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Analyzing the drivers that shape people's perceptions of the impact of changes in forest cover and human population on water availability in the Mt. Elgon water tower

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Forest-water resource management often fails to deliver intended effects as farmers are limited to adopt agroforestry/sustainable land-use practices due to several barriers to uptake the scientifically proven and ecologically valuable land-use planning and management practices. It remains uncertain why it is difficult to align agroforestry campaigns with local interests despite numerous existing natural resource frameworks, policies, and management structures. In this study, we examined the potential of Q-methodology as a tool to analyze drivers of stakeholders' perceptions on the forest–water–people nexus (FWP-nexus) in relation to water availability and quality. The study was guided by a research question: What are the drivers of perception differences and/or similarities of scientists and local stakeholders on the FWP-nexus in relation to water availability in an agroforested landscape? For both Sipi River Sub-catchment and River Manafwa Sub-catchment, we discussed with diverse stakeholder groups. In each sub-catchment, stakeholders expressed their views on forest-water issues and possible management options and solutions. Together with stakeholders' groups, we used the generated information on forest-water issues in addition to relevant literature to develop a Q-set. The study compares the scientific insights and local stakeholders' perceptions on the FWP-nexus using the Q-methodology across the two sub-catchments. Study showed that perceptions of the FWP-nexus varied slightly among the two sub-catchments and among the upper and lower zones of the sub-catchments. From the two Sub-catchment comparison, the results indicate the significance of perceived importance of forests in increasing local rainfall and effect of local communities' involvement in planting trees on tree cover increase. The results indicate that issues surrounding the forest-water are majorly due to institutional failure other than farmers unwillingness to adopt sustainable agroforested landscape management practices and conforming to existing policies. There is need for: empowering and funding natural resource management departments to overcome institutional failure; adequate information on the performance assessment of agroforestry/tree growing projects; and developing and implementing the integrated management of forest/trees and water resources. For this study, the Q-methodology can guide in developing, testing, and documenting/communicating sustainable agroforested landscape management scenarios for water towers of mountainous regions. While comparative analysis across two sub-catchments strengthens robustness and reveals both shared and context-specific perceptions, the limited geographic scope may affect broader generalizability. Nonetheless, the results offer valuable guidance for inclusive land-use planning and spatially nuanced water governance.

KEYWORDS

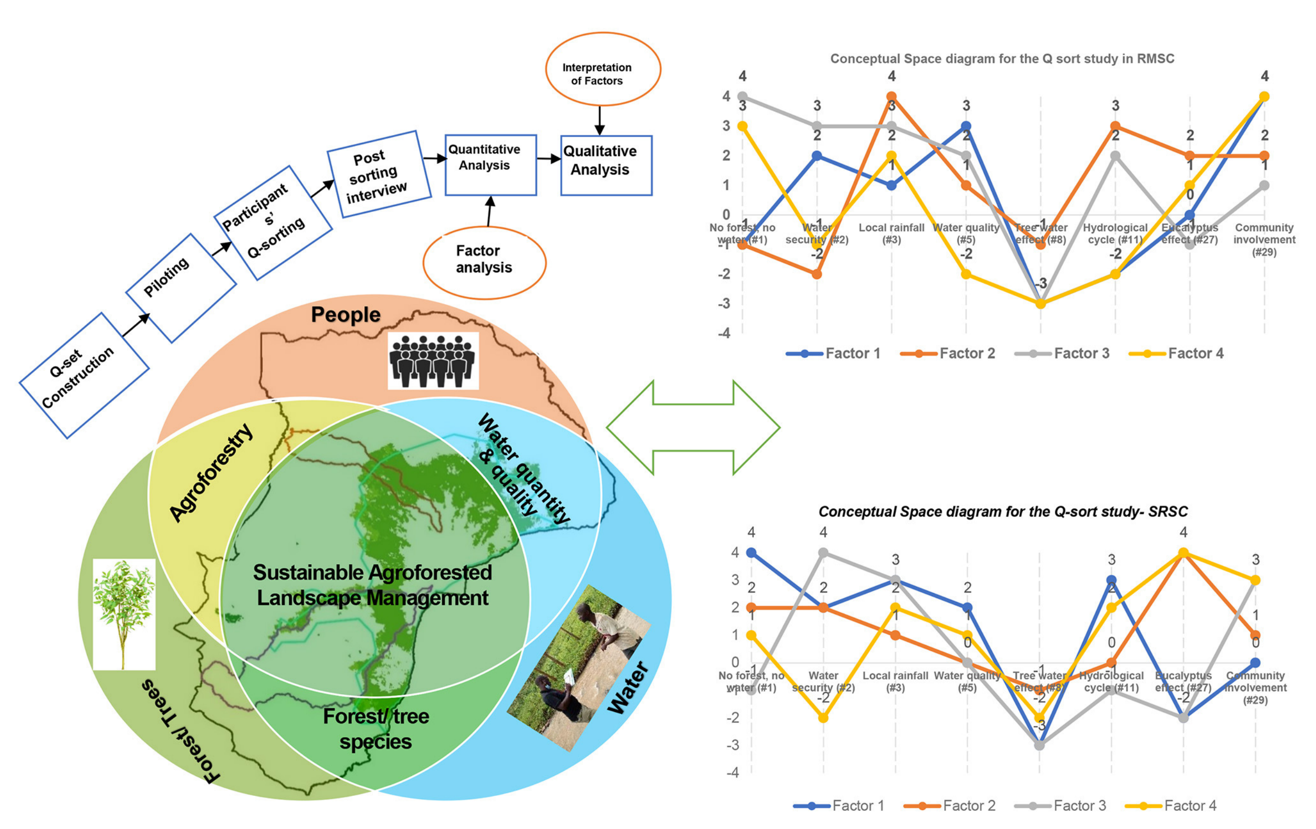
sustainable agroforested landscape management, River Manafwa Sub-catchment, Sipi River Sub-catchment, Q-methodology, agroforestry, watershed conservation and restoration

Highlights

- Promoting tree growing/agroforestry programs across entire region can contribute to water availability.
- Forest conservation in upper zone can lead to deforestation of most lower zone areas.
- Farmers prefer "economic" trees to "restoration" trees due to land fragmentation.
- Uncoordinated development of gravity flow schemes leads to less water downstream.
- Unregulated upstream (irrigation) water diversion leads to downstream water shortage.

1 Introduction

Communities, state and non-state actors, and other stakeholders are engaged and empowered regards decision-making and landscape policy process, while multilevel governance is in place. This can facilitate and enhance information exchange and feedback regarding conservation and landscape management strategies (Daniell and Kay, 2017). By providing more insight into sustainable land-use and planning, the participatory decision-making approach enhances stakeholders' comprehension of adaptation and reaction tactics. However, the idea of multilevel governance may entail procedures that lead to disputes and



GRAPHICAL ABSTRACT

inconsistencies. For instance, participating stakeholders could make conflicting assertions about the governance structure (García-Barrios et al., 2008; van Noordwijk and Coe, 2019; Patterson, 2017; Speelman et al., 2018). In addition, natural resource authorities may impose polices and laws to curb unregulated resource use, whereas local inhabitants will prefer protection of their rights to resources located in their vicinity (Langston et al., 2019b).

Multiple governance levels and spatial scales present challenges for environment governance and management (Moss and Newig, 2010). A socio-ecological system (SES) requires environmental governance strategies that can produce sustainable solutions to social and dynamic landscape related problems (Chaffin et al., 2014). Several SES studies have used the idea of adaptive governance (Karpouzoglou et al., 2016; Koontz et al., 2015; Schultz et al., 2015; van der Molen, 2018).

Local knowledge on hydrology, for instance, frequency of extreme events, long-term trends and relationship, hydrology parameters resulting from forest disturbance and land uses, is vital as it can be translated into traditional rules that can regulate utilization of the forestland by the surrounding communities (Eisenbies et al., 2007; Selim et al., 2015; Wilson et al., 2015). There is significant lack of policy frameworks and hydrologic knowledge gap to link forests, water, and people at all geographical scales (Ellison et al., 2017). Similar to many countries, Uganda's current scientific understanding of forest-water resources predominantly involves high level stakeholders including senior government officials. Most of this information is about forest-land use policies, leaving the involvement of communities in forest-water management underrepresented.

To influence the thinking of the forest-water stakeholders, there is a need to understand the dynamics of the SES. This can be achieved by using different participatory research frameworks such as the Q-methodology involving stakeholders with experience on forest-water projects. Tse et al. (2015) recommend that local communities should not only be target audience for sharing research findings but should also be involved in the research. The integration of the indigenous knowledge with the scientific literature findings on forest-water relationships and meteorological observations could produce useful information and reduce on the effect of hydrological data gap.

While the concept of agroforestry (Buyinza et al., 2020; Gram et al., 2018; Rahn et al., 2018) and the impact of land use and land cover changes on hydrology is scientifically well known (Bonell and Bruijnzeel, 2005; Mugagga et al., 2012; Oyana et al., 2015), it remains unclear how such information can best be linked with local knowledge (Eisenbies et al., 2007; Selim et al., 2015; Wilson et al., 2015). There is limited literature devoted toward translating hydrological knowledge into locally relevant guidelines for sustainable agroforested landscape management (SALM; Bonell and Bruijnzeel, 2005; Eisenbies et al., 2007; Selim et al., 2015; Wilson et al., 2015). Recent studies in Mt. Elgon are limited to analyzing and applying stakeholder perceptions to improve protected area governance (Omoding et al., 2020) and to collaborative resource management and rural livelihoods around protected areas (Nakakaawa et al., 2015). Moreover, to date, no study has analyzed the Mt. Elgon Water Tower (MEWT) as an "integrated system" by taking into account stakeholders' views and perceptions on forest-water interdependencies. Integration of local knowledge with the scientific literature findings could produce useful information reducing the FWP-nexus knowledge gap in SALM (Cavanagh, 2015; Norgrove and Hulme, 2006; Vedeld et al., 2016). Issues associated with landscapes are complex arising from natural and human-induced activities and thus call for concerted multilevel responses and require systematic and credible participatory approaches that promote dialogue, shared learning, and collective decision-making among local stakeholders (Galvani et al., 2016; Moran and Lopez, 2016).

Q-methodology is a research technique associated with theoretical and methodological concepts (Watts and Stenner, 2012) that can be used for exploring complex problems while involving diverse stakeholder perspectives (Zabala et al., 2017). The approach is mainly applied in personal experience, values, and beliefs. Q-methodology has been broadly applied in natural (especially forest and water) resource management (Armatas et al., 2017; Barletti et al., 2022; Steelman and Maguire, 1999) and environment-related research (Seghezzo et al., 2023; Sneegas et al., 2021; Webler et al., 2009). While exploring the perspectives of a group of experts in landscape approach, Langston et al. (2019a) applied Q-methodology to explore experts' view points on challenges to achieving sustainable landscape management in Indonesia. In addition, Barletti et al. (2022) applied similar approach to identify diverse understanding of various stakeholders on community forest management.

The study was guided by the following research questions: (i) What are the underlying factors shaping differences and similarities in perceptions of the FWP-nexus among scientists and local stakeholders? (ii) How do local ecological knowledge and scientific knowledge align or diverge in understanding forest-water relationships in agroforested landscapes? (iii) How do perceptions of institutional support or failure affect stakeholder willingness to engage in forest-water conservation practices? and (iv) How does the spatial position within the catchment (upper vs. lower) influence stakeholder perceptions of forest and water linkages?

