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Authors: Badu, Manoj, Nuberg, Ian, Cedamon, Edwin, and Sharma, Subodh

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Management of the Forested Catchments of Nepal's Mid-hills Amid Mismatched Perceptions of Forest–Water Relationships: Challenges and Opportunities

Manoj Badu[1]*, Ian Nuberg[1], Edwin Cedamon[1], and Subodh Sharma[2]
* *Corresponding author: manojbadu@hotmail.com*

[1] *School of Agriculture Food and Wine, University of Adelaide, South Australia, 5005, Australia*
[2] *Aquatic Ecology Centre, School of Science, Kathmandu University, P.O. Box 6250, Dhulikhel, Nepal*

*The expansion of community forestry practices since the late 1970s and, recently, outmigration have led forest cover to increase in Nepal's mid-hills catchments (>52% of the 4.3 million ha). The catchments traditionally provide food and income for local communities, and they are increasingly important for ecological functions, particularly downstream water use. While the hydrological effects of increasing forest cover are generally unclear in the mid-hills region, mismatched perceptions of forest–water relationships between sections of Nepalese society and scientists challenge the management of the catchments in meeting traditional community needs and growing water demand sustainably. This paper shows the prevalence of the culturally formed notion of "more forest–more water" within broader Nepalese society and the conservation-centric attitude of forest policymakers, who focus on reforestation and afforestation. These perceptions contradict general scientific evidence that shows forest development reduces catchment water yield. Conversely, the results of semistructured interviews (*n *=150) conducted among members of community forest user groups (CFUGs) in the Roshi Khola catchment of the mid-hills district Kavre showed that 44% of respondents consider that forests contribute to increased water quantity, and 37% think forests decrease it. Furthermore, the respondents that viewed forests as reducing water quantity disliked pine forests because these allegedly caused the reduction. Interestingly, there was a positive correlation between the duration of membership in the CFUG and the perception that forests increase water. Thus, while there is a high research need to understand the forest–water relationships in the mid-hills, extensive communication of research results and deliberation about them are crucial to developing widely acceptable plans for managing the catchments. This is particularly important in the context of expanding community forestry practices and the current debate on scientific forestry presented by Nepal's key forestry documents, including the* Forestry Sector Strategy 2016–2025 *and* Forest Policy 2019.

Keywords: *forest; water; community perceptions; Nepal mid-hills; community forestry*.

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Introduction

Current scientific literature largely acknowledges that increased forest cover in catchments reduces water availability due to, for instance, increased evapotranspiration (Bosch and Hewlett 1982; Zhang et al 2001), reduced stream flow, or runoff generation (Johnson 1998; Farley et al 2005). These relationships between forest area and catchment water yield have been reported for diverse vegetation and climatic conditions in Europe (Robinson et al 2003), Australia (Cornish and Vertessy 2001; van Dijk and Keenan 2007), and the tropics (Bruijnzeel 2004; Scott et al 2005), among others; many authors have found similar results from global catchment studies (Sahin and Hall 1996; Andréassian 2004; Brown et al 2005; Zhang et al 2017). Yet, beliefs that forests improve water availability persist and affect forest policymaking processes (Wilk 2000; Calder 2002, 2006, 2007; Gilmour 2014).

The belief that forests improve hydrological outcomes is commonly reiterated by the media, forestry practitioners, and development agencies globally. This association between forests and hydrological benefits has often led to increased focus on afforesting or reforesting degraded landscapes (Calder 2005). Thus, increased forest cover is strongly linked to realizing the United Nations' Sustainable Development Goals (Bastos Lima et al 2015; Gratzer and Keeton 2017; Gregersen et al 2017) and climate change mitigation (Ellison et al 2017), and forested landscapes are increasingly recognized for their ecological value, as well as their spiritual and cultural values. Accordingly, the forest area managed explicitly for soil and water protection has risen to over a billion hectares (>25% of the global forest area), while growing numbers of countries (42 in 1990 to 51 in 2015) have recognized the cultural values of forests (Miura et al 2015). This is matched by declining global deforestation rates overall, although high rates persist in many low-income countries (Keenan et al 2015; Sloan and Sayer 2015). Recently, however, some countries in this category, such as Nepal, have reported increases in forest area.

