in terms of deviation of biophysical components from the natural reference condition.

2.2.2 Assessment of the Current Status of Water Sources in Mbarali River Sub-catchment

Modification was made to EMC to simplify understanding of ecological status of water sources to local context (Table 1). It is important to note that local community is among important and key stakeholder to be considered in any implementation of particular management and conservation objective. In this study class A and B were merged as both of

Table 1: Assessment criteria for status of water sources

UN Environment EMC	Modified EMC	Attribute
A (Natural) B (Largely Natural)	Good	Natural ecosystem with minor modification. There is no or very minimal anthropogenic influence on the water source basically water fetching for domestic use
C (Moderate modified) D (Largely modified)	Degraded	The habitats and dynamics of the biota have been disturbed, and limited impacts on basic ecosystem functions. Some sensitive species are lost and/or reduced in extent. Alien species present. There are moderate anthropogenic influences surrounding the water sources but not within water sources
E (Seriously modified) F (Critical Modified)	Critical degraded	Large changes in natural habitat and ecosystems have been completely modified. Alien species present and Extensive anthropogenic influences around and within water sources

them representing no or minimal modifications have occurred ecosystem. Class C and D also combined as both of them shows considerable modification from the natural state with limited impacts and class E and F grouped together because are generally regarded as not acceptable changes.

2.2.3 Stakeholder Consultation to Evaluate Conservation Intervention

Consultations with key stakeholders including 10 staff from Rufiji Water Basin Office (RBWO), 43 members from WUA and 40 representatives from village environmental committee were made to get an overview on the status of the water sources, conservation challenges, and possible management options that could be taken to ensure sustainable and inclusive management of water sources from anthropogenic activities which are unsustainable.