The study was further grounded in three hypotheses: (i) *Local stakeholders and scientists significantly differ in their perceptions of the FWP-nexus, particularly in attributing causes of water scarcity to land-use practices;* (ii) *Institutional weaknesses are more commonly perceived by majority of stakeholders as a greater barrier to effective forest-water management than farmer unwillingness or lack of awareness; and (iii) Perception differences regarding the FWP-nexus are more pronounced between two studies sub-catchments (Sipi vs. Manafwa) than within zones of a single catchment (upper vs. lower).*

The overall aim of the study was to explore the drivers of scientific insights and local stakeholders' perceptions on the FWP-nexus in relation to water availability. In this study, Q-methodology was used to understand stakeholders' perceptions and views with regard to the practices in the forest-water interdependencies context at local and Sub-catchment level. The methodology was applied to explore both scientific (high) and local (low) stakeholders' views and experiences about forest–water–people nexus (FWP-nexus) using River Manafwa Sub-catchment (RMSC) and Sipi River Sub-catchment (SRSC) as case studies in Mt. Elgon Water tower. A comparative q-methodological study was conducted in RMSC and SRSC to understand how high-level stakeholders (scientists and key experts) and low-level stakeholders (farmers) perceive the forest–water–people nexus. The q-methodological approach was considered because it is a useful tool that enables us to explore human views about a certain subject matter (Zabala et al., 2018). The approach statistically follows analysis of qualitative and quantitative data (from questionnaires) to show similarities and or differences in subjective perceptions.

The Q-methodology was based on the procedure suggested by Stevenson (2015) and on the need to investigate famers and other stakeholders' agroforestry adoption and sustainable management in the context of increasing productivity and improving their livelihoods. Initially, the statements were to be translated from English to the three main languages (Lugisu, Kusabiny, and Luganda) spoken by the local stakeholders and then to English again by different interpreters to retain original meaning (Köksal and Yürük, 2020). However, due to failure by most local people to read the local language(s), research assistants that understood the common local languages were involved to reduce the wide cultural and language gap.

2 Methodological approach

2.1 Study area description

Mt. Elgon is the 7th highest Mountain in Africa rising to 4,320 m.a.s.l. Approximately 2,000 km^2 of the mountain ecosystem is protected for biodiversity and water catchment (White and Wanyama, 2006). The MEWT is situated along the eastern border of Uganda and Kenya and encompasses several Ugandan districts, including Kapchorwa, Mbale, Bulambuli, Sironko, Bududa, Manafwa, and Bukwo. Land use within the MEWT is highly heterogeneous, comprising protected montane forests within Mt. Elgon National Park, intensively cultivated smallholder farms, agroforestry systems, and grasslands or bushlands in more degraded or elevated areas, with projected 10% (1.9 million hectares) forest cover in 2024 (National Forestry Authority, 2018). The MEWT is a densely populated, landscape (Mbogga, 2013). The MEWT is densely populated, with an estimated 2.2 million people as of 2024 (Uganda Bureau of Statistics, 2024) and a population density exceeding 500 persons per square kilometer. The MEWT serves as the source of several important rivers, including the Manafwa, Sironko, Sipi, and Lwakhakha, contributing inflow to Lake Kyoga, Lake Victoria, the Nile River system, and Lake Turkana basins (Muhweezi et al., 2007). These rivers are crucial for domestic water supply, irrigation, and small-scale hydropower. In addition, numerous natural springs and wetlands across the region supplement local water access, particularly in upland and rural communities where piped infrastructure is limited.

The local economy is primarily based on rain-fed agriculture, with key crops including coffee, maize, beans, and bananas. Agroforestry practices are widespread but vary in structure and

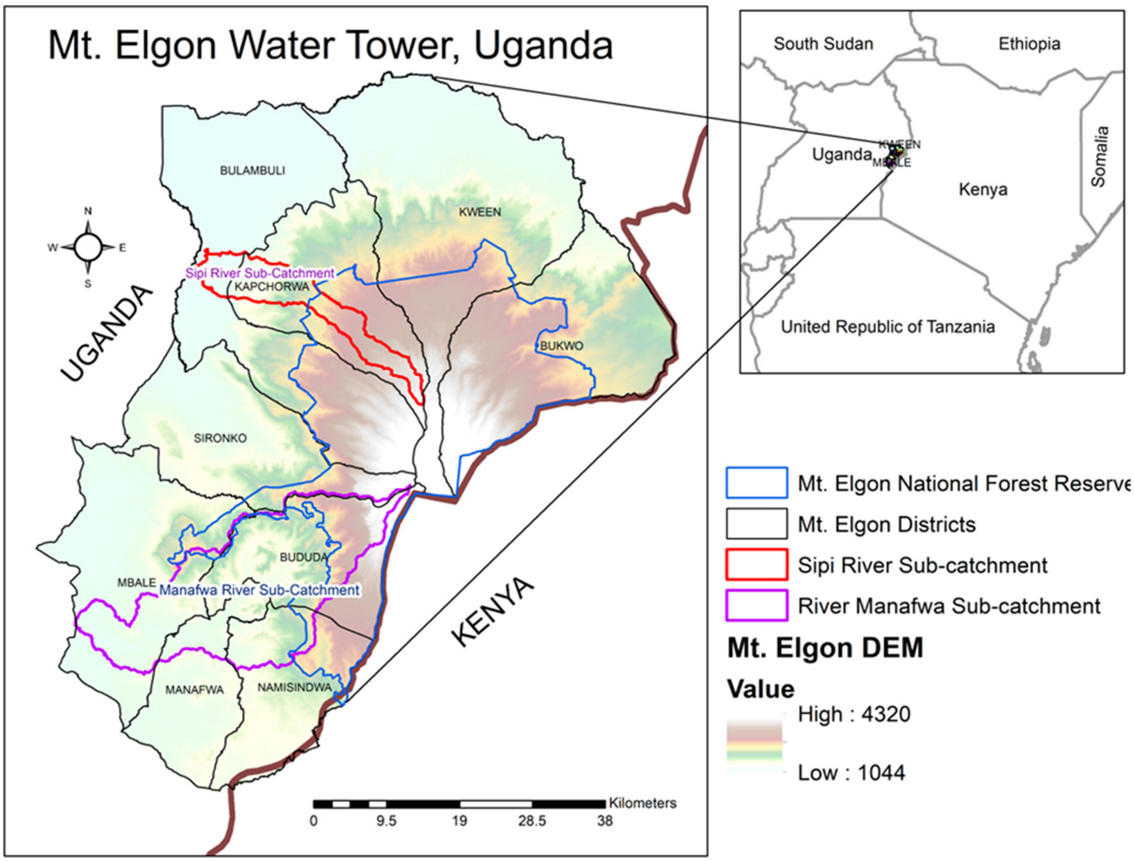


FIGURE 1
Location of the study area sites: River Sipi Sub-catchment and River Manafwa Sub-catchment (modified from Kimbowa et al., 2024).

intensity depending on elevation and community engagement. The region experiences a bimodal rainfall pattern, with peaks during March–May and August–November, and annual rainfall ranging from 1,200 to 2,200 mm, generally increasing with altitude. Soils are predominantly fertile andosols and nitisols, derived from volcanic ash and basaltic parent material, supporting high agricultural productivity.

Despite its ecological and hydrological importance, the MEWT is under increasing pressure from deforestation, agricultural encroachment, and climate variability, all of which have significant implications for water quality and availability. These challenges underscore the critical need for integrated and participatory watershed management strategies to ensure the sustainability of water resources and the resilience of local communities.

Study site along a transect that crosses the three zones of the water tower, focusing on catchments relevant for the FWP-nexus concept, was considered. Two sub-catchments (Figure 1) were considered: 1) the Sipi River Sub-catchment (SRSC) in Awoja Catchment, upper zone of Mt. Elgon that experiences increased degradation of land through unfavorable land-use practices, overgrazing, and deforestation, thus leading to flooding; 2) the River Manafwa Sub-catchment (RMSC) in Mpologoma catchment, middle and lower zone of Mt. Elgon (with outlet at the Manafwa waterworks) characterized by high population growth rates and low-income generating activities; high deforestation levels and decreasing Manafwa River base flows; seasonal downstream floods; and drying river streams from Mt. Elgon national park due to massive encroachment beyond the bamboo zone (Gunderman and Saravanan, 2010; Lang and Byakola, 2006; Mugagga et al., 2012). Local stakeholders were selected using snowball sampling to identify key stakeholders (Goodman, 2013) and stratified sampling (Kumar, 2019) to represent upstream and downstream farmers, conservation agencies, and local authorities. Farmers with fields distributed at upstream and downstream locations were considered based on informed consent.

2.2 Q-set and designing the Q-sorts

A representative sample of statements was generated based on discussions with key stakeholder groups (including farmers and key experts from environment, forestry, water, natural resources, production and marketing sectors at regional, local government, and local levels) in addition to reviewing recent relevant scientific literature focusing on peer-reviewed journal articles and academic databases such as Google Scholar, Web of Science, JSTOR, and Scopus.

The study employed a participatory fieldwork approach designed to integrate local knowledge systems with scientific inquiry, ensuring contextual relevance and stakeholder inclusivity. Fieldwork was conducted across two sub-catchments within the MEWT and selected to capture a range of socio-ecological conditions and land-use dynamics. Central to the fieldwork was the use of Q-methodology, which facilitated the structured elicitation and analysis of stakeholder viewpoints. The process began with preliminary community engagements, including interviews with key experts and focus group discussions with farmers. These interactions informed the development of the Q-set statements.

The process of selecting statements was participatory in order to cover the most appropriate forest-water-related issues in the region considering both spatial and temporal scales. The key concepts considered were based on participatory catchment management, integrated water resource management, policy analysis, and/or interventions. The statements in our q-methodological study were operationalized based on analysis of ecological knowledge and values of local stakeholders (key experts and farmers) in the agroforested landscape of Mt. Elgon water tower.

To develop and select Q-sorts, previous research and reports on Catchment Management Plans (CMPs), documents at Kyoga Water Management Zone (KWMZ) of the Uganda's Ministry of Water and Environment, and related literature was reviewed (Waalewijn et al., 2020). "Statement selection" was designed based on the approach suggested by Damio (2016). Initially, 37 items were developed. Together with key experts at School of Forestry, Environmental and Geographical Sciences, Makerere University, the items were revised and reduced to 30 items. A comprehensive list of items, explanations, and references is provided in Table A1 (see Supplementary material). Involving extensive interest groups in items explanation is a pivotal incentive in providing participants with wider range of statements (Walder and Kantelhardt, 2018) and thus wider opinions on FWP-nexus. The experienced and unbiased group of four experts from both departments of Geography and Environment of Makerere University were involved basing on their experience, knowledge and opinion in forest and water resource management, environment management, etc. The experts were individually contacted by the research team to express their opinions and viewpoints for each of the 37 items highlighting similarities among statements. The final list of items, in addition to explanation and references, is presented in A1. The Research team members read out Q sorts to the less educated stakeholders who could not read or write.

