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Role of water users in the conservation of forests on the southern slopes of Mount Kilimanjaro

Emmanuel H. Lyimo *, Daniel Kessy, Rudolf Mremi and Alex Kisingo
Department of Wildlife Management, College of African Wildlife Management, Mweka, P.O. Box 3031, Moshi, Tanzania
*Corresponding author. E-mail: lyimo.emanuel@gmail.com

EHL, 0000-0002-5750-8636

ABSTRACT

Mount Kilimanjaro Forest (MKF) is recognized as a major provider of hydrological services to people in northern Tanzania. However, little is understood in terms of the roles of upstream and downstream communities in protecting and conserving MKF. This article applies binomial generalized linear models to understand the role of the community in supporting the protection and conservation of MKF based on data collected through a questionnaire survey from 90 households on the southern slopes of Mount Kilimanjaro. Results showed that 99% of respondents were aware of the value of MKF as a major provider of hydrological services, however, this did not vary significantly across age groups, gender, level of education, and location (upstream vs. downstream). Further results showed that, contrary to downstream communities, upstream communities play a significant role in supporting the ecological integrity and hydrological functions of MKF by planting and protecting tree cover, joining efforts through conservation clubs, donating cash to finance its protection, and adhering to bylaws governing environmental management. Hence, adopting an approach that integrates upstream and downstream communities in managing catchment forests and ensuring the sustainable flow of hydrological services is critical. The study also has unleashed water user behavior that have enlightened demand for more studies in the area.

Key words: catchment forest, downstream community, hydrological services, upstream community, water

HIGHLIGHTS

- Little is known about the difference in roles played by upstream and downstream communities in protecting Mount Kilimanjaro Forest (MKF).
- 99% of all respondents were aware of the value of MKF as a major provider of water services.
- Upstream communities play a significant role in supporting the ecological integrity and hydrological function of MKF by planting and protecting tree cover, etc.
- Although Mt. Kilimanjaro forest offers invaluable hydrological services for livelihood, uncontrolled fires, deforestation, and climate change would trigger a water crisis. Hence, understanding the involvement and roles of communities in protecting MKF is critical for the sustainable flow of hydrological services.
- Further results showed that, contrary to downstream communities, upstream communities play a significant role in supporting the ecological integrity and hydrological function of MKF by planting and protecting tree cover, joining efforts through conservation clubs, donating cash to finance its protection, and adhering to bylaws governing its management. Hence, an approach that integrates upstream and downstream communities in managing catchments to ensure sustainable flow of hydrological services is critical.

1. INTRODUCTION

Catchment forests are widely known ecosystems for the provision of direct and indirect ecosystem services for human well-being (Núñez *et al.* 2006; Carvalho-Santos *et al.* 2014; Leitão *et al.* 2019; Mulamula 2020). Forests serve as repository habitats for pollinators, which offer pollination services, enable the renewal of soil fertility, and ensure carbon sequestration and climate stabilization (MEA 2005; Núñez *et al.* 2006; Corbera & Pascual 2012). The forests also offer hydrological services as one of the important life-supporting services for biodiversity and human well-being through agricultural production and hydropower generation in downstream areas (Shrestha *et al.* 2013; Mombo *et al.* 2014; Aznar-Sánchez *et al.* 2019). Despite the global importance of catchment forests, they normally face constant threats as a result of increasing deforestation, human activities, wildfires, and invasive plant infestations (Giliba *et al.* 2011; Grzybowski & Glińska-Lewczuk 2019; Hohner *et al.* 2019). In addition, climate change is also a phenomenon that affects forest functions and the resilience of the provision of hydrological services (Bosch & Gadow 2010; Said *et al.* 2019). This situation raises global concerns for stakeholders, including communities, regarding the management of catchment forests (Mombo *et al.* 2014; Strauch & Almedom 2014; Chinangwa *et al.* 2017). In other areas, such as the eastern Mediterranean, wastewater discharge also degrades water quality, resulting in brine water, which cannot be directly used by residents or industrial applications without a desalination procedure (Panagopoulos 2022; Panagopoulos & Giannika 2022a, 2022b). Eighty percent (2.8 million hectares) of the 33.5 million hectares of forests and woodlands in Tanzania are covered by catchment forests. Such forest catchments include those occurring in Mount (Mt.) Kilimanjaro, Eastern Arc Mountains, Mt. Meru, the Ngorongoro highlands, Hanang, and other mountains west of the Rift Valley escarpment (Bjorndalen 1992; Mckenzie *et al.* 2008; Vyamana 2009). The catchment forest stream is normally distributed from downstream and forms critical nodes, forming the main river basin and dams (Sarker *et al.* 2019; Sarker 2021; Gao *et al.* 2022). The Mount Kilimanjaro Forest (MKF) on the southern slopes is important in the hydrology of northern Tanzania because it serves as a reservoir for the Pangani River Basin (Kimaro *et al.* 2019). The basin supports the livelihood of more than 3 million people (Russi *et al.* 2013), residing in urban, peri-urban, and densely populated rural areas (Seeteram *et al.* 2019). Despite the invaluable role of MKF as a life-supporting system for people's livelihoods through the provision of water for agricultural production, domestic uses, and industrial uses (Bjorndalen 1992; Kimaro *et al.* 2019), there are mounting threats to the catchment that would eventually trigger a water crisis in the future (Martinez *et al.* 2013; Abell *et al.* 2019). Such threats include the effects of climate change and deforestation (Abell *et al.* 2019; Seeteram *et al.* 2019). Another factor is uncontrolled fires, which cascade the ecological role and functioning of catchment forests by reducing fog collection in sub-alpine forests. The sustainable supply of hydrological services from MKF to humans is therefore intimately linked to its efficient protection and management (Grove 1993; Mbonile 2005; Kangalawe *et al.* 2014). Thus, maintaining the hydrological functions of MKF requires the active involvement of local communities in decisions related to their conservation and direct protection of the catchment (Kangalawe *et al.* 2014; Lau 2022). A sizeable body of literature has extensively documented synergies existing between MKF conservation and the provision of hydrological services. For instance, studies assessing impacts of climate and anthropogenic pressure on hydrological services (Said *et al.* 2019), drivers of water discharge variability (Yanda & Mpanda 2018), factors for low flows of streams (Zemadim *et al.* 2011), and farmers response to shortage of water for irrigation downstream (Mbonile 2005). Other studies include assessing the linkage between forestry conservation and resource use (Yanda & Shishira 2001), water use conflicts in the Pangani Basin (Mujwahuzi 2001), and preferences for consumptive versus non-consumptive benefits (Kijazi & Kant 2010). However, little is known about the difference in roles played by upstream and downstream communities in protecting MKF for the provision of hydrological services. Hence, understanding the involvement and roles of the community in supporting the ecological integrity and the hydrological function of MKF to provide hydrological services is critical. This study, therefore, aims to understand the role of community on the southern slopes of Mt. Kilimanjaro. Two key questions were addressed in this study: (i) What is local communities' awareness of the value of MKF as a provider of hydrological services? and (ii) What are the roles of upstream and downstream communities in the conservation and protection of MKF? Findings are expected to provide insights into perspectives pertaining to the roles of upstream and downstream communities in managing catchment forests and enable them to forge a productive collaborative agreement with local governments, government institutions, private sectors, and civil society organizations for sustainability in the provision of hydrological services from MKF. This study is of relevance as it strives to achieve the UN Sustainable Development Goal – Goal 6, targeting to ensure the protection and restoration of water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes (Ellison *et al.* 2017).