3 Results and Discussion

3.1 Mapping of Water Sources

From the field survey of 20 villages of

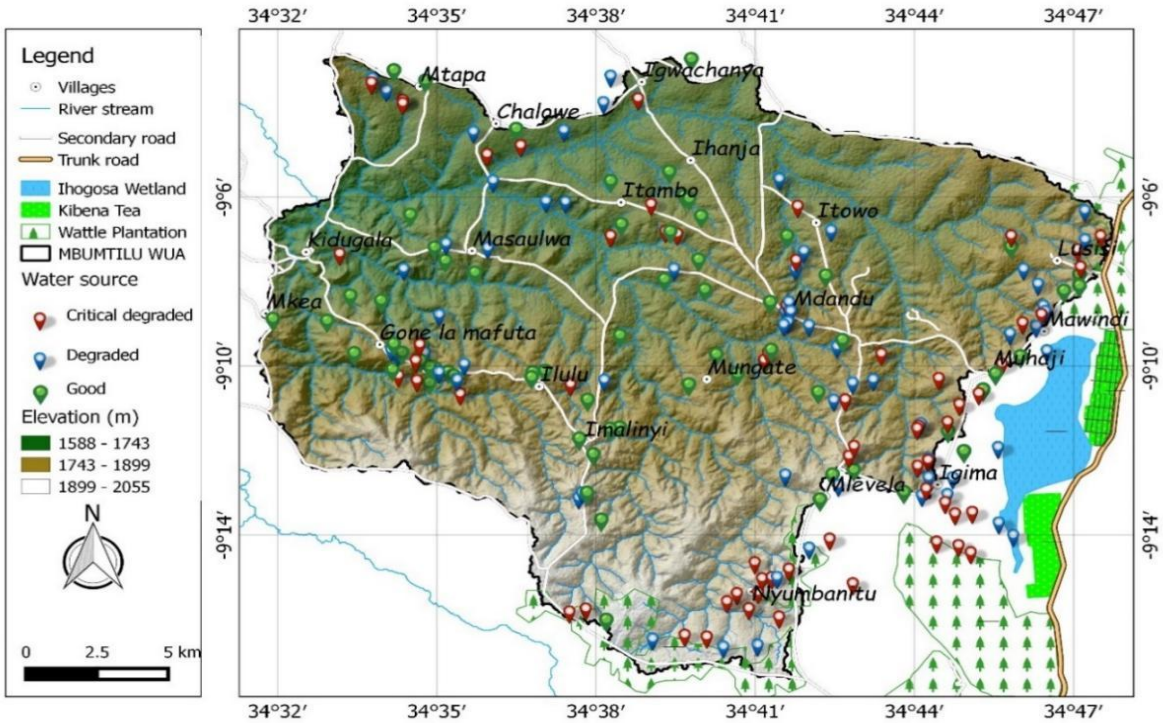


Figure 3. Spatial distribution of Water Sources in MBUMTILU WUA

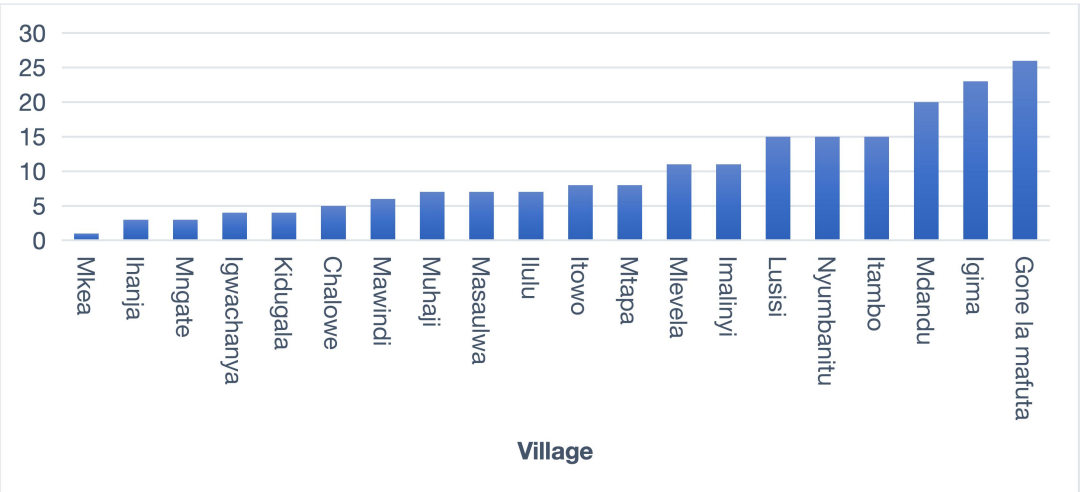


Figure 4. Number of Water Sources per Village in MBUMTILU WUA

MBUMTILU WUA, a total number of 200 water sources were identified and mapped (Figure 3). From identified water sources, 9 water sources found drain to Lihogosa swamp, 6 drains to Halali river, 4 water sources drain to Ruhuji river and 181 water source drain to Mbarali river. Among, water sources that drain to Mbarali river, 54 water source found in Mbukwa river drainage, 86 water sources found in Mtitafu river drainage and 41 sources found in Lumbidzi river drainage.

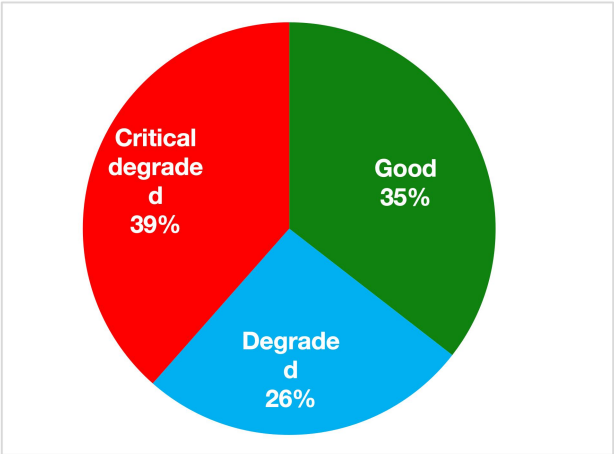


Figure 4. shows the distribution of water sources in each village forming MBUMTILU WUA. Results shows that Gone la Mafuta, Igima and Mdandu villages are the leading ones to have large number of water sources while Mkea, Ihanja and Mngate village have few water sources in MBUMTILU.

3.2 The Current Status of Water Sources in Mbarali River Sub-catchment

A total of 200 water sources were identified across 20 villages (Figure 5). It was further found that

Fig 5. Status of Water Sources in MBUMTILU WUA

seventy-one (71) water sources which counts for 35% were at good status with minimal to moderate anthropogenic activities. Such activities included water fetching for domestic purpose and agriculture activities conducted outside water sources. The remaining 129 water sources, equivalent to 65% of all identified water sources were found to be under anthropogenic disturbance, whereby 52 (26%) sources were found degraded and 77 (39%) were found to be in critical degraded (Figure 5).