2.3 Selection of participating stakeholders

The stakeholders were locally selected from two groups: (i) farmers (crops/trees/agroforestry) representing MEWT coffee–banana cropping systems and (ii) non-farmers stakeholders comprising forest-water professionals, policy enforcement officials, and local administration. A total of 32 stakeholders (both male and female) from three sub-counties within the Sipi River sub-catchment and 36 stakeholders from six sub-counties within the Manafwa River sub-catchment were voluntarily recruited to participate in the study. A proportional number of participating stakeholders are based on representative of the both local and regional stakeholders to allow for diversity of stakeholder perceptions (Haddaway et al., 2017). The total number of participants was 68. It should be noted that each participant is associated with a code (Tables 1, 2). For instance, participant 1 from RMSC is RMSC01M55UMDKEDPO. RMSC01 stands for participant 01 in River Manafwa Sub-Catchment, gender (M = male), age (= 55), level of education (UM = University

TABLE 1 Calculating factor loadings, eigen values, and variance (RMSC).

Q-Sort	Code	Factor 1	Factor 2	Factor 3	Factor 4	Communality (h2)	(h^2) %
1	RMSC01M55UMDKEDPO	0.37	0.51	0.02	0.31	0.50	50
2	RMSC02F40UBDKEDFO	0.30	0.33	0.30	0.62	0.67	67
3	RMSC03M45UMDKEDNRO	0.58	0.32	−0.32	0.17	0.57	57
4	RMSC04F39UBDKEDEO	0.37	−0.11	0.68	0.34	0.73	73
5	RMSC05M52UMDKEDWO	0.73	0.29	0.20	0.12	0.67	67
6	RMSC06M42UMDKEDPO	0.64	0.31	0.23	0.16	0.59	59
7	RMSC07M50UBDKEDWO	0.31	0.58	0.31	0.20	0.56	56
8	RMSC08F42UBDKEDEO	0.51	0.15	0.18	0.51	0.58	58
9	RMSC09M40UMDKEDFO	0.70	−0.15	0.26	0.46	0.79	79
10	RMSC10M41UPGKEDPO	0.37	0.41	−0.45	0.23	0.56	56
11	RMSC11M48UBDKEDFO	0.41	0.14	0.32	0.60	0.65	65
12	RMSC12F43UMDKEDWO	0.35	0.63	−0.24	0.23	0.63	63
13	RMSC13F44UPGKEDEO/DNRO	0.56	−0.20	0.36	0.35	0.61	61
14	RMSC14M50UMDKEDPO	0.59	0.31	0.21	0.08	0.50	50
15	RMSC15M47UBDKEDFO	0.74	0.30	0.26	0.21	0.75	75
16	RMSC16M37UBDKEDWO	0.30	0.61	0.48	0.18	0.72	72
17	RMSC17M58UMDKEDNRO	0.78	−0.06	−0.01	0.26	0.68	68
18	RMSC18F50UMDKEDEO	0.54	0.04	0.08	0.27	0.38	38
19	RMSC19F48UBDLOLZTCA	0.25	0.66	0.11	0.34	0.63	63
20	RMSC20M31UBDLOLZC	0.79	0.25	−0.02	0.19	0.73	73
21	RMSC21M35SOFUZTC	0.46	0.55	0.36	−0.25	0.70	70
22	RMSC22M34UDFUZA	0.13	0.77	−0.13	0.20	0.66	66
23	RMSC23F35SOFUZA	0.09	0.82	0.26	−0.15	0.76	76
24	RMSC24M61SOFUZTC	0.18	0.45	0.19	0.33	0.38	38
25	RMSC25M49SOFUZTC	−0.09	0.77	0.03	0.02	0.61	61
26	RMSC26M78PFUZTCA	−0.07	0.27	0.74	−0.14	0.64	64
27	RMSC27F65PFUZTC	0.53	0.28	0.30	0.15	0.47	47
28	RMSC28M46SOFUZTCA	0.21	0.46	−0.12	0.58	0.61	61
29	RMSC29M60PFLZTC	0.09	−0.04	0.60	0.16	0.40	40
30	RMSC30M51UPGFLZTC	0.72	0.02	0.16	0.06	0.54	54
31	RMSC31F73UDFLZTC	0.13	0.04	0.16	0.78	0.65	65
32	RMSC32M55SAFLZTCA	0.78	0.26	−0.08	0.05	0.69	69
33	RMSC33F37SOFLZA	0.15	0.46	−0.29	0.62	0.70	70
34	RMSC34M46SOFLZTCA	0.41	0.16	0.73	0.08	0.73	73
35	RMSC35F49PFLZTC	0.24	0.26	0.65	0.42	0.73	73
36	RMSC36F54PFLZA	0.53	0.36	0.08	0.04	0.41	41
Eigenvalue	10.29	8.13	6.15	6.10			
Explained variance in %	29	23	17	17			
Number of defining Q sorts	14	9	5	5			
Correlation between factor scores							
Factor 1		0.46	0.46	0.57			
Factor 2			0.35	0.49			
Factor 3				0.39			

TABLE 2 Calculating factor loadings, eigen values, and variance (SRSC).

Q-Sort	Code	Factor 1	Factor 2	Factor 3	Factor 4	Communality (h2)	(h^2)%
1	SRSC01F44UPGKEDNRO	0.41	0.15	0.33	0.47	0.52	52
2	SRSC02M54UBDKEDWO	−0.03	0.51	0.52	0.30	0.61	61
3	SRSC03M39UBDKEDFO	0.47	0.12	0.13	0.80	0.89	89
4	SRSC04M59UPGKEDPO	−0.34	0.43	0.37	0.53	0.71	71
5	SRSC05M45UPGKEDEO	0.32	0.42	−0.15	0.62	0.70	70
6	SRSC06M31UBDKEDFO	0.66	−0.04	0.52	0.30	0.79	79
7	SRSC07M53UBDKEDWO	0.13	0.11	0.56	0.43	0.53	53
8	SRSC08M36UMDKEDPO	0.27	0.19	0.33	0.62	0.60	60
9	SRSC09F36UMDKEDEO	0.69	0.03	0.42	0.33	0.76	76
10	SRSC10M59UMDKEDNRO	0.58	−0.03	0.60	0.15	0.72	72
11	SRSC11M55SOFLZTCA	0.70	0.14	0.11	0.02	0.52	52
12	SRSC12M55SOFLZTC	0.76	0.18	0.19	0.13	0.67	67
13	SRSC13F45SOFLZA	0.74	0.24	0.39	0.13	0.78	78
14	SRSC14M33SOFLZC	0.52	0.35	0.20	0.41	0.59	59
15	SRSC15F57UDFLZA	−0.01	0.12	0.06	0.84	0.72	72
16	SRSC16M52SOLOLZTC	0.78	0.39	−0.03	0.10	0.77	77
17	SRSC17M47SOFLZTC	0.72	−0.16	0.35	0.25	0.73	73
18	SRSC18M43PFLZA	0.17	0.60	0.62	−0.21	0.81	81
19	SRSC19M59SOFUZTC	0.22	0.19	0.59	0.34	0.54	54
20	SRSC20F31SOFUZTC	0.15	0.78	0.05	0.19	0.67	67
21	SRSC21M41UDFUZCA	0.08	0.77	0.11	0.15	0.64	64
22	SRSC22F29SOFUZTC	0.21	0.02	0.81	−0.02	0.69	69
23	SRSC23F42SOFUZTC	0.84	0.01	0.40	0.04	0.88	88
24	SRSC24M48PFUZTC	0.30	0.15	0.65	−0.10	0.54	54
25	SRSC25M64SOFUZA	0.43	0.59	−0.09	0.39	0.69	69
26	SRSC26M49SOFUZA	0.24	0.16	0.70	0.27	0.65	65
27	SRSC27M61SOFUZA	0.28	0.63	0.33	0.19	0.62	62
28	SRSC28M53PFUZA	0.73	0.29	0.18	0.15	0.66	66
29	SRSC29M46SOFUZA	0.40	−0.03	0.33	0.19	0.31	31
30	SRSC30M49PFUZA	0.61	0.19	0.02	0.15	0.43	43
31	SRSC31M47SOFUZA	0.51	0.60	0.08	0.07	0.63	63
32	SRSC32M63SOFUZA	0.71	0.37	0.26	−0.04	0.70	70
Eigen value	10.20	6.38	6.91	6.05			
Explained variance in %	32	20	22	19			
Number of defining Q sorts	12	5	6	4			
Correlation between factor scores							
Factor 1		0.50	0.63	0.47			
Factor 2			0.37	0.50			
Factor 3				0.38			

TABLE 3 Frequency distribution: Source (Kimbowa et al., 2025).

Ranking value	−4	−3	−2	−1	0	+1	+2	+3	+4
Number of items	1	2	4	5	6	5	4	2	1

Masters), participant category (KE=Key Expert), and role in the Sub-catchment (DPO= District Production Officer). In addition, participant 32 in the other Sub-catchments is SRSC32M63SOUZA. SRSC32 stands for participant 32 in Sipi River Sub-Catchment, gender (M = male), age (= 63), level of education (SO = secondary ordinary), participant category (UZ = upper zone farmer), and farmer category in the sub-catchment (A = agroforestry).

2.4 Q-sorting

This was conducted on a face-to-face basis (Alexander et al., 2018) with selected participants at each sub-county. The Q-sorts/statements were designed in English. However, for easy and proper administration, in case a participant could not read English, research assistant fluent in each of the common local languages (Gishu and Sabiny) translated the statements. The classic forced quasi-normal distribution used by study participants during Q-sorting is presented in Table 3. The statements were tested to ensure they were succinct, clear, and meaningful. In this regard, pilot study was conducted with six undergraduate students at the Department of Environmental Management, School of Forestry, Environmental and Geographical Sciences at the College of Agricultural and Environmental Sciences, Makerere University, to test whether the Q-sorts are representative. In order to avoid the translating influencing the Q-sorting, a pilot study was conducted with half the participants (3) coming from the study area (Birbili, 2000). As suggested by Warwick and Osherson (1973), pre-testing participants were also asked for their interpretation of each of the Q-sort's meaning. The pilot study was to the feasibility of the study design, and thus, the data from pilot study were not analyzed. Guiding instructions were read to participants step-by-step. The Research team, while taking notes, responded to participants questions and clarified on Q-sorts. In addition, interviews were conducted to validate the "priority piles" of the Q-sorts by participants. The Q-sorting process was recorded. The Q-methodology survey and collection of data in both RMSC and SRSC was conducted over a period of 5 weeks (August–September, 2023), and subsequent data analysis took 3 months (October–December, 2023).

2.5 Factor extraction and analysis

This study aimed at hearing more stakeholders' voices regarding forest–water–people nexus as much as possible. The statistical analysis method was based on criteria suggested by Watts and Stenner (2012). To analyze Q studies data from the two sub-catchments, PQMethod version *2.35 with PQROT 2.0* was used (Schmolck, 2014). Extracting two centroids/factors gave a higher average squared residual correlation of 0.026 and 0.024 for RMSC and SRSC, respectively. According to Watts and Stenner (2014b), factor extraction comprises categorizing patterns of similarity among Q-sort arrangements. Factor loadings expressed as correlation coefficients were extracted from datasets of the two representative sub-catchments in MEWT with the first factors accounting for the largest study variance.

Factors were extracted and retained based on guidelines in Watts and Stenner (2005, 2014a,b). According to Watts and Stenner (2014b), 1 factor can be extracted for every 6–8 participants and thus 4–6 factors could be extracted for this study. Eigen values and factor variances are potential indicators of strength and powerfulness of extracted factors (Watts and Stenner, 2014b). Factors account for 35–40 or above percent (Brown, 1980; Kline, 2014). Considering the 30 statements, significant factor loadings were calculated basing on two or more loadings that were significant at the 0.01 level. The values of residual correlation, eigen values, and factor variances were calculated following the outlined procedure in Kimbowa et al. (2025). Guided by Kimbowa et al. (2025), significant loading and standard error were 0.47 and 0.16, respectively. Thus, significant factor loadings are those >0.47.