2. MATERIALS AND METHODS

2.1. Study area description

The study was carried out on the southern slopes of Mt. Kilimanjaro in Tanzania at 3°1309″S–3°17041″S and 37°9024″E–37° 25019″E targeting Lyasongoro and Oria villages (Figure 1). Lyasongoro is close to forest catchments in the highland belt and people (upstream communities) residing in this village are directly involved in forest management and in ensuring a sustainable supply of ecosystem services. The village is predominated by Chagga people, who primarily practice farming and zero-

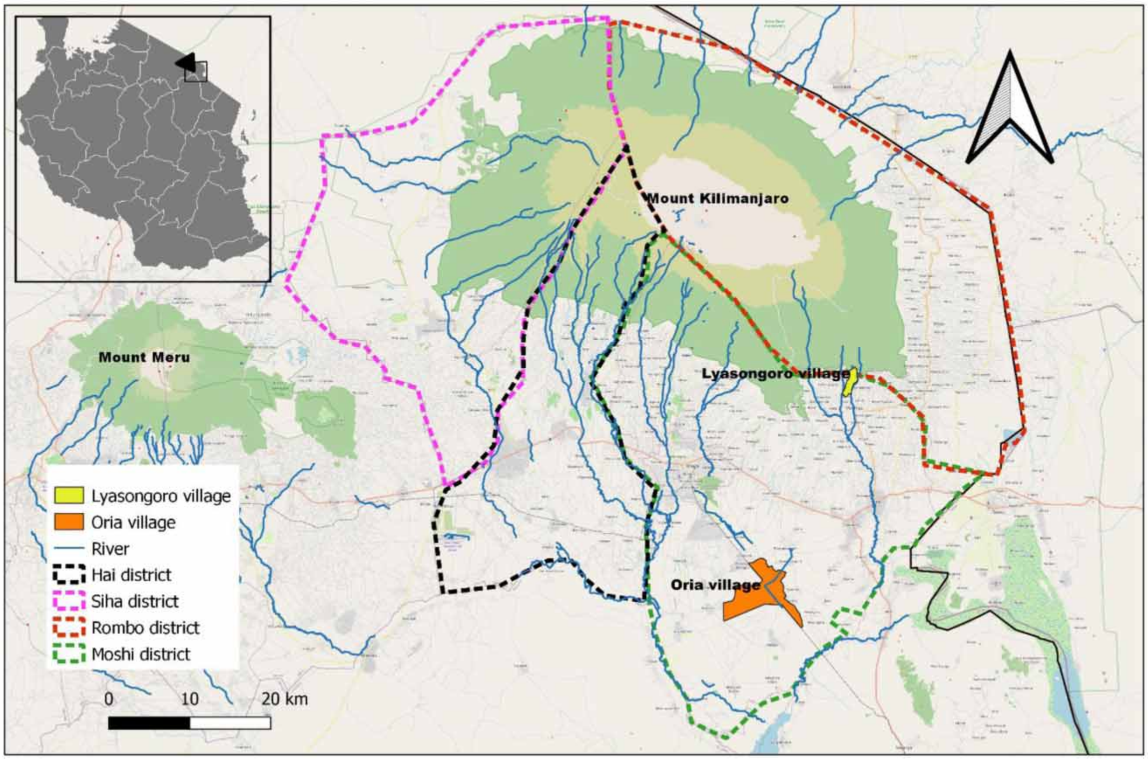

Figure 1 | Study villages and catchment tributaries from Kilimanjaro Mountain. The inset map of Tanzania (left) shows the location of the study area.

grazing animal husbandry as their main economic activities (Ichinose *et al.* 2020). Lyasongoro was selected to represent upstream communities because it possesses several water streams and rivers encompassing a rich source of water for people living downstream (Figure 1). Oria village, on the other hand, is in the lowland belt of the lower Moshi rangelands, where people practice pastoralism and extensive agriculture involving irrigation schemes (Figure 1). Unlike Lyasongoro village, Oria village is characterized by a dry climate with a mean annual temperature ranging from 18.8 to 23.4 °C and a low mean annual relief of between 680 and 834 mm (Mathew *et al.* 2016; Said *et al.* 2019; Classen *et al.* 2020). Lyasongoro is much wetter with mean annual rainfall and temperature ranging from 900 to 1300 mm and 18.8 to 16.1 °C, respectively (Mathew *et al.* 2016; Said *et al.* 2019; Classen *et al.* 2020).