Comparison of water sources status across MBUMTILU villages (Figure 6) revealed that, three (3) villages (Mungate, Ihanja, and Mkea) were the leading villages in conservation of water sources as all of water sources identified within were found to be in good status. The five (5) villages (Kidugala village, Ilulu village, Imalinyi village, Masaulwa village and

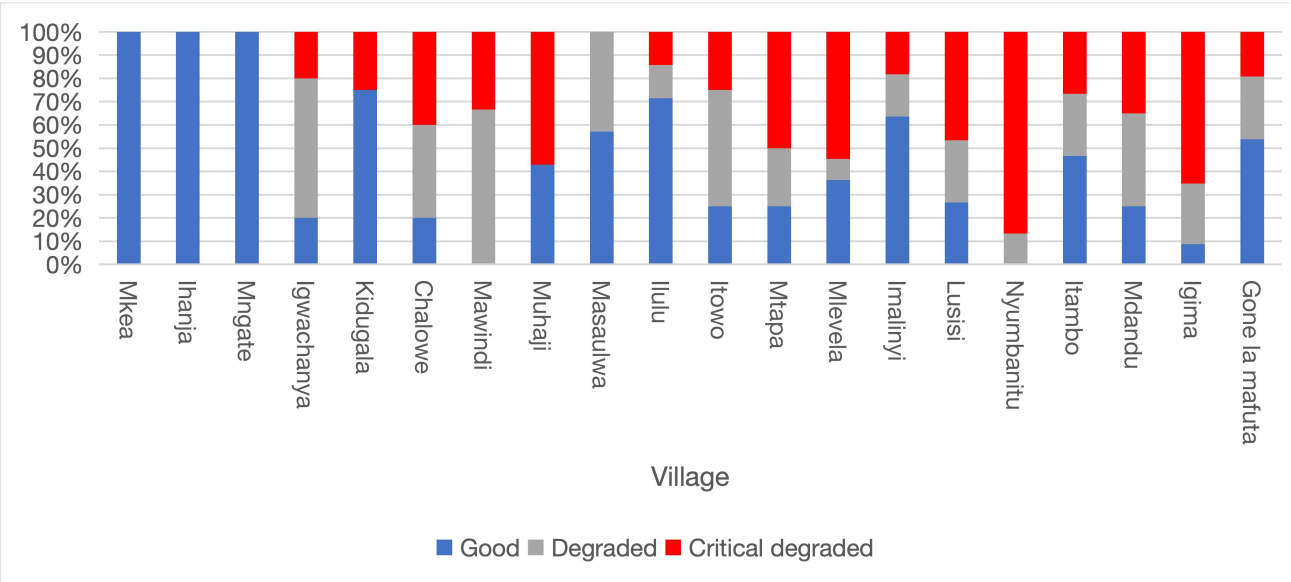


Figure 6. Water sources status comparison across MBUMTILU villages

Gone la Mafuta village) were found to have good condition of water sources identified with higher number as compared to degraded ones.

The remaining villages had higher number of degraded water sources than good condition water sources. Nyumbanitu village was found to be extreme with 87% critically degraded water sources, followed by Igima (65%), Muhaji (57%) and Mlevela (55%). These require immediate interventions for restoration.

Figure 7. illustrates the observed human-induced threats to water sources and their incidence across 20 villages in the MBUMTILU WUA. Bottom valley cultivation emerged as the major threat to water sources, followed by livestock grazing, agricultural encroachment, fire, and the presence of alien species