2.6 Factor rotation, factor estimates, and factor arrays

The aim of factor rotation is well emphasized in Kimbowa et al. (2025) and Watts and Stenner (2014b). The choice of by-hand factor rotation method is explained in Brown (2006). Due to a larger dataset (N>30), and to ensure overall solution maximizes the study variance (Watts and Stenner, 2014b), varimax rotation was considered. In addition, varimax reveals the subject matter that every participant might recognize and consider important (Abdi, 2003). The rotated factors were inspected to explore whether the viewpoints of several factors satisfactorily focused from the perspective based on the after-Q sort interviews (AQSI). Factor estimates and flagging were determined following suggestions by Kimbowa et al. (2025) and Taherdoost et al. (2014).

3 Results

3.1 Factors and their relative importance

The unrotated factor loading values for both RMSC and SRSC are presented in Tables 1, 2. Following guidelines by Samuels (2016), Taherdoost et al. (2014), and Zwick and Velicer (1986), seven factors were initially extracted, but only four factors (1, 2, 3, and 4) resulted in two or more significant loading. However, for RMSC, Factor 3 and Factor 4 passed with only six significant loadings while Factor 4 passed with only six significant loadings for SRSC. Considering the RMSC, the estimated standard error of 0.36, the cross products of the highest Factor 1 loadings were 0.62 (0.78 × 0.79) and thus passed. Similarly, cross products for highest factor loadings for Factor 2, Factor 3, and Factor 4 were 0.63, 0.54, and 0.48, respectively. Obviously, for the RMSC, cross products for all factors passed this criterion. A summary of the factor statistics for RMSC and SRSC is presented in Table A2 (see

Supplementary material). Similarly, considering the SRSC and the estimated standard error of 0.36, the cross products of the highest Factor 1 loadings were 0.66 (0.78 × 0.84) and thus passed. Similarly, cross products for highest factor loadings for Factor 2, Factor 3, and Factor 4 were 0.60, 0.57, and 0.67, respectively. Clearly, for SRSC, cross products for all factors passed this criterion. The communality, an indicator of how much a particular Q sort holds in common with other Q sorts, was also calculated (Tables 1, 2). The residual correlation matrix of participants for both RMSC and SRSC is presented in Supplementary Tables A3, A4, respectively, in the Supplementary material. As presented in Table 1, Factor 1 accounts for 29% (over a quarter) of the common study variance that the Q sorts have in common. Importantly, each of the final factors should account for as much variance in the original correlation matrix as much as possible. The four factors considered for RMSC account for 86% of the study variance, a value that is above the 35% value suggested in Kline (2014) and thus likely to offer an inclusive solution considering common factors. Similarly, from Table 2, Factor 1 accounts for 32% (almost a third) of the common study variance that all the Q sorts have in common. The four factors considered for SRSC accounted for 93% of the study variance, a value that is above the 35% value suggested in Kline (2014) and thus a reliable solution.

The solution accounts for 27 out of 30 study Q sorts and for 26 out of 30 study Q sorts for RMSC and SRSC, respectively. The non-significant Q sorts were 3 and 4 for RMSC and SRSC, respectively. The factor arrays for the four study factors are also presented in Table 4. Summaries of data about the participants in the Q sort study are presented in Tables 5, 6 for RMSC and SRSC, respectively. Notably, Factor 1 for RMSC has ranked six items significantly different from other items. That is items 5, 14, and 29 have been ranked significantly higher, whereas items 8, 20, and 22 are ranked significantly lower (Table 4). Similarly, Factor 1 for SRSC has ranked six items significantly different from other items. That is items 1, 3, and 11 have been ranked significantly higher, whereas items 8, 20, and 22 are ranked significantly lower.

3.2 Factor analysis: RMSC

3.2.1 Factor 1: involving local communities in planting trees increases tree cover and thus keeping water clean

Evidently, planting more trees in a water source area means lowering the cost of treating water (item 24 ranked at +1), and thus, tree planting is considered a reversal remedy for water problems (item 6: +1). Factor (F1) participants perceived trees to have less competition for water with crops (item 7: −2). Nonetheless, in some onion growing areas such as Bumbo and Bukokho sub-counties in upper RMSC, farmers highlighted that trees can outcompete onions. According to the AQSI results, "F1 participants" perceived that the sub-catchment was not experiencing challenges with the type of trees planted. For instance, one key expert emphasized *"…some trees develop a root structure deeper than that of crops and thus less competition for water…"*. In the lower zone of RMSC, there is an evidently decreasing forest/tree cover due to population, and social and financial pressures (Contreras-Hermosilla, 2000). Similarly, most of the ground and surface water sources especially boreholes and streams are drying up, and thus, there is need to extend gravity flow schemes (GFS). As a result, F1 participants perceived that planting more trees means more water in the streams (item 8: −3). According to one of the participants, *"…at Bubulo Girls high school (lower RMSC), there are many trees, but there is less water…"*. These communities have experienced severe hydrological extremes for instance the drought of 1999 and 2010 and floods of 1997 (Kimbowa et al., 2024).

One of the District Water Officer (DWO) from the upper RMSC noted, *"…trees play a key role in rainfall formation and therefore they cannot be the ones leading to less water in the steams…". Besides, some trees are considered good for water while others are not (item 18: −1).* Another District Natural Resources Officer (DNRO) from the lower RMSC noted *"…ecologically, rainfall formation is a scientific process that involves trees and or/forest(s)…"*. It is very vital in the context of F1 that health of streams is dependent on the presence of trees along its banks (item 26: +2) and thus forests keep water clean (item 5: +3). According to one of the key experts of the RMSC, *"…. streams and rivers cannot be easily contaminated due to presence of trees and other vegetation and thus reducing flow of surface water…"*. Due to excessive use of agrochemicals leading to soil and water contamination, there is need to plant trees and grass to control the quality of river and stream water. It can be contended that involving local communities in planting trees increases tree cover (item 29: +4). From the AQSI results, participants associated with F1 generally perceive that due to private land ownership in the region, involving communities in tree planting will increase tree cover. One of the F1 participants form the lower RMSC emphasized that *"… we don't have natural forest reserves or 'permanent forest estates' in our area, we instead only have trees on farms, the hills and 'fragile' areas are bare thus involving communities will increase the tree cover…"*. According to AQSI, the average household landholding in RMSC is 3 acres for most low-income communities deriving their livelihoods from farming. In addition, land tenure system empowers individuals and/or communities' ownership of land and thus less control over land-use planning and choices.

From the context of F1, forests and trees secure all sources of water and thus forests keep water in streams throughout the year (item 2: +2; item 13: +2). F1 participants perceived that cutting down sacred trees has less effect on water availability in the sub-catchment (item 21: −2). Accordingly, rainfall formation is considered a natural and scientific process that can be influenced by human activities. Therefore, items 20 and 22 were considered as myths that cannot be scientifically proven. One farmer emphasized *"… it's a big lie. why can't rain makers make rain during the dry season but instead only during the wet season…"*. Another F1 participant also wondered *"…spirits cannot determine rainfall because we have been having droughts during the dry season and the spirits could not help and thus these are just myths…august is meant to be a rain month but is now dry…"*. However, most participants responded based on their religious beliefs. For instance, most participants did not believe in spirits and gods and as a result did not see any scientific relationship between water, trees, and the spirits. Such participants believe God is responsible for rainfall and hydrological extremes (floods and drought). For instance, another

TABLE 4 Factor arrays for the four study factors in River Manafwa and Sipi River Sub-catchments.

Item No.	Statement	RMSC				SRSC			
		F1	F2	F3	F4	F1	F2	F3	F4
1	No forest, no water	−1	−1	4	3	4	2	−1	1
2	Forests and trees secure all sources of water	2	−2	3	−1	2	2	4	−2
3	Forests increase rainfall locally	1	4	3	2	3	1	3	2
4	Tree planting in deforested areas brings back water	1	0	1	3	1	2	2	2
5	Forests keep water clean	3	1	2	−2	2	0	0	1
6	Tree planting is a reversal remedy for water problems	1	−1	−2	2	1	0	−1	0
7	Trees compete with crops for water	−2	1	0	0	0	−1	−1	3
8	More trees mean less water in the streams	−3	−1	−3	−3	−3	−1	−3	−2
9	Forests protect from floods	0	0	0	−1	2	0	1	−1
10	Logging and thinning increases water flow from the forests to streams	−1	−1	−2	−2	−2	−2	−2	−1
11	Forests generate clouds	−2	3	2	−2	3	0	−1	2
12	Forests increase rainfall elsewhere	−1	2	1	−1	1	1	0	−2
13	Forests keep water in streams throughout the year	2	−3	2	−1	1	−2	2	0
14	Trees and forests make the air cooler	3	3	2	1	2	1	1	2
15	More diversity of trees leads to more water in the soil	1	−2	0	2	−2	−3	2	0
16	Trees protect crops from weather extremes (floods and droughts)	0	1	1	1	1	0	1	1
17	The effect of trees on water availability depends on location	−2	1	0	0	−1	1	−1	−1
18	Some trees are good for water, some are not	−1	1	−2	1	0	3	0	−3
19	The age, roots, shape size and type of tree influence its impact on water availability	0	−1	−1	0	−1	0	0	−2
20	Spirits determine rainfall	−4	−4	−4	−4	−4	−4	−4	−4
21	Cutting down sacred trees will result in less water	−2	−2	0	0	−2	−2	−2	−3
22	Drought and floods are an act of god	−3	−3	−3	−3	−3	−3	−3	−1
23	Disrespecting nature will result in problems with water	2	0	−2	1	−1	2	1	0
24	More trees in a water source area means lower cost of treating water	1	0	−1	−2	0	−1	1	0
25	Planting large canopy trees over impervious surfaces, reduces storm water	−1	0	0	0	−1	−1	0	0
26	Health of streams is dependent on the presence of trees along its banks	2	0	−1	−1	0	−2	2	1
27	Fast-growing trees such as eucalyptus consume a lot of water	0	2	−1	1	−2	4	−2	4
28	Eucalyptus trees take more water than other commercial trees such as pines	0	2	−1	0	−1	3	−2	1
29	Involving local communities in planting trees increases tree cover	4	2	1	4	0	1	3	3
30	More trees mean more ground water in dry area	0	−2	1	2	0	−1	0	−1

F1 participant emphasized *"…I can't think that way… because rainfall comes from forests… in case (forest) trees are cut, gods can't bring them back …and we shall not receive rainfall …"*. Arguably, this is partly due to fact that most participants did not have sacred trees in their areas. Despite the fact that tree planting in deforested areas brings back water (item 4: +1), these participants perceived that water availability is not solely dependent on presence of forests (item 1: −1). In addition, they agree that disrespecting nature will result in problems with water (item 23: +2).

Notably, most major springs and sources of GFS are based in the protected forested areas to ensure good water quality. Interventions such as agroforestry and SLM practices are exacerbated by poor attitude and sometimes ignorance by farmers and/or communities. For instance, one of the F1 participant noted *"…many people think if you plant trees, government will take your land…"*. In addition, there is need for catchment-based approaches and thus conservation practices such as promoting agroforestry by providing seedlings including for indigenous tree species and thus encouraging crop productivity.