In terms of vegetation, the southern highland belt is covered by an expanse of lowland and upper montane forests protected in Kilimanjaro National Park. Close to lowland forests are areas where residents practice agroforestry dominated by coffee, bananas, and multipurpose trees such as *Albizia schimperiana*, *Grevellea robusta*, and *Cordia africana* (Wagner *et al.* 2019). The lower-story vegetation, which includes dry savannah with parches of grassland, woody trees, and shrubs depends mainly on stream/river flow with their sources in highland belt catchment forests (Figure 2).

2.2. Data collection

A cross-sectional study design involving the collection of data at one point in time was employed for this study. A semi-structured questionnaire consisting of both open- and closed-ended was used to collect data on local communities' awareness of the value of catchment forests as providers of water services and community support on the conservation of catchment forests (Davies *et al.* 2014; Ilyushin & Azbel 2017). The survey was carried out in May through June 2021 in two villages – Lyasongoro in the highland belt, representing the upstream communities and Oria in the lowland belt, representing the downstream communities. Before data collection, a permit from Moshi District Council was obtained and presented to the Village Executive Officer (VEO) as a part of ethical practice in community data collection (Cleaton-Jones & Curzon 2012). Stratified random sampling was employed to select households for interviews from each village (Turner 2003). A total of 45 respondents (6%) of all registered households were obtained from Lyasongoro, while 7% ($n = 45$) were sampled from Oria. A

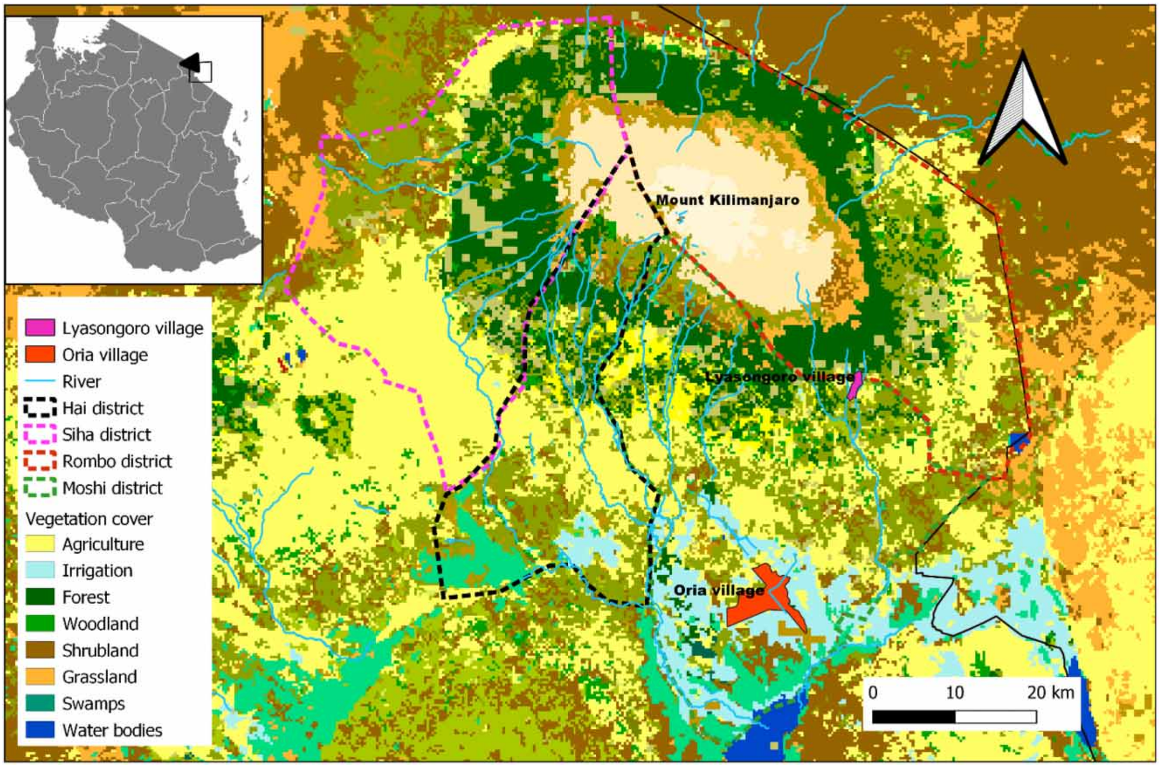

Figure 2 | Land use and land cover in the study area. The inset (left) is the map of Tanzania showing the location of the study area.

questionnaire consisting of 16 questions was firstly pretested by administering it to 12 respondents from Oria village and the final questionnaire was obtained after revision of the original questionnaire based on the pretest results (Hilton 2017). The final questionnaire had four main sections: respondents' profiles, awareness of respondents on the value of catchment forests as providers of water services, respondents' willingness to support the conservation of catchment forests, and factors hindering full participation communities in the conservation of catchment forests. Additionally, we obtained verbal consent from the respondents before administering the questionnaire (Brod & Feinbloom 2016). The questionnaire was administered to the head of the selected households or any senior member of the household aged at least 18 years using the Kiswahili language, which was understood by all respondents. Although the study did not require local research ethics approval, we took care that the rights and well-being of all participants were respected and ensured no sense of injustice during the whole process of data collection. Each respondent was assured that the information provided would be treated as confidential and that each respondent was identified by a number (Kaiser 2009). We also obtained information from four key informants from the irrigation scheme and hydroelectric power plant, and from village leaders.