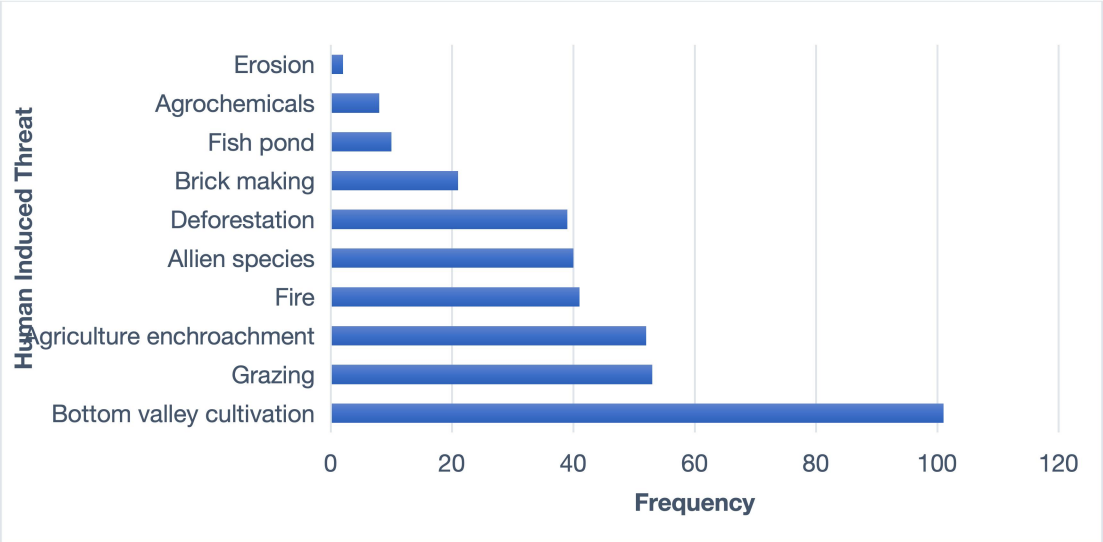


Figure 7: Human induced Threats to Water sources in MBUMTILU Villages

4 Discussion

Water sources degradation is a critical environmental issue that poses a significant threat to human health, ecosystems, and overall sustainable development (Raphael, 2023; Munishi, 2022). The ongoing water source degradation in Mbarali river sub-catchment is attributed to a range of human activities and natural processes as highlighted and some of the drivers were already reported in several studies (Raphael., 2023; Doggart., 2020; Kashaigili., 2009) as the pressing environmental challenges in Tanzania. Likewise, increased population is another potential driver (Kangalawe, 2010) which intensifies the competition and conflicts for water sources (Kannan, 2020), deforestation to fulfil demand for fuel, settlement and cultivation land in response to a growing population (Doggart, 2020; Mahoo, 2015).

Furthermore, the study reveals most of degraded water sources are private owned, which clearly depict the poor understanding of communities with regards to environmental laws and regulations which restrict human activities within 60 meters from a water source (National Water Policy, 2002; Water Resource Management Act, 2009; Environmental Management Act, 2004).The outcome of the ongoing degradation of water sources in Mbarali river catchment has already been experienced and articulated in many studies. The study by Kashaigili *et al*. (2006) on environmental flow modelling in the Usangu wetlands showed the decline of 70% of inflows to the wetland in the dry season months (July to November) resulted in a decrease in the dry season area of the wetland by approximately 40%. Furthermore, the study by Kashaigili *et al*., (2008), Kashaigili *et al*., (2007), Mutayoba *et al.,* (2018), Kihwele *et al.,* (2018) all revealed the decrease of flows in Mbarali river.

Water source status in Mbarali river catchment is now demanding immediate attention and proper actions to intervene, noticing its socioeconomic and

ecological significance to downstream users including Mpanga Kipengere Game reserve, Mbarali rice plantation, Usangu wetland, Ruaha National Park and Mtera HEP (Mazengo, 2022: Mutayoba, 2018). Preserving the quality and availability of water sources in is not just an environmental imperative but a fundamental necessity for the well-being and ecological integrity (Schaafsma, 2022). Restoration and conservation of water sources in Mbarali river catchment is an indispensable component of Tanzania in achieving the Sustainable Development Goals (SDG). As the global community strives to meet the 2030 agenda, prioritizing the preservation and sustainable management of water sources is not only imperative for achieving SDG 6 (Yang, 2020: Bhaduri, 2016), has far-reaching implications for several other SDGs. It embodies the interconnectedness of these global goals and highlights the importance of holistic and sustainable approaches to water management (Weerasooriya, 2019).

Furthermore, sustainable management of water sources promotes 'source to sea' initiatives aimed at reducing unsustainable human activities on land, within aquatic systems, and at sea. This approach effectively connects green and blue businesses in a sustainable manner from a broader perspective (Zandaryaa, 2021)."The actions will direct contribute to the implementation of the Strategic Action Programme for the protection of the Western Indian Ocean from land-based sources and activities' (WIO-SAP) under United Nation Environmental Programme (UNEP).

The study emphasizes on the need of collaboration between the government, private sector, civil society, and individuals (Asryan, 2018) to implement sustainable practices and policies. By addressing the root causes of water degradation and implementing effective solutions, to safeguard its water resources, protect ecosystems, and secure sustainability of Mbarali river sub-catchment. Proposed solutions must be innovative and nature based (NbS) (Ramírez-Agudelo, 2020) so as to ensure a sustainable and harmonious relationship between humans and the natural world. Sustainable water management practices, water sources restoration and public awareness on conservation of water sources should be strongly emphasized. Educating communities about the importance of water conservation and pollution prevention can foster a culture of responsible water use and collective action to protect water sources (Singha, 2022).