In the context of RMSC, key experts highlighted the role of restoration of catchment areas by tree planting toward improving water quality and quantity and thus moderating local climate, reducing disasters, and increasing soil fertility; promoting biodiversity (sustaining bird species such as crested cranes); and

TABLE 5 Q-sorting participant's characteristics for RMSC.

Respondents' characteristics	Whole Sample	Factor 1	Factor 2	Factor 3	Factor 4
Number of participants	36	14	9	5	5
Average age	48.06 (31–78)	48.86 (31–65)	45.78 (34–61)	54.40 (39–78)	48.80 (37–73)
Gender (female)	13 (36.1%)	4 (28.6%)	3 (33.3%)	2 (40%)	3 (60%)
Average years spent in area	34.04	28.44	26.22	51.25	35.0
Key experts	20 (55.6%)	10 (71.4%)	5 (55.6%)	1 (20%)	2 (40%)
Farmers	16 (44.4%)	4 (28.6%)	4 (44.4%)	4 (80%)	3 (60%)
Average acreage	4.3 (1–0–17.0)	7.3 (1.5–17.0)	1.3 (1.0–5.0)	2.0 (1.0–4.0)	4.5 (1.0–9.0)
Level of education					
Primary/vocational	5 (13.9%)	2 (14.3)	_	3 (60%)	_
Secondary	8 (22.2%)	1 (7.1%)	3 (33.3%)	1 (20%)	2 (40%)
University	23 (63.9%)	11 (78.6%)	6 (66.7%)	1 (20%)	3 (60%)
Farmers' characteristics					
Trees	12 (75%)	3 (75%)	2 (50%)	4 (100%)	2 (66.7%)
Crops	12 (75%)	3 (75%)	2 (50%)	4 (100%)	2 (66.7%)
Agroforestry	8 (50%)	2 (50%)	2 (50%)	2 (50%)	2 (66.7%)
Average acreage	4.4 (1.0–17.0)	10.6 (6.0–17.0)	1.5 (1.0–2.5)	2.0 (1.0–4.0)	4.5 (1.0–9.0)

TABLE 6 Q-sorting participant's characteristics for SRSC.

Respondents' characteristics	Whole Sample	Factor 1	Factor 2	Factor 3	Factor 4
Number of participants	32	12	5	6	4
Average age	47.66 (29–64)	47.83 (31–64)	48.8 (31–64)	49.5 (29–59)	44.25 (36–57)
Gender (female)	08 (25%)	4 (33.3%)	1 (20%)	1 (16.7%)	1 (25%)
Average years spent in the area	35.84	39.42	48.8	36.5	26.25
Key experts	11 (34.4%)	3 (25%)	_	2 (33.3%)	3 (75%)
Farmers	21 (65.6%)	9 (75%)	5 (100%)	4 (66.7%)	1 (25%)
Average acreage	2.9 (0.5–15.0)	3.3 (1.0–15.0)	2.1 (1.0–15.0)	2.8 (1.0–5.0)	2.25 (1.0–5.0)
Level of education					
Primary/vocational	4 (12.5%)	2 (16.7%)	_	1 (16.7%)	_
Secondary	16 (50.0%)	8 (66.7%)	4 (80%)	3 (50%)	_
University	12 (37.5%)	2 (16.7%)	1 (20%)	2 (33.3%)	4 (100%)
Farmers' characteristics					
Trees	10 (47.6%)	4 (44.4%)	2 (40%)	3 (75%)	_
Crops	08 (38.1%)	4 (44.4%)	2 (40%)	3 (75%)	_
Agroforestry	13 (61.9%)	6 (66.7%)	4 (80%)	1 (25%)	1 (100%)
Average acreage	3.0 (0.5–15.0)	3.6 (1.0–15.0)	2.1 (1.0–4.0)	3.6 (1.0–5.0)	5 (5)

restoring cultural sites. The roles and insights of key experts, as identified through post–Q Sort interviews, are summarized in Table A5 (see Supplementary material). Most F1 participants perceived that trees and forests make the air cooler (14: +3), expressing that more trees planted around homes are for fresh cool air and shade during dry season. *One* senior District Environmental Officer (DEO) from lower RMSC highlighted that "... *In Mt. Elgon, we are suffering due to degradation, excess floods and droughts and thus a need for soil and water conservation. For instance, in Buwagogo Sub County, there was some restoration activities conducted and the protected spring that had previously dried recovered in nearly 2 years...*". During the peak of the dry season, some sections of River Manafwa completely dry and thus leading to water rationing in Mbale city. Yet, in the wet season, the sub-catchment experiences extreme floods. One of the F1's key experts indicated "... *nowadays every valley in Manafwa has sand because the top soil layer has been* *washed away...* ". According to F1 participants, the trees' impact of age, roots, shape size, and type on water availability was not clear (19: 0). However, F1 participants perceived deep rooted trees to allow deeper water penetration, and due to bigger canopies, such trees reduce the impact of rainfall on soil. One participant noted that "*...stripping hills of vegetation cover for agriculture increases runoff and thus floods...*". These participants were neutral about trees' protection of crops from weather extremes (16; 0). Instead, they perceived that trees are useful in retaining soil for crops, creating a micro-environment favorable for crop growth, and thus improving soil fertility.

One of the senior DEOs from lower RMSC further emphasized "*...there is 'over projectising of interventions'. For instance, agroforestry and tree growing campaigns in Mt Elgon region are failing due to closure of projects... unlike projects, programme if guided by policies can yield more benefits...*". There is lack of take-up of projects championed by international NGOs by Uganda government such as International Union of Conservation of Nature (IUCN) project(s). In addition, one of the DNRO in lower RMSC also shared "*... at local government level, since everyone is for himself and God for us all, multisectoral coordination is very weak affecting sustainable use of natural resources...*". One District Water Officer (DWO) from upper RMSC highlighted "*...We used to think that when you have trees on your land, landslides are reduced but nowadays trees are also swept by natural calamities for instance in Buwangani town council, eucalyptus is very prone to landslides....*". It is worth noting that from the early 1990s up to 2020, individual farmers commonly planted eucalyptus trees privately to supply the ready market for electricity transmission poles offered by the government. However, this practice declined following the introduction of concrete poles. Commercialization of eucalyptus trees as a source of cash has led to abandonment of indigenous trees by communities. There is need to promote and encourage growing of indigenous, agroforestry and fruit tree species. Government efforts toward environmental protection should focus on continuously sensitizing communities on values of (indigenous) trees/agroforestry and possibly 'promote and reward' farmers who preserve trees on farm and strict enforcement of by-laws.

In RMSC, some communities have embraced tree planting while others have not. For instance, farmers producing high value horticultural crops such as onions keep clearing (forest) trees to expand onion production area. In addition to high poverty levels among the (over populated) communities, due to urbanization, there is growing demand for timber, construction poles, and commercialization of firewood due to high demand by institutions. This results in premature harvesting of trees with limited efforts to replant and thus tree cover is reduced.

One of the DNRO in upper RMSC emphasized "*...we are doing more exploitation than planting. There is need for mindset change among communities that think tree planting requires substantial land yet the limited land is already under agriculture...*".

In the upper RMSC, there is illegal water abstraction especially from the main rivers especially using irrigation pumps for horticultural crops (onions and cabbages) during dry season. In addition, there is high-water pollution levels along the river banks due to unregulated use of agrochemicals and local brewing. In lower RMSC, river bank and wetland encroachment for farming and settlement is common in Bulucheke, Busheyi, and Bushigani sub-counties. In addition to allowing animals to graze and drink directly from the streams, there is excessive rice growing resulting in diversion of water from the streams. Consequently, digging along river banks and springs leads to drying of streams especially in Busukuya and Bunabwana sub-counties, for instance, Nakunuku stream dried due to rice cultivation along the stream. It should be noted that one of the Ministry of Water and Environment (MWE)'s GFS water source at Wanaponye in the Mt. Elgon National Park dried, and the water yield reduced so much leading to relocation of the source.

Sensitization and participatory involvement of communities in tree planting and thus management can follow bottom-up approaches. For instance, one of the F1 participant noted "*...when project for planting bamboo trees was initiated, implementers emphasized leaving 100 m as buffer and thus people refused thinking that government wanted to take their land and instead uprooted the bamboo...*". Youth should be specifically oriented to environmental management to increase tree cover as one of the F1 participant indicated "*...as the community elders are planting trees, the youth are busy cutting...*".

In upper RMSC, tree cover is majorly eucalyptus that consumes more water especially when planted along stream. However, White et al. (2014) emphasize that eucalyptus is a fast growing tree that efficiently converts water to wood. Despite hill tops acting as water catchments for rivers and water body recharge (agricultural), activities in upper RMSC reduce the quality, making water treatment costly and thus high-water tariffs incurred by downstream communities. One key expert emphasized "*...nowadays in lower RMSC especially Mbale city, water rationing is common compared to the 1980s....many waterfalls have disappeared due to human activities within Namatala central forest reserve...*". This, however, can be arguably related to expected increasing water demand over time.

In view of F1 participants in RMSC, over 70% key experts and 75% of the participating farmers were from lower RMSC. Since key experts know the values of trees, they perceive that involving local communities in planting trees increases tree cover and thus keeping water clean. Consequently, these participants perceive forests and trees to secure all sources of water, and thus, forests keep water in streams throughout the year (item 2: +2; item 13: +2). Less expected, these participants disagreed that trees compete with crops for water (7: −2) compared to other factors. Since more than half of the F1 participants in RMSC are key experts, their perceptions could be more reliable.

3.2.2 Factor 2: forests significantly contribute to cloud formation within MEWT and thus increase rainfall locally

According to F2 participants, growing more trees does not result in more ground water in dry area (30: −2). In addition, cutting down sacred trees does not result in less water (21: −2). Obviously, F2 participants perceived forests to contribute to generation of clouds (11: +3) and thus increase rainfall locally and elsewhere (**3**: +4; item 12: +2). One participant from lower RMSC noted "*...Mt. Elgon forests contribute to clouds formation and thus rainfall outside the forest even in our area...large canopy trees from*

Mt. Elgon Forest generate a lot of clouds with most water going to Butaleja district where rice is grown...". Both farmers and key experts especially from the upper RMSC agreed that despite rainfall formation being determined by internal and external factors, for the case of MEWT (forest), trees contribute to cloud formation and thus contributing to rainfall formation. Some farmers from the upper RMSC emphasized that most indigenous trees around Mt. Elgon Forest contribute to rainfall and thus water availability. In addition, participants' perception on effect of trees on water quality was not well distinct (24: 0). Clearly, participants perceived the effect trees on water availability to be insignificant (13: −3). Consistently, the participants seemed to disagree that forests and trees secure all sources of water (2: −2) and thus with the notion "no forest, no water" (1: −1). One lower RMSC participant urged *"Trees will not secure all water sources especially the boreholes...".*

RMSC in MEWT is one of the sub-catchments where communities largely depend on farming (including tree growing and/or agroforestry) due to readily accessible markets for trees/products. However, the market value offered by local traders is usually too low. Agroforestry/tree planting does not make economic sense to most youths in Uganda because of the usually long waiting time for returns. (Indigenous) trees/products should be a profitable investment due to time and costs involved. However, most farmers are cheated by the middlemen and thus discouraged to grow indigenous and agroforestry trees.