Based on its 2015 Forest Resource Assessment (DFRS 2015), the total forest area in Nepal reached approximately 6 million ha, while it was 5.6 million ha in 1978/1979 and 4.3 million ha in 1994. By contrast, the forest areas allocated for soil and water protection grew by nearly 14% to 650,000 ha from 1990 to 2015 (FAO 2015). Moreover, the forested area composed of naturally grown or planted varieties of broadleaf and pine species constituted over 52% of the 4.3 million ha of the country's mid-hills catchments, mostly as a result of prevalent community forestry practices since the late 1970s and, increasingly, outmigration (Tiwari and Bhattarai 2011; Jaquet et al 2015; Pandey et al 2016; Kc et al 2017; Poudel et al 2017). This increase is notable because the region's allegedly high deforestation rates during the mid-1970s caused severe hydrological effects of transnational significance (Eckholm 1976), prompting large-scale revegetation programs (Gilmour 2003) while concurrently raising concerns about the programs' inability to incorporate local community needs and principles of scientific forestry (Bajracharya 1983).

Recently, forestry documents, including the *Forest Policy 2075* (GoN 2019a) and *Forestry Sector Strategy 2016–2025* (GoN 2016), have underlined the importance of scientific forestry, mainly due to the realization that forests contribute suboptimally to the national economy. At the same time, the *Scientific Forest Management Guidelines 2014* estimated an annual gain of NPR 15 billion (about US$126 million) through scientific management of nearly 247,000 ha of southern *Terai* forests (MFSC 2014b). More recently, the first national Silviculture Workshop (19–21 February 2017) emphasized the incorporation of silvicultural principles for improved forest production and income generation (DoF 2017). Despite the progress, consideration of the hydrological effects of forest growth or management is mostly missing at the practical or policy level in Nepal, and it is poorly understood overall for increases in forest cover through afforestation or reforestation (Venkatesh et al 2014). This is particularly valid for the broader mid-hills region, where nearly 0.4 million ha plantations of mainly pine species (*Pinus roxburghii* and *Pinus patula*) have been generated since the 1980s (Dangal and Das 2018). These plantations were implemented jointly by local communities, the Nepal government, and international development agencies, particularly the Nepal–Australia Forestry Project (Gilmour 2003; Nuberg et al 2019). They are now predominantly managed by local communities, who are organized into community forest user groups (CFUGs), as part of the community forestry program that began in the late 1970s (Gilmour and Fisher 1991; Thwaites et al 2018).

This article aims to support sustainable management of the forested catchments of Nepal's mid-hills, which encompass a variety of broadleaf and pine species, provide livelihoods to over 11 million local inhabitants (Pathak and Lamichhane 2014), and supply water for drinking, irrigation, and hydropower generation to a much larger downstream population (GoN 2011). Importantly, the mid-hills constitute a hydrologically important mountainous region characterized by a complex society–water interface (Nüsser 2017). They experience a highly variable seasonal discharge owing to the prevailing climate, where nearly 85% of the annual rainfall is concentrated during June–September (Merz et al 2003). This regularly causes socioeconomic hardships to local and downstream communities (Adhikari 2013; CRED 2018). The catchments' water sources face mounting pressure in supplying the growing urban population (Gyawali and Dixit 2010; Udmale et al 2016) amid shifting hydrological regimes due to climate change (Sharma and Shakya 2006; Shrestha et al 2016). At the same time, there is growing recognition of the catchments' ecological services, including providing water (Birch et al 2014; Bhatta et al 2015; Rai et al 2015; Van Oort et al 2015; Bhandari et al 2016; Paudyal et al 2017), while concerns about the forests' role in the declining water sources grow, particularly in areas of the mid-hills that were reforested to pine (Sharma et al 2016; Shrestha 2016; CBS 2017; Poudel and Duex 2017).