5. Conclusion

The study's findings disclose the persisting unsustainable activities pose a critical threat to ecosystems, human livelihoods, and sustainable development in Mbarali River Sub-catchment. The degradation stems from a combination of human activities, such as deforestation, population growth, and poor land-use practices, compounded by insufficient awareness of environmental laws and regulations. The documented impacts, including reduced water flows and wetland areas, underscore the urgency of addressing this issue to ensure the ecological, social, and economic benefits of these water sources. Immediate and strategic actions are necessary to halt further degradation and secure the long-term sustainability of water resources, particularly given their significance to critical downstream users and global efforts to achieve the Sustainable Development Goals (SDGs).

To mitigate these challenges, strengthening policy enforcement and compliance is essential. This includes improving the implementation of existing laws by enhancing surveillance, collaborative partnerships with local governments in monitoring efforts and raising public awareness through education campaigns to ensure communities understand and comply with legal regulations. Nature-based solutions (NbS) should be prioritized for sustainable restoration, such as reforesting riparian zones, adopting agroforestry, and implementing sustainable farming practices. Adopting sustainable water management practices is critical to ensure efficient use of resources. Technologies for water-efficient irrigation should be promoted to reduce water wastage. Equitable distribution of water resources must also be ensured to minimize conflicts and competition among users. Additionally, aligning

local conservation efforts with international frameworks for biodiversity conservation and carbon markets can link conservation and community livelihood sustainably.

Acknowledgement

The authors extend their appreciation to all the individuals, collaborators, and institutions that indirectly supported this research endeavour. Their collective contributions were vital in making this study possible.

Funding

The author acknowledges funding from UNEP-Nairobi Convention, through the Sustainable Catchment Management through Enhanced Environmental Flows Assessment and Implementation for the protection of the Western Indian Ocean from land-based sources and activities in Tanzania (EFLOWS Project).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Asryan, A., Baialieva, G., Cassara, M., Doerre, A., & de la Croix, J. F. (2018). Actors, approaches and cooperation related to water management and natural hazards under climate change in Central Asia and Caucasus. Managing disaster risks and water under climate change. 20

Bhaduri, A., Bogardi, J., Siddiqi, A., Voigt, H., Vörösmarty, C., Pahl-Wostl, C., ... & Osuna, V. R. (2016). Achieving sustainable development goals from a water perspective. Frontiers in Environmental Science, 4, 64.

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the world water development report. NPJ Clean Water, 2(1), 1-6.

Doggart, N., Morgan-Brown, T., Lyimo, E., Mbilinyi, B., Meshack, C. K., Sallu, S. M., & Spracklen, D. V. (2020). Agriculture is the main driver of deforestation in Tanzania. Environmental Research Letters, 15(3), 034028.

Famiglietti, J. S. (2014). The global groundwater crisis. Nature Climate Change, 4(11), 945-948.

Greve, P., Kahil, T., Mochizuki, J., Schinko, T., Satoh, Y., Burek, P., ... & Wada, Y. (2018). Global assessment of water challenges under uncertainty in water scarcity projections. Nature Sustainability, 1(9), 486-494.

Kangalawe, R. Y., & Lyimo, J. G. (2010). Population dynamics, rural livelihoods and environmental degradation: some experiences from Tanzania. Environment, Development and Sustainability, 12, 985-997.

Kannan, N., & Anandhi, A. (2020). Water management for sustainable food production. Water, 12(3), 778.

Kashaigili, J. J. (2008). Impacts of land-use and land-cover changes on flow regimes of the Usangu wetland and the Great Ruaha River, Tanzania. Physics and Chemistry of the Earth, Parts A/B/C, 33(8-13), 640-647.

Kashaigili, J. J., Mccartney, M., & Mahoo, H. F. (2007). Estimation of environmental flows in the Great Ruaha River catchment, Tanzania. Physics and Chemistry of the Earth, Parts A/B/C, 32(15-18), 1007-1014.

Kashaigili, J. J., Rajabu, K., & Masolwa, P. (2009). Freshwater management and climate change adaptation: experiences from the Great Ruaha River catchment in Tanzania. Climate and Development, 1(3), 220-228.

Kashaigili, J. J., Mbilinyi, B. P., Mccartney, M., & Mwanuzi, F. L. (2006). Dynamics of Usangu plains wetlands: Use of remote sensing and GIS as management decision tools. *Physics and Chemistry of the Earth, Parts a/B/C*, *31*(15-16), 967-975.