In addition to high poverty levels (sometimes manifested in theft of trees and seedlings), land fragmentation limits available land to extensively plant trees and grow food to support the increasing population and thus livelihoods. Thus, most farmers focus on economic trees such as eucalyptus that bring in money other than restoration trees. However, F2 participants perceived eucalyptus to consume more water, which requires more land thus leading to hunger due to limited land for growing food. Given the various values of eucalyptus such as timber source, energy fuel, and income, the participants growing eucalyptus consider its water consumption as a myth. There is need to equally focus on "restoration" trees in addition to "economic" trees such as eucalyptus.

Unlike in Kenya that has a tree growing policy and a clear strategic plan (County Government of Elgeyo Marakwet, 2020; Kenya Forest Service, 2023), in most parts of MEWT, provision of tree seedlings follows a top-down approach. However, with both top-down and bottom-up approaches, communities effectively adapt to changes fast and are likely to appreciate values of the risky tree growing projects and programs. Regarding tree competition with crops for nutrients (7: +1), F2 participants suggest that farmers need to be continuously sensitized and trained on sustainable agroforestry systems. For instance, crops should only be integrated with trees for timber production when trees are still young. These participants noted the importance of alternative energy saving technologies for cooking to minimize high dependence on fuel and charcoal wood resource.

Outside the Mt. Elgon National Park boundary, land tenure system is individual plot land ownership, and thus, there is arguably unregulated and premature harvesting of trees without replacement and thus poor management of trees on private farms. In lower RMSC, deforestation is driven by high demand of tree products. Yet available tree seedlings are majorly eucalyptus and thus a need for local government to further sensitize, train, and incentivize communities to get involved in planting more agroforestry trees focusing on indigenous and fruit trees.

Farmers associated with F2 perceive that planting trees (bamboo) and grass (elephant grass) near riverbanks is good for watershed restoration. According to one key expert in lower RMSC, "*...in 1993, Kapkwai was heavily degraded, since 1994, the area has been restored by planting trees especially on hills, evident with several water falls currently in the area...".* One expert from local conservation agency also shared experience *"...there was a case of an open water reservoir in Wanale and leaves from neighboring trees could fall and decompose from the reservoir dirtying the water and thus end up cleaning water at high cost..." (24: +1)....just like the case in Bwindi National Forest Park, I have experienced rainfall in Kapkwai, Mt. Elgon National Forest Park but just after driving 2km, the rainfall is over..." (12: –1).* F2 participants in RMSC for instance consider ficus tree as an indicator of water availability but that does not affect water availability (18: −1). Generally, sacred trees were perceived to be similar to other trees and very few in the Mt. Elgon region trees to cause a significant impact. It is noted that over 50% of F2 participants were key experts, and thus, the perceptions and views represent the true ground situation more reliably given that same percentage of the total sample of participants were also key experts.

For instance, one participant from upper RMSC indicated *"...here in Bududa all our water originates from forests.... e.g. river Manafwa and other streams comes from Mt. Elgon national park. ...when constructing GFS, water is sourced from the park...". A* participant from lower RMSC emphasized "*...where there are no forests/trees in Manafwa, there is no rain for instance in Bubuulo,* Namuwali *and Walanga,* trees were massively cut and thus less rainfall...".

Possibly, some participants consider role of trees in protecting crops from weather extremes (floods and droughts; item 16: +1). In addition to local land disputes due to houses and farms boundary conflicts, horticultural farmers are discouraged from planting trees since trees are perceived sources of pests and diseases to the crops. In some areas, communities have embraced tree planting while others have not. For instance, farmers producing onions, because of the high value of the crops they do not embrace tree growing instead of onions so they keep clearing forests to expand onion production area.

3.3 Factor analysis: SRSC

3.3.1 Factor 1: no forest, no water because forest-driven rainfall modifies microclimate

Evidently, tree planting in deforested areas brings back water (item 4 ranked at +1), and thus, tree planting is considered reversal remedy for water problems (item 6: +1). However, it was not clear whether trees compete with crops for water (item 7: 0). In addition, F1 participants in SRSC disagreed that more trees mean less water in the streams (item 8:−3). Also, it can be argued that despite perceiving forests to generate clouds and thus increase rainfall locally and elsewhere and thus water availability (11: +3; 3: +3; 12: +1; 1: +4). These participants argued that even in some parts of lower SRSC where there are no trees, people still get water from boreholes. F1 participants did not clearly indicate whether involving local communities in planting trees increases tree cover (29: 0). Like in RMSC, F1 participants from SRSC did not associate themselves with: spirits determination of rainfall; cutting down sacred trees resulting in less water; and drought and floods as an act of god (20: −4; 21: −2; 22: −3). Several participants disagreed differently: "…rainfall formation is a scientific fact that has nothing to do with spirits…"; *"…I can't depend on myths and thus no justification. Drought and floods are a result of human activities…"; "…God is responsible for rainfall that when it is too much it becomes floods. This is because farmers dig up to the cliff and thus rainfall sweeps everything as the soil is too soft…"*; and "…Spirits don't help at all in bringing rainfall." It should be noted, however, that most participants did not have sacred trees in their areas.

To a lesser extent, participants considered water-related problems to be resulting from disrespecting nature (23: −1). In addition, the participants perceived that trees contribute to ground water discharge and forests contribute to rain formation, and thus, tree cutting increases the drought effect impact. There is an increasingly high demand for charcoal and firewood in Kapchorwa town (upper SRSC). Consequently, F1 participants indicated that lower SRSC sub-counties including Kaptanya and Kapsinda had less tree cover and thus generally received less rainfall while the upper SRSC sub-counties such as Kabenywa, Sipi, and Munarya experience more rainfall. One F1 participant noted *"…based on nature, in case man does not intervene, we expect water to be conserved where there are trees…"*. Like in RMSC, some rivers have dried in deforested areas of SRSC. One F1 participant from lower SRSC noted *"…where there is water without trees, the water easily dries up…trees keep soil intact even when there are heavy rains, also keeping our crops from being washed away if erosion had taken place..."* (16: +1).

In lower SRSC, there was perceived surface (stream) water pollution from agro-chemicals and coffee processing plants such as the Kawacom Uganda limited in Chema sub-county.

In addition to wetland encroachment and planting eucalyptus along river banks that end up drying up the streams, farmers also divert a lot of water during dry season causing conflicts between communities. In addition, there is uncoordinated development of GFSs where water is tapped from different points along the same stream resulting in diminishing water levels downstream.

In lower SRSC, in addition to limited land for tree planting, there is premature harvesting of trees for timber and construction without replanting. Thus, there is need for community sensitization and involvement in tree planting especially on farms, hillsides, and boundaries. This can be achieved through sensitizing, training communities on alternative energy saving technologies, nursery bed, and agroforestry demo farm establishment. There is need to avoid growing of eucalyptus trees near water points and rivers and instead plant alternative trees such as 'lira-lira' that grows fast yet consumes less water. One participant indicated *"…water is from wetlands and thus people should not plant eucalyptus near wells…"*. Another participant emphasized *"…somehow, some people still plant eucalyptus along the river banks yet it consumes a lot of water…"*. There is need to minimize burning forests by hunters and grazing from forests as animals eat all grass and young trees which support forest. F2 participants encouraged communities to appreciate planting of bamboo trees and grass along the rivers such as Kaptekor and to have mindset change that government wants to take their land by planting bamboo. According to F1 participants, in most parts of SRSC, rivers, streams, springs, and swamps are very insufficient yet they are the major sources of water for the area. In addition, participants were neutral on effect of planting more trees in a water source area on cost of treating water (24: 0).

One elder farmer highlighted *"…eucalyptus consumes a lot of water and when it is planted in a dry area it dies… Kumweny river used to dry but after cutting the eucalyptus tree that had stayed for over 100 years, there was increase in amount of water in the river and thus increase in flow of gravity scheme abstracting from the same river…"*. Another participant stressed *"…people should plant indigenous trees such as Mvule (African teak) because 'dangerous trees'* such as *eucalyptus makes crops grow thin..."*. One of the F1 participant in SRSC emphasized *"…like in some parts of Ethiopia, forests/tree planting can be a solution to water problems…for instance the MWE in Eastern Uganda extended an intake of a GFS to the park since the source outside the park used to have dirty water (due to human activities) resulting in high treatment costs…"*.

3.3.2 Factor 3: forests increase rainfall locally and thus forests and trees secure all sources of water

According to F3 participants in SRSC, health of streams is dependent on the presence of trees along its banks (item 26: +2). F3 participants did not perceive eucalyptus as a higher water consuming tree compared to other commercial trees such as pines (27: −2; 28: −2). Such participants perceived more tree diversity to lead to more water in the soil (15: +2). In addition, they perceived forests and trees to secure all sources of water (2: +4) and to keep water in streams throughout the year (13: +2). However, these participants do not believe that forests solely generate clouds and determine water availability (11: −1; 1: −1), and thus, tree planting is less considered as a reversal remedy for water problems (3: −1). On a contrary, it was clearly perceived by the participants that sub-counties in lower SRSC such as Kaptanya and Kapsinda have less trees and thus receive less rainfall amount while those in upper SRSC such as Kabenywa, Sipi, and Munarya experience more rainfall. This spatial rainfall distribution can be attributed to the presence of the forest in the upper SRSC (Kimbowa et al., 2024). One participant indicated *"…naturally, in case man does not intervene and trees are many in an area, we expect them to attract rain, and trees along streams help keep water clean especially in small streams for people to drink …when forest is cut, some places don't get water…"*.

In SRSC, due to limited land, cultivation is up to the edge of river banks. This calls for communities' involvement in tree planting (29: +3). Unlike the protected zone, water resources within the communities are polluted by agricultural activities. One participant noted *"…I am located in a such a place where it is a little bit cool…"* (14: +1). Considering relationship between spirits and rainfall formation, one F3 participant noted "…I can't depend on myths. No justification that spirits are responsible for rainfall formation…" (20: −4). Another narrated *"…Spirits cannot* *determine rainfall; it is instead the way we conserve the natural resources especially trees. when we plant more trees, we attract more rain...".*

These participants stressed the need for soil and water conservation; nursery bed and agroforestry demo farm establishment; timely distribution of tree seedlings and community sensitization about tree planting; and training individual farmers and communities on energy saving technologies. Another F3 participant stressed *"...nowadays the is rain season is unpredictable...".*

Clearly, in MEWT, management of natural forest park is better than management of woodlots and thus poor tree cover outside protected boundaries. Tree cutting for short-term gains and quick returns especially onion and Irish growing is very common in upper SRSC. Like in RMSC, Government should take on projects by international NGOS such as IUCN's conservation project of Sipi River.

In the MEWT, there are few indigenous trees as communities prefer commercial eucalyptus that competes with crop for water, need to sensitize and involve communities about importance and in planting indigenous and agroforestry tree species. In upper SRSC, since eucalyptus trees require large pieces of land, there are conflicts among neighboring farmers with limited land and thus are discouraged. *"...you can't plant trees near neighboring garden...".* In lower SRSC, there is rampart and unregulated irrigation schemes due to growing of crops off rain season, leading to river water diversion for instance on Sipi River along Nakapipirit road in addition to diversion of GFS water by cutting pipes. In some places of lower SRSC, rivers dry during dry season affecting government irrigation projects, e.g., Ngenge on Atari River. There is need to invest in micro-dams for water storage such that projects such as Ngenge irrigation schemes do not lack water during dry season.