Balancing forest–water relationships for effective catchment planning

There is a clear need for improved scientific understanding of forest–water relationships that takes into account the site- or species-specific hydrological effects of forest development in Nepal's mid-hills catchments. This understanding is crucial for developing evidence-based management plans for the forested catchments, as found in certain countries such as South Africa (Edwards and Roberts 2006), the United States (Jones et al 2009; Gartner et al 2013), and Australia (Vertessy 2000; Stirzaker et al 2002; Keenan et al 2003). Importantly, effective implementation of such plans requires extensive deliberation and communication among various sectors of the community (Creed and van Noordwijk 2018). It provides opportunities to develop a consistent knowledge base and minimize risks associated with the biophysical and socioeconomic complexities of resource use that are characteristic of the mid-hills (Ives 2004), as well as the broader mountainous region (Kotru et al 2015; Breu et al 2017).

Conversely, however, this article shows the prevalence of divergent views about forest–water relationships among sections of the Nepalese community that pose a restrictive policy environment on developing and implementing such plans. This is mostly due to the culturally formed general notion of "more forest–more water" held by the broader Nepalese society, and the conservation-centric attitude of the forest policymakers, who largely focus on reforestation or afforestation activities (Ojha 2017). On the other hand, the perceptions of the CFUGs, as the direct users and managers of the majority of the mid-hills forests (Sharma et al 2017; Thwaites et al 2018), presented here are consistent, to a greater extent, with the limited scientific evidence on forest–water relationships in the region.

The broad consistency between available scientific evidence and CFUG perceptions, representing the deeper experiential understanding of forest management, presents opportunities for developing evidence-based catchment management plans that are locally applicable, particularly for integration into the widespread CFUG programs in the mid-hills (DFSC 2019). This is prudent because the traditional policymaking practices in Nepal's forestry sector inadequately integrate the expertise or interests of the local communities despite the well-founded knowledge systems of forest management (Nightingale 2005). This attitude of the forest policymakers further impedes policy innovation and effective implementation in Nepal (Ahlborg and Nightingale 2012; Ojha 2013; Sunam et al 2013; Ojha et al 2016). Incorporation of divergent views on forest–water

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TABLE 1 Broader societal perceptions of forest–water relationships from selected Nepal media.

Excerpts of the reported propositions	Source
Water sources restored because of the community forests	Shahi (2011)
Water sources restored because of the community forests	Silwal (2013)
Ban on tree cutting within 100 m of water sources for improved water availability	Ghimire (2014)
Water sources drying up fast in eastern Nepal due to deforestation, locals saving forests to avert the situation	Khadka et al (2016)
In addition to the other traditional community benefits, recent increase in the forest cover contributes to water sources availability	Basnet (2016)
Deforestation contributing to rampant water scarcity, need to plant broadleaf tree species that induce rain and retain moisture, not pines	Anonymous (2018)
Forest loss around the lakes contributed to their drying up	Kantipur (2019)

relationships increases the acceptability of the ensuing catchment management plans (Calder 1996; Pant et al 2005; Calder and Aylward 2006) and improves contextual appreciation of resource use. This is because both the forest and water resources are used, managed, and symbolized uniquely across societies (Baviskar 2007).

Sociocultural interpretations of forest–water relationships in Nepal

Religious faiths strongly inspire forest management globally (Hamilton 2002; Bhagwat and Rutte 2006; Nelson 2013), including in Nepal (Ingles 1994). Nepalese society maintains a firm cultural base constructed predominantly on Hindu–Buddhist philosophies (81% Hindus and 9% Buddhists) (Dahal 2014) that explicitly recognize the role of forests (Clark 2011; Baltutis 2016) and their ability to influence other ecosystem components, particularly water (Bhagwat et al 2014; Allison 2015). Accordingly, numerous tree species evoke a tradition of worship (Majupuria and Majupuria 1978; Niroula and Singh 2015), and, thus, Nepal's overarching forestry document, the *Forest Act 2076* (NLC 2019), incorporates provisions for managing parts of the national forest as religious forest to signify the sacred values assigned by the local communities; this area constituted over 2000 ha in 2014 (MFSC 2014a). This is perhaps why Nepal is known to have embraced an "enlightened" approach to conservation (Heinen and Yonzon 1994; Ormerod and Juttner 1999), which constitutes an inherent aspect of Hinduism (Adhikari 2016).