2.3. Data analysis

Data were coded and entered in Statistical Package for Social Sciences (SPSS), then changed to Excel before being exported into the R 3.6.2 environment (R-Core-Team 2019) for analysis. Generalized linear models (GLMs) with a binomial distribution (Warne 2020) were used to address two research questions to assess if (1) local communities' awareness of the hydrological value of MKF varies between men and women, farmers and non-farmers, downstream and upstream users, and across respondents with different levels of education and (2) local communities are willing to support the ecological integrity and hydrological function of MKF by (i) participating in planting and protecting forest tree cover, (ii) joining conservation efforts through conservation clubs, (iii) donating cash to finance its protection, and (iv) adhering to bylaws governing its protection. To address this question, four separate binomial GLMs were fitted with response variables from (i) to (iv) being binary with one agreeing to support the protection of catchment forests or zero, otherwise and for the first question about awareness, a binary response variable with one agreeing to be aware of the hydrological value of MKF while zero being not aware. Gender, age, level of education, location of the community (i.e., upstream and downstream), and the main economic activity respondents are involved in were treated as explanatory variables for each candidate model. The parsimonious model for each candidate model fitted was obtained by single-term deletion based on *p*-values from the likelihood ratio chi-square (χ^2) test using Anova of the *car* R-package. The significance level was determined at $p < 0.05$. To visualize significant terms for each final model, the *ggplot2* R-package (Wickham 2009) was used. Furthermore, we used descriptive statistics to understand the demographic characteristics of respondents. All analyzes were performed using R 3.6.2 (R-Core-Team 2019). Additionally, information obtained from the interview with the key informant and open-ended questions was filtered and presented in the form of quotations.

3. RESULTS AND DISCUSSION

3.1. Demographic profile of respondents

A total of 90 respondents were interviewed from two villages: Lyasongoro, representing the upstream community of water users ($n = 45$, 50%) and Oria, representing downstream users ($n = 45$, 50%). About 65.5% of the 90 respondents were male ($n = 59$) while the female was 34.5% ($n = 31$). Most respondents had an age class of 18–35 years ($n = 37$, 41%) followed by 36–54 years ($n = 34$, 37%), and 21% ($n = 19$) above 54 years. Most respondents ($n = 64$, 71%) had a primary education, whereas the remaining 29% had either a secondary or college education. Further results showed that 81% ($n = 73$) of respondents engaged in agricultural activities, whereas 11% ($n = 11$) and 8% ($n = 7$) of respondents were found practising business and livestock husbandry, respectively.

3.2. Community awareness of the hydrological role of MKF

Respondents were asked if they are aware of the value of the MKF as a major provider of water services, overall results show that 99% of respondents are aware, whereas only 1% are not aware. This finding suggests that irrespective of where the community is located (i.e., upstream or downstream), the level of awareness about the role of MKF as a major provider of hydrological services was both high because the synergy between forest conservation and water flow has a direct effect to human welfare, communal ways of life, and livelihoods. High awareness of upstream and downstream communities of hydrological values in the Eastern Arc Mountains were also found by Said *et al.* (2019).

We further tested if the awareness is influenced by the demographic profiles of the respondents and the results showed that respondents' locations ($\chi^2 = 0$, df = 1, $p = 0.99$, Figure 3(a)), level of education ($\chi^2 = 1.04$, df = 2, $p = 0.59$, Figure 3(b)), and

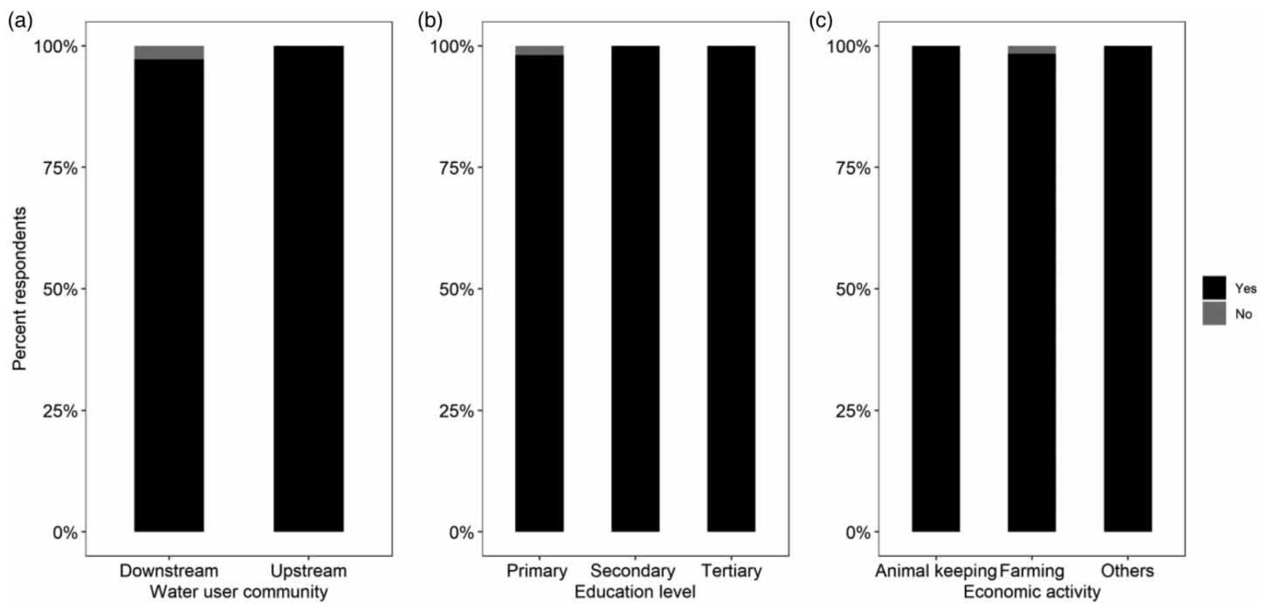

Figure 3 | Percent of respondents indicating awareness of the hydrological value of MKF as across (a) respondents' location; (b) respondents with different levels of education; and (c) respondents engaging in different economic activity.