In addition, participants were neutral about reduction of storm water due to planting large canopy trees over impervious surfaces (25: 0). Tree cutting has accelerated the drought effect/impact in lower SRSC (Kimbowa et al., 2025). In 2002, people from Kween district close to (upper SRSC) were chased from the Mt. Elgon National Park (MENP) and settled in conserved areas, cut trees, and thus later experienced drought. However, with introduction of District Natural resources Officers (DNRO), all districts of MEWT led to more planting of trees. Local governments at sub-county and village level have been advocating for tree planting for instance through ordinances such as "*cut 1 plant 4 trees*." The correlation matrix of participants in RMSC and SRSC is presented in Supplementary Tables A3, A4.

Overall, 50% and 62% of the participating farmers practiced agroforestry in RMSC and SRSC, respectively. In addition, only 75% and 38% of the participating farmers grew trees on separate fields in RMSC and SRSC, respectively. Fifty percentage and 75% of the F1 participating famers in RMSC practiced agroforestry and tree growing, respectively. Same proportion (50%) of the F2 participating famers in RMSC practiced agroforestry and tree growing, respectively. For SRSC, 44% and 66% of the F1 participating famers practiced agroforestry and tree growing, respectively. Similarly, for F3, the proportion of participating famers that practiced agroforestry and tree growing were 75% and 25%, respectively.

4 Discussion

4.1 Factor interpretations and discussion

Similarities and differences among the four factors were noted in both sub-catchments. The most seeming positive similarity across all four factors/viewpoints in both RMSC and SRSC is: forests increase rainfall locally (item 3); and involving local communities in planting trees increases tree cover (item 29). "F1 participants" in RMSC perceived that communities plant trees because forests/trees keep water clean and make air cooler (29: +4; 5: +2; 14: +3). This can also be credited to the introduction of DNROs, local government officials that advocate for planting trees in all districts of MEWT. Undoubtedly, there is a reasonable positive correlation among all the four factors in both sub-catchments. The highest correction was between factor 1 and factor 4 and between factor 1 and factor 2 for RMSC and SRSC, respectively (Tables 1, 2). Watts and Stenner (2005) noted "*...if two factor arrays are significantly correlated this may mean they are too alike to interpret as separate factors and that they could, in fact, simply be alternative manifestations of a single viewpoint...*". Therefore, the discussion is largely focused on Factors 1 and 2 for RMSC and on Factors 1 and 3 for SRSC. The study findings are similar to those of Bennett and Barton (2018) who noted that forests are believed to generate rain locally and regionally. There is a distinct link between forest/tree cover and rainfall (Ellison et al., 2012). Similarly, the study findings are in agreement with those of Danquah et al. (2023) and Pincetl (2010) that emphasize that involving communities in tree planting increase tree cover especially in urban areas. However, Martin et al. (2021) highlight that people more often plant trees for utility than for biodiversity. This is also the case for some areas in MEWT, due to individual ownership land tenure, most people planting on private lands are not accountable to any stakeholders and thus can prematurely harvest trees any time. However, decrease in (rate of) deforestation can be attributed to increase in land tenure security and accelerating the titling process (Walker et al., 2023). As emphasized by Martin et al. (2021) and Ota et al. (2020), participants across all four factors in both RMSC and SRSC agree that government and other stakeholders support to watershed restoration activities is inadequate. In addition, most participants noted that most farmers primarily grow agroforestry crops (bananas and coffee) and thus subsequent increase in agroforestry tree cover due to a positive perception of trees' effect on local climate. This is quite well reported in the available literature (Brown et al., 2018; San et al., 2023; Tschora and Cherubini, 2020; Ullah et al., 2023).

Our study showed that the choices and decisions regarding trees grown depend on utility of tree species, availability, and prices of tree seedlings at local tree nurseries. As noted by Kimbowa et al. (2024), Nakileza et al. (2017), and Vedeld et al. (2016), forest-water challenges in MEWT can be partly explained by the population pressures, high poverty, history, etc. Forest protection in one area may result in loss of biodiversity of other ecosystems. Evidently, conservation and protection of the forest in the upper zone of MEWT, to some extent, led to deforestation of most areas in the lower zone of the region. Arguably, poor communities face challenges in implementing conservation activities compared to

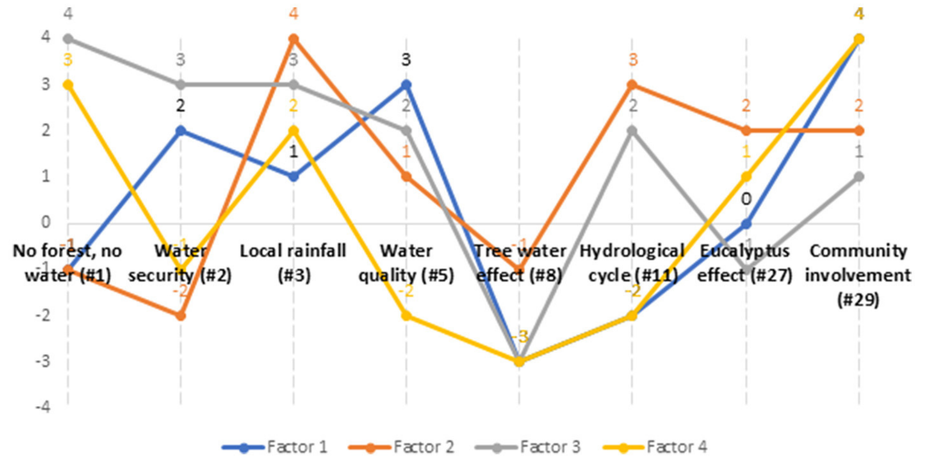


FIGURE 2
Conceptual space diagram for the Q-sort study in River Manafwa Sub-catchment.

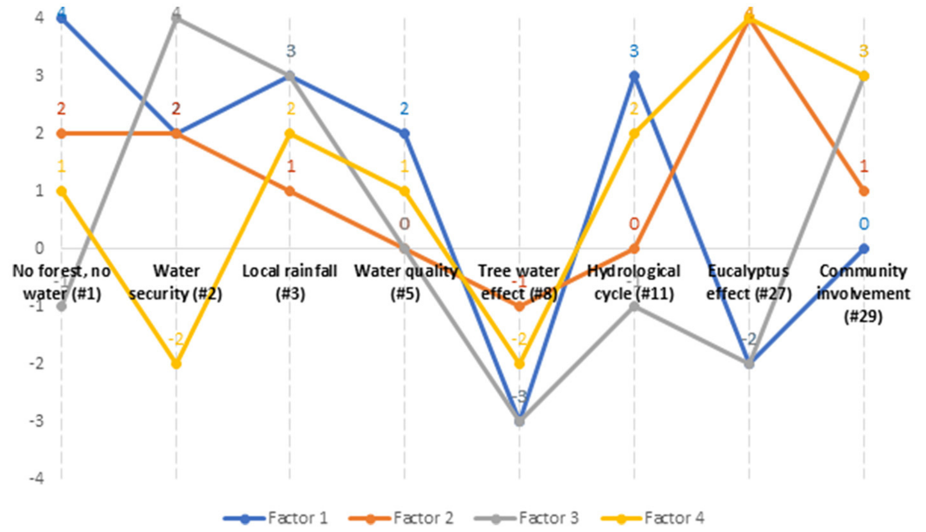


FIGURE 3
Conceptual space diagram for the Q-sort study in Sipi River Sub-catchment.

their counterparts (Gatzweiler and Baumüller, 2014). Stakeholder engagement including farmers in forest-water-related watershed restoration decisions at catchment level is well recognized in literature (Amblard et al., 2023; Hassanzadeh et al., 2019; Mekuria et al., 2021; Smyth et al., 2021; Urcuqui-Bustamante et al., 2021).

For each of the two sub-catchments, the four categories of stakeholders/participants associated with the viewpoints are summarized as presented in Figures 2, 3 and Tables 2, 4. A conceptual space diagram was graphed in view of the distinctive statements shared by all four factors of the Q sort study across the two sub-catchments (Figures 2, 3). A selection of pictures of some study participants is presented in Figure 4.

Despite the multiplicity in viewpoints, F2 participants in RMSC neither consider forests and trees securing all sources of water (2: −2) nor forests keeping water in streams throughout the year (13: −3). The diversity of trees and tree cover area do not result in more soil and ground water in an area (15: −2; 30: −2).

From AQSI findings, all the F2 farmers were from upper RMSC. Since farmers lack knowledge and access to various tree seedlings and are rarely involved in tree species selection, in most cases they are forced to plan the available species (Do and Mulia, 2018; San et al., 2023; Ullah et al., 2023). Clearly from the perspectives of F3 participants in SRSC, government funding is inadequate, which in turn affects other items, such as management and monitoring of tree growing. This has led to limitation in adoption of agroforestry and/or tree growing in Uganda and/or Africa despite heavy investments in restoration initiatives and program (Martin et al., 2021; Ntakimanye et al., 2018; Ullah et al., 2023). Surprisingly, F2 participants in RMSC acknowledged that individual farmers and communities are involved in conservation and watershed restoration activities such as planting bamboo trees by local governments (29: +2). However, the fear by most farmers that the government is interested in taking their land shoots down these efforts.

10.3389/frwa.2025.1576366

FIGURE 4
A selection of pictures of some participants that participated in Q-sorting and post-sorting face to face interview from the River Manafwa Sub-catchment and the Sipi River Sub-catchment of the Mt. Elgon water tower.

Arguably, F4 in RMSC represented the viewpoints of the female participants, since approximately 3/5 of the total participants from RMSC were females. When interpreting factor results, it was noted that viewpoints by participants are related to their standards of living (Alt and Phillips, 2021). For instance, despite women having less right to own land, most of the farm work is done by women. However, in most cases, men still decide on what is grown on the land. Notably, most restoration and conservation activities are done by women, and thus, they perceive involving people in tree planting increases tree cover (item 29). This subsequently results in bringing back water in deforested areas and reversing water problems (item 4 and 6).

For SRSC, 66% of the F1 participating farmers were from lower zone of SRSC while 80% of F3 participating farmers were from the upper SRSC. Among all the four viewpoints under comparison, F3 participants in SRSC strongly agree that forests and trees secure all sources of water. This finding is similar to that of Creed et al. (2019) who also assessed the role of forests and trees on water availability problems. F1 and F4 participants in RMSC appear to be the only ones from the study sample that strongly agree that fast-growing trees such as eucalyptus consume a lot of water. This finding supports the argument of Albaugh et al. (2013), Mugunga et al. (2015), and White et al. (2021). However, water consumption varies with the variety of the eucalyptus (Albaugh et al., 2013) and the tree's consumption can be adjusted based on water availability (Christina et al., 2017).

The AQSI data analysis is dependable. For instance, more than 70% of participants associated with F1 in RMSC were key experts. Only F3 and F4 participants in RMSC were associated with more proportion of female participants than whole sample. In SRSC, only F1 had a higher percentage of female participants than whole sample. There is inadequate information on the performance assessment of agroforestry/tree growing projects in Uganda and the successes and challenges associated with management of trees on private fields/farms. This requires broader-based and integrated planning approaches by various stakeholders. The results are representative of the real status quo in the water tower of a mountainous region. For instance, a lot of eucalyptus plantations, cultivation along the river banks, and degraded areas was evidently seen during the field walks of the sampled sub-counties.