The interpretations of forest–water relationships are embedded in various forms of sociocultural faiths and rituals (Calder 1999; Sitthisuntikul and Horwitz 2015). In Nepal, planting or protecting trees, particularly around religious sites and water sources, is customary (Basnet 1992). For example, Jana and Paudel (2010) identified a number of religious and cultural sites across the country that integrate forests and water bodies, particularly ponds and lakes that are conserved and protected by local community groups. While these practices are manifestations of the dominant religious faiths in Nepal, the local belief systems intermixed with these consider water availability or scarcity as an "act of god," as are other natural events such as floods, landslides (Sherry and Curtis 2017), and the onset of rain (Khatry 1996).

Nevertheless, while tree planting is practiced as a strategy to tackle water scarcity at the community level (Yang et al 2014), the perceptions that forests improve hydrological outcomes, such as water availability, are prevalent in the broader Nepalese society, including the mid-hills, as seen in Table 1. The selected excerpts from media coverage in Table 1 highlight the important role of the media in influencing public debate on broader environmental issues in Nepal (Khatri et al 2016). These suggest the prevalence of the "more forest–more water" beliefs in Nepalese society that are also common globally (Calder 2005; Gilmour 2014).

Traditional forest policies focus largely on reforestation/afforestation activities

The hydrologic importance of trees and forests, including for improved water availability, has been historically documented in Nepal. For example, in 2000 BC, cultural customs about communal use of natural resources became authoritative decrees to protect forest resources, including specific trees, such as *Shorea robusta*, a broadleaf deciduous tree endemic to South and Southeast Asia (Orwa et al 2009), to sustain groundwater (Oli 1996). Likewise, Rule Fourteen of King Ram Shah during the early AD 1600s ordered the protection of trees around springs for continuous water supply and applied a NPR 5 fine (similar to fines applied for social offenses, eg illicitly accusing someone of witchcraft) to those cutting down trees near water sources (NLC nd).

Until the mid-20th century, successive regimes systematically exploited the forests to consolidate political and financial power (Bajracharya 1983; Gautam et al 2004b; Gautam 2006; Springate-Baginski and Blaikie 2007), giving rise to protection-centric legislation, which was further supported by the growth of nature-centered tourism and concerns for nature conservation globally (Heinen and Shrestha 2006). However, emphasis on increased forest cover to improve hydrological outcomes grew after the widely publicized but contested (see Ives [2004] for details) environmental crisis (Eckholm 1976), as many national and international agencies linked this deforestation to reduced water availability. For example, a World Bank Report (1979) predicted that all accessible hill forests would disappear by 1990 and linked forest loss to the drying up of the springs, giving advice to reforest at annual rates of 50,000 and 10,000 ha until 1990 and 2000, respectively (Sattaur 1987).

Subsequent emphasis on afforestation and reforestation activities is evident in the government's development plans, mainly the 5 year periodic plans of the National Planning Commission (NPC 2016a). For example, the sixth such plan (1980–1985) aimed to afforest and improve forest in over 125,000 ha, while the seventh plan (1985–1990) aimed for 175,000 ha, stating "no single forest patch to remain in the following two decades" if the prevailing forest loss continued (NPC 2016b: 54). The seventh plan also reported increased difficulty in obtaining water in the mid-hills due to forest loss, and the eighth plan reiterated drying up of springs and submitted proposals to plant trees along the riverbanks and catchment zones of the larger irrigation and hydropower projects for increased water accretion and hydrological stability (NPC 2016a). Aptly, therefore, increased water availability due to forest development is commonly reported in many parts of the mid-hills that generally host broadleaf species (eg Gurung et al 2013; Lamsal 2014; Adhikari et al 2015; Thapa et al 2018).

As seen globally (Robbins 2000; Adams and Hutton 2007; Neumann 2014), forest protection or expansion is often a political rather than a scientific issue. This is also true in Nepal, as suggested by the ways forestry policy and decisions are made (Amatya et al 2017). For instance, in 1999, the Ministry of Forests and Soil Conservation banned all types of green felling. Then, in 2002, they developed a biodiversity strategy that pushed a limited and nonscientific approach to forest management that did not consider forest-dependent communities (Ojha et al 2007). In 2003, the ministry stipulated planting 25 saplings for each tree lost due to a development activity (Uprety 2003, 2013). Then, in 2014, the government declared the 10 year period from 2014–2024 to be a "forest decade" with the tag "one household one tree, one village one forest, one city many parks" (MFSC 2015). These directives, while seeming to reinforce proconservation policies, systematically overlook the principles of scientific forestry, particularly silviculture, for improved socioeconomic returns, and thus they impede sustainable forest management (Ojha 2017). In a thorough account of Nepal's forestry sector, Hobley and Malla (1996) called this approach "populist," prioritizing forest protection over local community needs with concurrent emphasis on reforestation or afforestation.