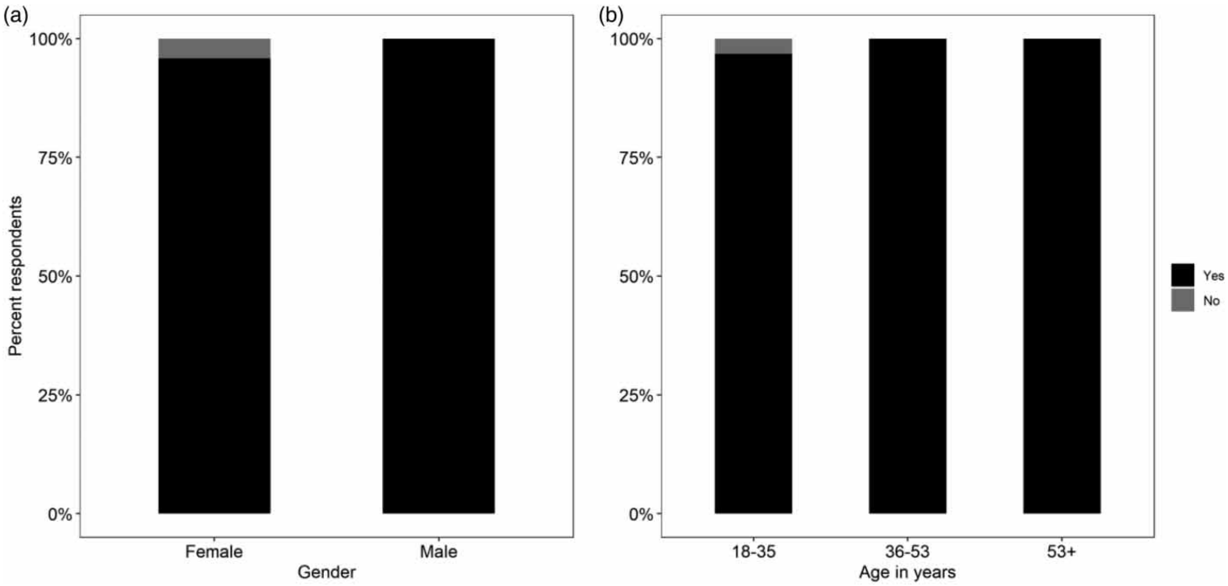

Figure 4 | Percentage of the respondents indicating the awareness of the local community on the value of MKF as a catchment across (a) respondent's gender and (b) age categories.

main economic activity they are involved in ($\chi^2 = 1.04$, df $= 3$, $p = 0.79$, Figure 3(c)) did have a significant influence on community awareness.

Similarly, results showed that the age of respondents ($\chi^2 = 1.72$, df $= 2$, $p = 0.42$, Figure 4(a)), respondent's gender ($\chi^2 = 3.72$, df $= 1$, $p = 0.5$, Figure 4(b)) were also not significant predictors of community awareness toward conservation of MKF as a catchment.

These findings indicate that respondents' level of education, location (upstream or downstream), age, gender, and the main economic activities in which the community is involved were not important predictors of awareness of the community on the importance of MKF as a provider for water. This is because water is among the major determinants of well-being and a public concern for all community groups, especially during low flows (Diez & Martín-García 2012; Mushi *et al.* 2020). Communities are also triggered to increased awareness following increasing global and local rhythms in water supply for economically important projects such as hydroelectric power generation, agricultural production, and industrial and domestic uses (Brown 2013; Mushi *et al.* 2020). Our results are also related to Lugazo (2017), where the majority of the community was aware of the protection of the forest and just 10% ($n = 100$) of the respondents in west Usambara Forest had low awareness about forest conservation practices.

3.3. Communities support on conservation of MKF

3.3.1. Community participation in planting and protecting tree cover in and adjacent to MKF

Nearly 83% of respondents showed that they support the conservation of forests by planting and protecting a tree cover in and adjacent to MKF, while 17% do not. To understand if community responses toward planting and protecting a tree cover vary across respondents' profiles, we found that respondents' location ($\chi^2 = 13.12$, df $= 1$, $p = 0.0003$, Figure 5(a)) was associated with 98% of upstream community members being more positive in planting trees and 69% of the respondents downstream supporting it. This suggests that upstream communities play a significant role as forest managers and forest service users, whereas downstream communities are mostly users of forest services (especially water). Unlike downstream communities, the upstream communities incur relatively higher opportunity costs to protect and maintain the tree cover of MKF, and live in fragile and inaccessible mountain areas with limited resource opportunities (Nepal *et al.* 2014). Thus, an approach striving to balance their roles through incentivization and financial compensation schemes should encourage and acknowledge their contributions. Tree planting and protection of forest cover are major forest management activities that protect the catchment and ensure the sustainable flow of forest-related services, including water (Ellison *et al.* 2017; Thapa *et al.* 2018). This also safeguards the integrity of the local community through the provisioning of forest ecosystem services, particularly water services.