Nevertheless, upon participatory field walking and reviewing existing local government departmental reports and/or documents, it was discovered that some of the respondents' information was biased compared with specific ground observations. For instance, despite majority of the respondents perceiving small land holdings to limit tree growing, the estimated respondent household acreage of 4.4 and 3.0 in RMSC and SRSC, respectively, is relatively greater than the national average acreage of 1.3 reported by Uganda Bureau of Statistics (2022). In addition, most local government reports and documents at local governments were prepared in English, yet according to the AQSI results, the sampled farmers' literacy rate was 68% and 80% in RMSC and SRSC, respectively. This partly explains some farmers' negative perceptions about citing government's (and other stakeholders) deliberate intentions to avoid effective dissemination of the agroforestry and tree growing information. Besides, several terms were identified by participants as unclear or difficult to interpret, leading to the omission of certain items during analysis (see Appendix B in the Supplementary material).

Item 1, ranked at +4, suggests that forests and trees play a very important role in rainfall received in SRSC and that as a result Factor 1 seems to understand their feelings. This is clearly reflected in similarly positive (+3) ranking of item 3 and item 11. From the results of "after-sort" interviews, F2 participants in SRSC generally perceive eucalyptus to be the most commonly grown tree. This is confirmed by the negative ranking of items 15 and 26. None of the F2 participants in SRSC is a key expert. There is a lack of access to agroforestry inputs such as seedlings and fertilizers to support farmer investment in agroforestry activities (Muthee et al., 2022). Where support is available, farmers are required to provide well-documented track record of agroforestry performance by international NGOs, which they usually lack.

There is lack of ordinances and by-laws and sometimes poor enforcement/implementation of conservation acts/policies by public and private agencies. For instance, there were perceptions from upper RMSC participants that forest rangers allow people to cut trees from the forest. Most of the times, there is reported political interference during enforcement of such by-laws and acts. In addition, there are conflicting laws and policies [for instance, whereas the national agriculture policy promotes increasing land under agricultural production, the national environment act 2019 emphasizes protection and sustainable use of fragile areas; (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), 2017; Parliament of Uganda, 2019)]. In some areas of MEWT, the increase in human population demands for more land for agriculture (Opedes et al., 2022) even in fragile areas and thus there is need for well-coordinated inter-sectoral policies.

4.2 Policy implications and recommendations

The study results can be key in implementing previously developed strategies under the Catchment Management Plans (CMPs). The study findings can have implications for the existing management of forest/trees and water resources in Uganda, with particular consideration given to promoting the sustainable agroforested landscape management and thus people's livelihoods. First, agroforestry promotion and or tree adoption campaigns should involve all stakeholders at all levels. In addition, focus should be on (re-)introducing affordable indigenous and agroforestry trees suitable for specific local conditions. Sensitization and participatory involvement of communities in tree planting, long-term maintenance, and thus coordination and management can follow bottom-up approaches. There is need for planning needs assessment, training progress, follow-up, mentor agroforestry/tree growing farmers, monitor, and measure survival rates of planted trees. Second, the government structures and institutional arrangements should be designed and intended to respond to availability of high-quality tree seedlings, regulating the tree produce quality and market to enable (agroforestry) tree communities to profitably benefit from their sweat and hence improve their livelihoods. Through rural economic development centered policies, private tree farmers, for example, can benefit from appropriate value addition chains, harvesting time control/regulation, thus encouraging timely availability of tree products to prevailing local and regional markets. Consequently, this can promote access to improved agroforestry/tree management guidance, inputs, and funding. There is need for sustainable funding and motivation of catchment management committees and water user committees for proper management of GFS especially in upper zones of MEWT. Third, access to finances and trade policies can be designed to emphasize lending for agriculture to promote rural economic development. As a result, communities' livelihoods can be prioritized guided by policies protecting the nation's agricultural sector, that is, subsidized loans and limitations on importation and exportation of forest/tree produce and products. Fourth, agroforestry/tree growing programs should be designed to meet environmental objectives and equally important to support local communities' economic development and thus livelihoods. There should be proper and reliable communication among all stakeholders (including public and private research, and financial and support organizations/institutions; Martin et al., 2021).

The study can contribute to advancing theoretical knowledge on forest–water–people nexus in water towers of developing countries such as the MEWT. The knowledge can empower local communities and other forest-water stakeholders to make timely and conversant decisions to mitigate and adapt to hydrological extremes as well as planning and use of available forest-water resources. This can promote and fasten the implementation of watershed restoration activities listed in catchment management plans in MEWT. Following the participatory approach utilized in study plan, the results may contribute to an increased awareness of the necessity of stakeholders' (key experts, farmers, etc.) participation in sustainable forest-water management in (agro) landscapes, watershed restoration, and environmental conservation. In addition, there is possibility for an increased understanding of effective engagement of multilevel stakeholders in sustainable agroforested landscape management options and scenario planning, negotiation, and implementation (Leys and Vanclay, 2011).

For forest/trees and water resource management in Uganda, following prevailing policies, the government's Ministries Departments and Agencies (MDAs) are institutionally entrusted with and responsible for training, sensitizing at times provide planting materials/tree seedling, among other roles. However, the management, information, and implementation gaps between the various MDAs are evidently significant, especially in the case of disease outbreak and tree infestation, etc. In addition, there is limited land to extend tree growing by most (agroforestry) tree growing communities; sensitization and training on SALM practices restrict agroforestry/tree planting promotion and water resource promotion. In a nut shell, there has been limited research and development corresponding to suitable and best environmental conservation and watershed restoration practices (Mutekanga, 2012; Rwakakamba, 2009). The study results may contribute to sustained knowledge and learning on SALM.

There is need for: 1 more and further "solution-oriented" research in addition to bottom-up and multi-level sectoral approaches for agroforestry and water projects; 2 increased funding for monitoring, sensitization, and establishing agroforestry demos; 3 incorporate tree growing and soil and water conservation practices as part of Environmental and Social Impact Assessment (ESIAs); 4 sustainable use of wetlands, rainfall harvesting technologies and riverbanks protection and restoration, and implementing SLM practices; 5 collaboration of government MDAs at all levels to jointly develop and enforce by-laws in addition to revising existing policies, provide and distribute enough tree seedlings especially of indigenous tree species and other inputs; 6 involving youth in tree planting projects; and 7 enabling environment to implement and enforce government policies and ordinances by agencies such as NFA, UWA, and NEMA. By implementing policies, for instance, farmers can be forced to cultivate at least 30 m away from the river banks and to avoid uproot of bamboo planted along the riverbanks.

In the upper RMSC, the high population pressure and limited land has led to (over) cultivation up-to cliff and sometimes beyond the river banks. In case of limited land, in addition to agroforestry, communities can plant trees along the boundaries, paths, and road reserves to capture carbon from vehicles while contributing to rain formation. In addition, message on tree planting should be well packaged to suit deforested areas by for instance promoting woodlots for only downstream communities while encouraging agroforestry and fodder trees in the upstream communities.

In Mbale, apart from protected forest reserves, there are no natural forests; thus, Government could prioritize compensation of all communities owning land in Mt. Elgon National Park and conservation areas such as Namatala forest reserve. To boost the environmental sector, Government could consider building capacity by establishing assistant environmental/forestry and conservation officers at Sub-County level.

There is a need to protect and restore riverbanks and natural sources of water by planting (bamboo) trees. However, in some areas of lower RMSC, river bank restoration using bamboos is considered less beneficial compared to commercial trees.

For future improvements in the SALM, it is recommended that target communities should be strategically involved as key and/or equal stakeholders at all stages of agroforestry promotion, adoption from planning, and implementation to management. Regarding Uganda's forestry/trees and water policies and frameworks, there is a need to develop and implement the integrated management of forest/trees and water resources approaches in agroforested landscape planning, development, and management at all levels. In addition, there is a need for support programs to promote forest/trees-water-related studies and data dissemination to improve the availability of information for SALM.

The participatory development of the Q-set ensures that perspectives of local stakeholders are authentically represented, and thus, local knowledge is meaningfully incorporated, enhancing the relevance and legitimacy of the findings. In addition, the comparative analysis across two sub-catchments enhances the robustness of the findings, allowing for insights into both shared and context-specific perceptions.

While the focus on only two sub-catchments limits the generalizability of the findings, the study offers key insights into the institutional constraints that hinder the adoption of sustainable land-use practices, suggesting that limited uptake is often less about farmer reluctance and more about gaps in institutional capacity and coordination. The cross-sectional nature of the research also highlights the need for longitudinal studies to capture temporal shifts in perception.

Importantly, the study demonstrates how Q-methodology can bridge local and scientific knowledge systems, providing a participatory framework for co-developing land-use planning strategies that are socially acceptable and ecologically viable. These findings are particularly relevant to mountainous water tower regions, where competing land uses and climate variability intensify the urgency for effective, integrated, and inclusive socially grounded forest-water strategies.

5 Conclusion

This study focused on exploring the driving factors of stakeholders' perceptions of the FWP-nexus using Uganda's MEWT as a case study. By applying Q-methodology in the two sub-catchments of MEWT, four viewpoints were identified and explored for each sub-catchment based on stakeholders' perceptions of the forest–water–people nexus. The study showed that perceptions of the forest–water–people nexus varied slightly among the two sub-catchments and among the upper and lower zones of the sub-catchments. Considering correlation between factor scores, only Factor 2 and Factor 3 could be taken as an independent viewpoints for RMSC and the remaining two factors to alternatively manifest a single viewpoint. Similarly, for SRSC, only Factor 2 and Factor 4 could be taken as an independent viewpoint.

The study is unique in such a way that drivers of stakeholder's perceptions on FWP-nexus are explored based on existing scientific literature. The study approach can possibly have drawbacks such as wrong perceptions leading misinterpretations in addition to strained interactions, susceptibility to bias and distortion.

The study findings imply that demographic aspects influence individual perception on FWP-nexus and attitude toward forest/trees and water resource management. In addition, the study emphasizes collaborative enforcement of forest-water conservation policies, laws, and by-laws by stakeholders. Importantly, collective awareness and community participation in tree growing is pivotal in fostering SALM. Willingness and commitment by conservation and policies implementing agencies to support law enforcement, implementation of interventions, and livelihood improvement schemes further promote the possibility for joint action to address forest/trees-water challenges across the entire Mt. Elgon region.

Overall, developing countries should focus on promoting SALM capacity, restructuring extension services to (agroforestry/trees) farmers, responding to economic aspects of agroforestry promotion and management, streamlining land tenure systems and ensuring reforms, and developing national agroforestry adoption guidelines and tools. In addition, there is a need to encourage public–private partnerships enabling considerable investment in SALM. There is a need for significant funding to university and other (agro)forestry research and training institutions to enable reliable training of (agro)forestry professionals at all levels to facilitate SALM.

From this study results, it is clear that while implementing agroforestry and tree growing programs, all stakeholders' perceptions (including farmers) should be considered especially during tree species selection. Adequate funding and incentives are essential to promote agroforestry adoption and tree planting, supported by agricultural extension services aimed at encouraging farmer participation and improving livelihoods. An enabling environment and coordination among MDAs besides proper enforcement of conservation policies to increase and sustain agroforestry and tree growing.

The study contributes to existing knowledge by providing supporting evidence to the ideologies of adaptive and multilevel governance and thus stakeholder's engagement in decision-making in the context of FWP-nexus. By understanding local knowledge on agroforestry and hydrology using participatory research frameworks such as the Q-methodology, policymakers and other stakeholders at various levels can develop and implement targeted interventions and collective action strategies to promote SALM practices in Mt. Elgon region. Based on the study findings, further studies can be conducted to: explore human population and tree cover change effect on water availability, develop a holistic model to simulating the FWP-Nexus dynamics, and explore the effectiveness of existing forest and water-related policies in Mt. Elgon region.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2025.1576366/full#supplementary-material

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