Kihwele, E., Muse, E., Magomba, E., Mnaya, B., Nassoro, A., Banga, P., ... & Wolanski, E. (2018). Restoring the perennial Great Ruaha River using ecohydrology, engineering and governance methods in Tanzania. Ecohydrology & Hydrobiology, 18(2), 120-129.

Langford, M. (2005). The United Nations concept of water as a human right: a new paradigm for old problems? International Journal of Water Resources Development, 21(2), 273-282

Mahoo, H., Simukanga, L., & Kashaga, R. A. L. (2015). Water resources management in Tanzania: Identifying research gaps and needs and recommendations for a research agenda. Tanzania Journal of Agricultural Sciences, 14(1).

Mazengo, M., Kifanyi, G. E., Mutayoba, E., & Chilagane, N. (2022). Modeling Surface Water Availability for Irrigation Development in Mbarali River Sub-Catchment Mbeya, Tanzania. Journal of Geoscience and Environment Protection, 10(4), 1-14.

Munishi, L. K., Blake, W., Comber, S., Hutchinson, T. H., & Ndakidemi, P. A. (2022). Towards sustainability: Threat of water quality degradation and eutrophication in Usangu agro-ecosystem Tanzania. Marine Pollution Bulletin, 181, 113909.

Musamba, E. B., Ngaga, Y. M., Boon, E. K., Giliba, R. A., Sirima, A. and Chirenje, L. I. (2011). The economics of water in paddy and non-paddy crop production around the Kilombero Valley Ramsar Site, Tanzania: Productivity costs returns and implication to poverty reduction. Journal of Agricultural Science 2(1): 17–27.

Mutayoba, E., Kashaigili, J. J., Kahimba, F. C., Mbungu, W., & Chilagane, N. A. (2018). Assessing the Impacts of Land Use and Land Cover Changes on Hydrology of the Mbarali River Sub-Catchment. The Case of Upper Great Ruaha Sub-Basin, Tanzania. Engineering, 10(09), 616.

Mutayoba, E., Kashaigili, J. J., Kahimba, F. C., Mbungu, W., & Chilagane, N. A. (2018). Assessment of the Impacts of Climate Change on Hydrological Characteristics of the Mbarali River Sub Catchment Using High Resolution Climate Simulations from CORDEX Regional Climate Models, Journal of Applied Physics Research 10(09), 61-73

Ramírez-Agudelo, N. A., Porcar Anento, R., Villares, M., & Roca, E. (2020). Nature-based solutions for water management in peri-urban areas: barriers and lessons learned from implementation experiences. Sustainability, 12(23), 9799.

Raphael, A., Ngaga, Y., & Lalika, M. (2023). Watershed degradation and water provision in Morogoro Municipality, Tanzania. Ecohydrology & Hydrobiology, 23(2), 272-279.

Schaafsma, M. (2021). Natural environment and human well-Being. Life on Land, 688-699.

Singha, B., Eljamal, O., Karmaker, S. C., Maamoun, I., & Sugihara, Y. (2022). Water conservation behavior: Exploring the role of social, psychological, and behavioral determinants. Journal of Environmental Management, 317, 115484.

Spijkers, O. (2020). The sustainable human right to water as reflected in the sustainable development goals. Utrecht Law Review, 16(2), 18-32.

Sood, A. Smakhtin, V. Eriyagama, N. Villholth, K. G. Liyanage, N. Wada, Y. Ebrahim, G. Dickens, C. 2017. Global environmental flow information for the sustainable development goals. Colombo, Sri Lanka: International Water Management Institute (IWMI). 37p. (IWMI Research Report 168). doi: 10.5337/2017.201

Weerasooriya, R. R., Liyanage, L. P. K., Rathnappriya, R. H. K., Bandaa, W. B. M. A. C., Perera, T. A. N. T., Gunarathna, M. H. J. P., & Jayasinghe, G. Y. (2021). Industrial water conservation by water footprint and sustainable development goals: a review. Environment, Development and Sustainability, 23(9), 12661-12709.

Yang, S., hao, W., Liu, Y., Cherubini, F., Fu, B., & Pereira, P. (2020).Prioritizing sustainable development goals and linking them to ecosystem services: A global expert's knowledge evaluation. Geography and Sustainability, 1(4), 321-330.

Zandarya, S., & Frank-Kamenetsky, D. (2021). A source-to-sea approach to emerging pollutants in freshwater and oceans: Pharmaceuticals in the Baltic Sea region. In Source-to-Sea Management (pp. 60-75). Routledge