The reasons for this attitude of the forest policymakers in Nepal include an inadequate appreciation of forest ecosystems (Gautam 2006), historical predominance of state interests in forest management (Ojha et al 2010), and the influence of Western environmental protectionist philosophies in the forestry sector (Nightingale 2003) that are conveyed financially and technically by the international development community (Malla 2001). In recent decades, much protection-centric forestry has centered around environmental schemes such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Ojha et al 2013), which have been extended to catchment management, focusing largely on afforestation and reforestation and implemented extensively through foreign aid. For example, in 2015, there were 12 major forestry projects of this nature countrywide, while nearly a quarter (23.5%) of the annual forestry budget (year 2015/2016) was composed of foreign aid (MFSC 2015).

Survey of CFUG perceptions of forest–water relationships

Study area

Roshi Khola catchment (85°23′–85°49′E; 27°23′–27°41′N) has an approximate area of 564 km^2 in the mid-hills district of Kavre, Nepal (Figure 1). Typical of the mid-hills, agriculture and forest are the major land-use types in the catchment, with expanding community forestry practices since the late 1970s that affect the land-use patterns of the catchment considerably. For instance, forest fragmentation has been reduced by pine plantations and regeneration (Gautam et al 2003), with an overall increase in forest during 1976–2000 (Gautam et al 2004a), while high forest areas increased at the cost of shrub and cultivated land during 1978–1992 (Gautam et al 2002).

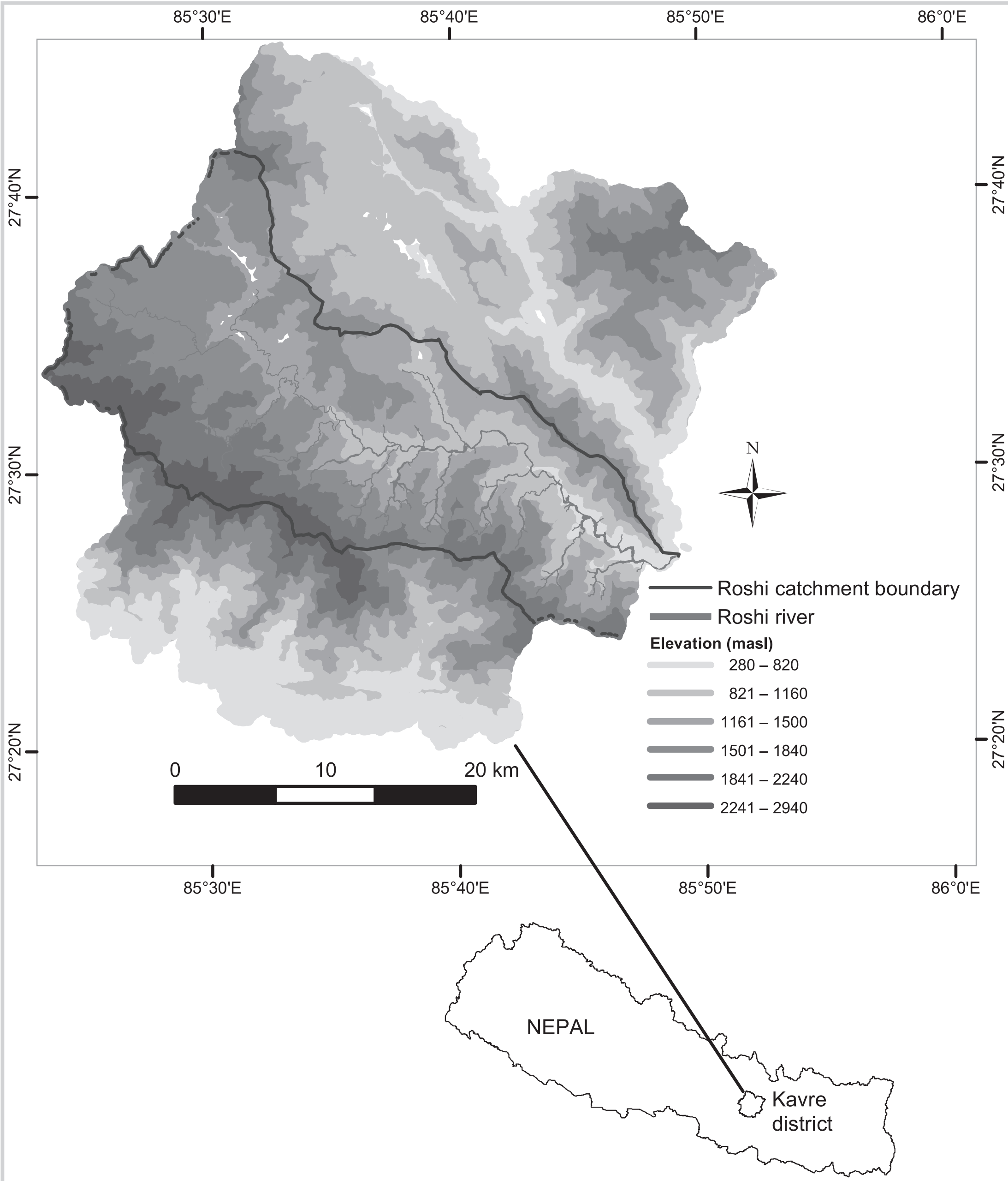
The climate varies from subtropical below 1000 m above sea level (masl) to cool-temperate above 2000 masl. Rainfall is between 1300–2000 mm annually, with nearly 80% occurring during June–September. These variations in turn influence the vegetation distribution, such that *Shorea robusta* grow below 1000 masl, *Quercus* occurs in the cooler temperate areas above 1700 masl, and natural and planted species of *Castanopsis*, *Schima wallichii*, and *P. roxburghii* dominate elevations in between (DFO Kavre 2014).