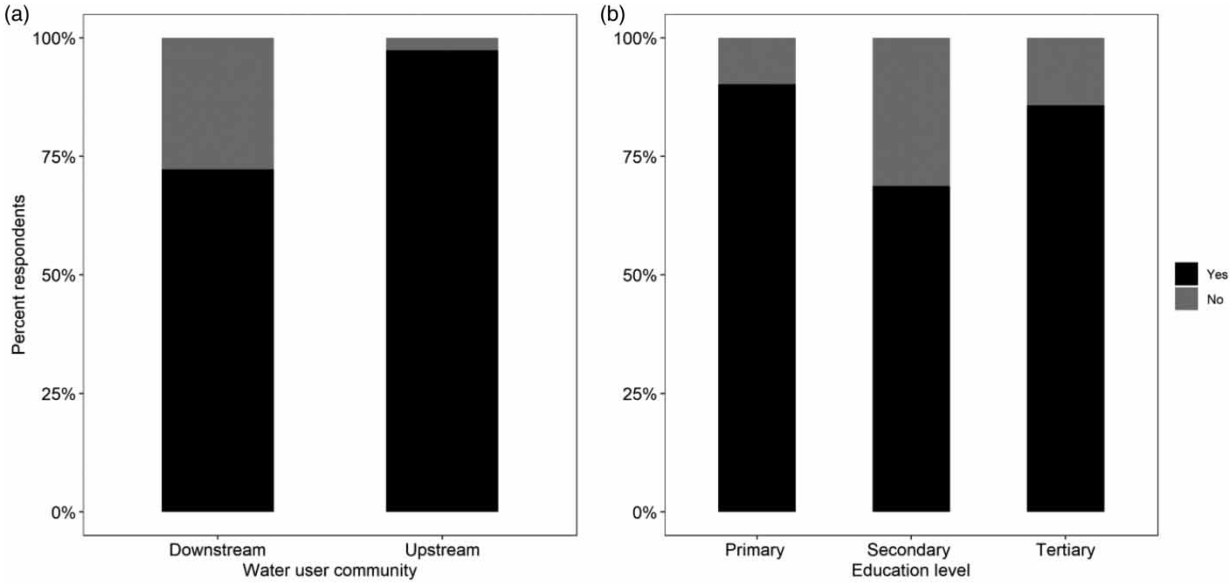

Figure 5 | Percent of respondents' responses indicating their support for the conservation of forests by planting trees adjacent to catchments: (a) responses between locations and (b) responses from individuals with varying levels of education.

Findings from sizeable literature align with our findings. For instance, people living adjacent to West Usambara, Tanzania, and Kuang Si participate more in planting trees to enhance environmental conditions and improve the ecological values of the forests than those far away downstream (Lau 2022). Additionally, a study addressing synergy between the upstream and downstream users of hydrological services in the Himalayan region found similar findings (Nepal *et al.* 2014). Similarly, Mombo *et al.* (2014) also obtained that upstream communities participate in the planting and protection of tree cover of the Kilombero wetlands catchment area more than downstream communities.

Education was also a significant predictor with individuals having primary and college education participating more than those who attained secondary level education ($\chi^2 = 6.58$, df $= 2$, $p = 0.03$, Figure 5(b)). The level of education influences community decisions in the protection of natural resources (Wekesa 2017). Despite variations in the level of education, both upstream and downstream educated communities were positive in the protection of the MKF.

3.3.2. Community willingness to finance conservation of MKF

When respondents were asked whether they willingly donate money to enhance the conservation of catchment forests if ought to, results showed that respondents who achieved college or university education were significantly willing to donate money for conservation compared with those with primary and secondary education ($\chi^2 = 7.89$, df $= 2$, $p = 0.01$, Figure 6(a)). This implies that community members who have attained higher education (college) have more understanding of the existing synergy between the power of financing MKF and its positive consequences on water flow. They further understand that forest protection needs financial support for efficient ecological management and functions (Thompson *et al.* 2018; Bremer *et al.* 2019).

Although upstream communities were found to be more responsive in donating money than downstream communities, there was no significant variation ($\chi^2 = 3.51$, df $= 1$, $p = 0.06$, Figure 6(b)). Based on the results, we found that the level of willingness of upstream and downstream communities to finance the conservation of MKF to ensure that the flow of water is the same. However, there was a slight difference in that, unlike downstream communities, upstream communities are more willing to donate cash for the conservation of MKF. This is because people upstream are close to the forest and can gain more services (pollination, rainfall, and regulation of micro-climate) than water. Additionally, the focus of government and other institutions is biased toward upstream communities than those occurring downstream. Pangani Water Basin has to encourage the willingness of both upstream and downstream communities to donate for the conservation of the catchment forest of Mt. Kilimanjaro, as also observed in the Hai district, where the community was willing to pay Tanzanian Shillings 100,000 (45 US$) for protection of the catchment forest (Sila 2019). Large-scale water users provide financial

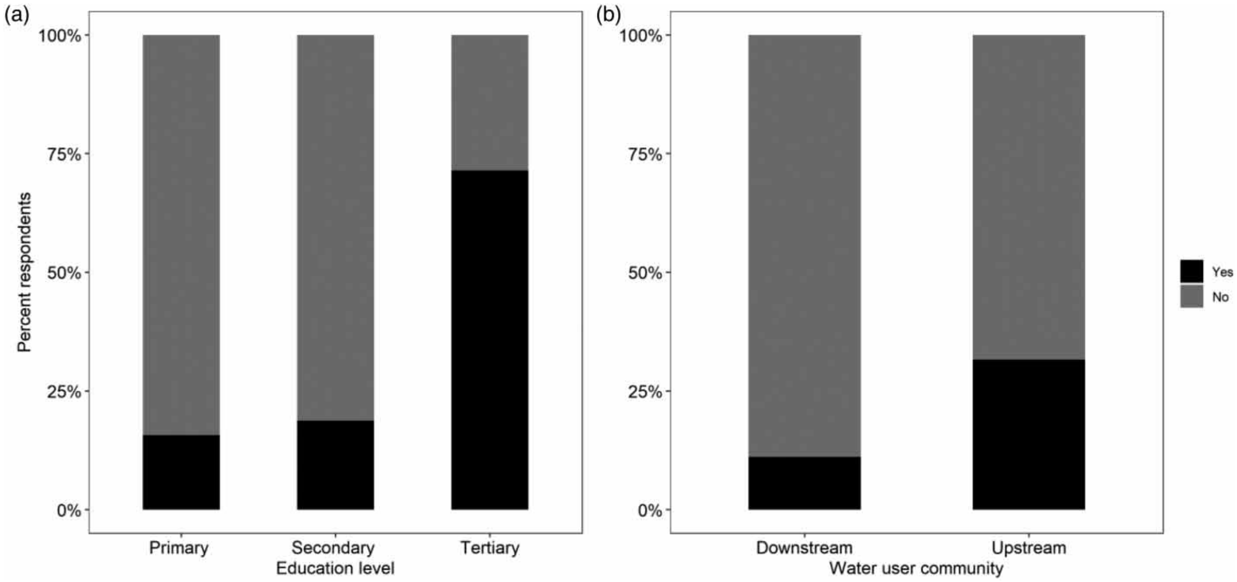

Figure 6 | Percent of respondents' responses indicating a willingness to donate money for the conservation of catchment forests: (a) responses from individuals with varying levels of education and (b) responses between locations.

support to forest authorities so that they can run different conservation programmes that seek to safeguard the forest ecosystem. '…most of the institutions use pricing to reconcile their stakeholders…' (Participant one interview, 12 August 2020). Hence, financial support is of high significance because their production activities strongly depend on the availability of water from the forest ecosystem.

3.3.3. Community commitment to join efforts in managing MKF

In line with our expectation, we found that the upstream communities are highly contributing to the protection and conservation of MKF by joining clubs for big conservation results than downstream communities ($\chi^2 = 24.01$, df $= 1$, $p < 0.0001$,

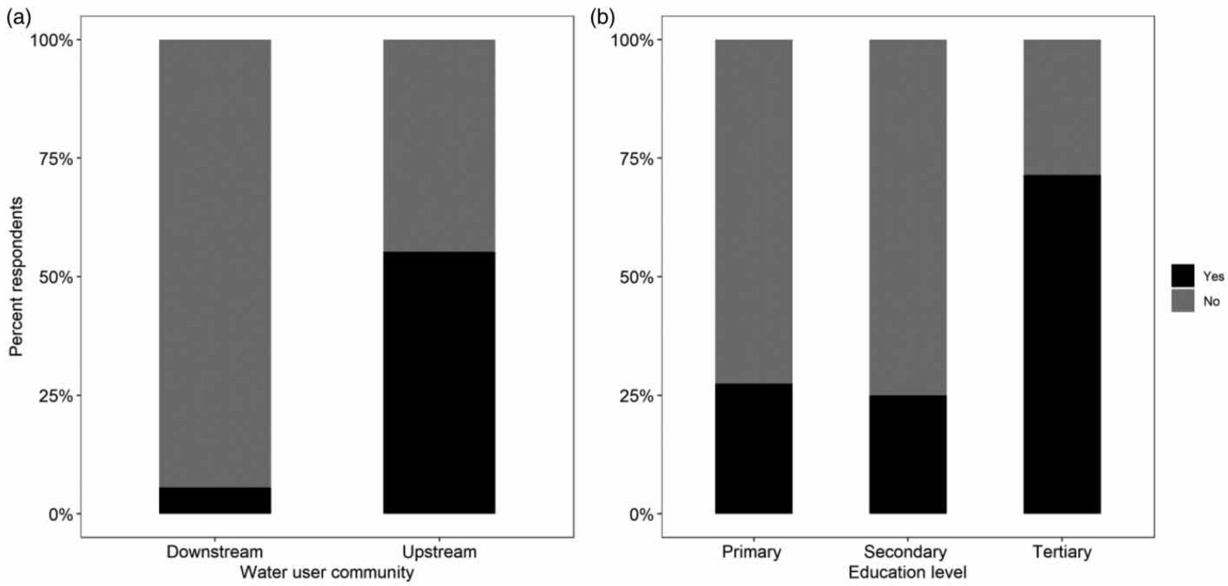

Figure 7 | Percentage of respondents' responses indicating a commitment to join efforts in protecting and conserving catchment forests: (a) responses between locations and (b) responses from individuals with varying levels of education.

Figure 7(a)). Further results show that community responsiveness in joining forest conservation clubs is not dependent on education, gender, age, and economic activities they are involved in (Figure 7(b)). Local conservation groups are important in addressing conservation issues requiring concerted efforts, such as forest and catchment management. Through these groups, they create awareness about the significance of forest conservation and encourage people to participate in different environmental actions that contribute positively to the improvement of the forest (Mckinley *et al.* 2016). Different conservation clubs and groups, for example, Malihai, Roots and Shoots, Floresta, and others contribute directly to the conservation of catchment forests. The study revealed that upstream communities showed a high response concerning joining conservation clubs and groups as compared with downstream communities. This is because upstream communities have a positive perception toward conservation following the direct benefits that they obtain from the ecosystem. Therefore, encouraging the formation and joining of community members to conservation groups both in upstream and downstream areas communities is likely to raise awareness of the community and consequently participate in supporting the conservation of catchment forests (Chinangwa *et al.* 2017).

3.3.4. Community commitments to adhering bylaws governing the protection of MKF

All respondents showed that their village has bylaws governing the protection of forests, water sources, and other environmental resources. When asked if respondents are happy with the bylaws and whether they adhere to them, we found that upstream communities were more comfortable and committed to adhering to bylaws limiting harvesting of forest resources near the catchments than downstream communities ($\chi^2 = 12.95$, df = 1, $p = 0.0003$, Figure 8(a)). Additionally, people involved in agriculture were significantly more responsive than those engaging in pastoralism and other activities (i.e., employment and business) ($\chi^2 = 13.57$, df = 3, $p = 0.001$, Figure 8(b)). High pressure of anthropogenic activities including agricultural activities and livestock keeping as well as the high demand for different forest products such as timber and medicinal plants affect catchment forests, hence, there is a need to provide a legal means of protecting the forest at the local scale (Schumacher 2018; Kimaro & Bogner 2019; Qi *et al.* 2019). The establishment of different village conservation bylaws and adherence to different laws imposed by village governments and forest authorities are efforts of protecting the forest (Ylhäisi 2003; Durrant *et al.* 2008; Strauch & Almedom 2014). The study correlates with the study conducted by Brockington (2007), which claimed that, after the establishment of village conservation bylaws in Duru-Haitemba Forest in Babati district, villagers abide by all bylaws and imposed by the village government and village forest committee. Therefore, village conservation bylaws are very important in conserving forests and community participation through adhering to conservation bylaws and is necessary to enhance forest conservation (Babili & Wiersum 2013; Maguo *et al.* 2020).

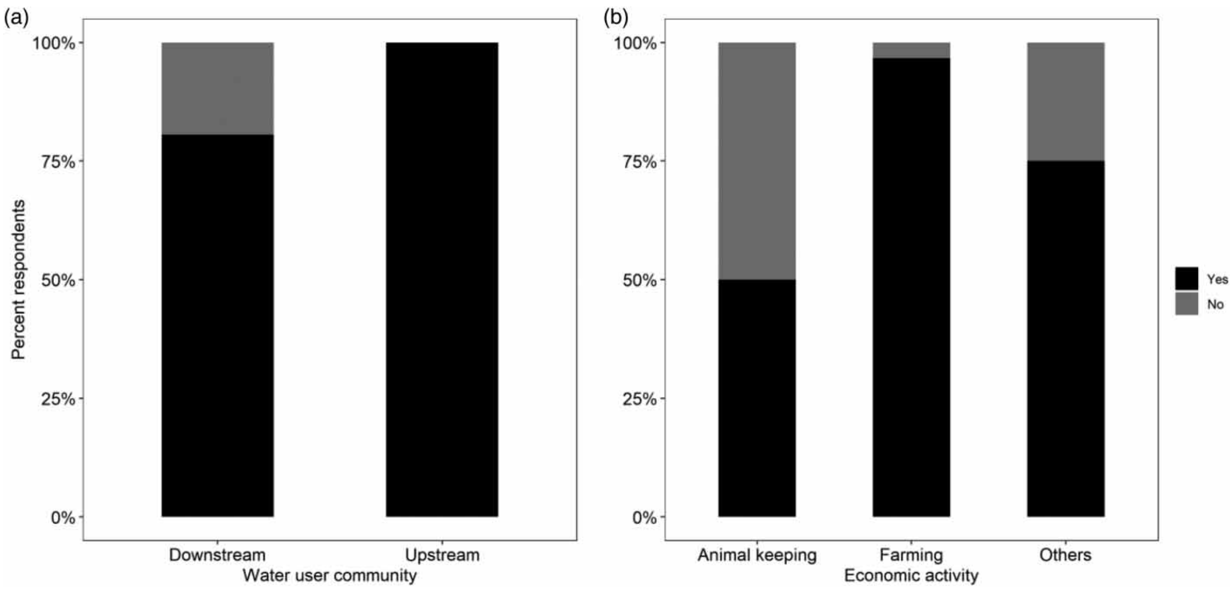

Figure 8 | Percentage of respondents' responses indicating a willingness to adhere to bylaws governing protection and conservation of catchments: (a) responses between locations and (b) responses from individuals engaging in different economic activities.

4. IMPLICATIONS OF THE STUDY

The study found that upstream communities have substantial contributions in implementing activities aimed at enhancing MKF management and consequently flow of hydrological services as compared with downstream communities. Findings from this study inform the formulation and implementation of a comprehensive ecosystem approach that integrate community perspectives and their contribution in the management of the MKF and a riverine ecosystem. Integrating community perspectives from upstream and downstream communities in managing the forests for sustainable flow of water services is critical. Additionally, the findings are important in unleashing the scheme for payment of ecosystem services (PES) by considering the benefits and burdens of management practices for MKF and water flow among the upstream and downstream communities. Accordingly, it should take into account upstream communities as resource managers pay relative high costs for conserving MKF than downstream communities, which are more secondary resource users.

5. CONCLUSIONS

This study highlights the role of communities in supporting the conservation of MKF on the southern slopes for the provision of hydrological services. Based on our findings, we conclude that, despite the high awareness of people on the hydrological value of MKF, upstream communities showed a substantial contribution in supporting the ecological integrity and hydrological functions of MKF when captured to downstream. Our findings provide evidence of the significant involvement of upstream communities in tree planting and forest cover protection, including joining efforts through conservation clubs, donating cash to finance MKF protection, and adhering to bylaws governing environmental management of MKF contrary to communities downstream. In the face of climate change and increasing human pressures on the use of forest resources and services, upstream and downstream communities need to be involved equally in decisions pertaining to the protection of MKF to ensure sustainable flow and use of ecosystem services offered by MKF. It is worth to underscore that sustainable management of MKF is vital for its functioning and ultimately the well-being of people, especially those living in northern Tanzania. Although we cannot be certain that this paper covered all community perspectives regarding the roles of communities in supporting the ecological integrity and hydrological function of MKF, we are confident to have covered a representative sample of households from each village surveyed for this study. This study was unable to study the roles of urban dwellers in protecting MKF and ensuring the flow of water services for economic activities in urban areas. Also, we could not account for the roles of the economically important water users (i.e., industries, agricultural plantations, and hydroelectric plants) and social service provision institutions (i.e., schools, hospitals, and colleges/universities). Thus, further study taking these issues into account is recommended.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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