Large sections of the catchment drain either directly into the Roshi River or into its tributaries, including streams and ponds. Roshi discharge is used for drinking water, irrigation, and hydropower generation (DDC 2014), with increasing demand to supply the growing urban population. For example, the ongoing Kavre Valley Integrated Water Supply Project aims to supply drinking water to the urban populations of Dhulikhel, Panauti, and Banepa municipalities in Kavre district (GoN 2014), which have jointly undergone more than a 100% population rise since 2011 to 134,385 in 2017 (Subedi 2014; MFALD 2017).

Data collection to understand community perceptions and analysis

Topographic maps obtained from the Survey Department of Nepal were used to delineate catchment boundaries and determine the local administrative units, called Village Development Committees (VDCs), that constituted the catchment. (Note: These local units have been rearranged since the elections in 2017 as per the new constitution passed in September 2015.) The records available until July 2013 at the District Forest Office, Kavre, showed that a total of 288 community forests were handed over to the CFUGs in the VDCs comprising the Roshi Khola catchment in part or whole, from which 30 (ie >10% of total) were randomly chosen to represent the catchment. This region is pioneering community forestry practices representing the typical lifestyle of the mid-hills (Gautam et al 2002, 2004a; DFO Kavre 2014). Further, 5 randomly selected members of the chosen CFUGs were interviewed, bringing the total number of respondents to 150. Interviews were conducted during January–March 2015, using a semistructured questionnaire (Badola et al 2012), through household visits. This method provided the opportunity to collect perceptions that were most reflective of the respondents' usual life and experience (Vihervaara et al 2012).

FIGURE 1 The study area: Roshi Khola catchment in Kavre District, Nepal. (Map by Manoj Badu)



The interviews were conducted in the *Nepali* language by the first author of this paper and 2 local field assistants. In addition to the name, gender, and primary occupation of the respondents, the interviews gathered information that highlighted the respondent's role within the CFUG (ie whether an active CFUG member or also a member of the executive committee), and the duration of membership in the CFUG. Similarly, the respondents were asked to report their understanding of changes to the water quantity (whether more or less water) and quality (whether more or less visibly turbid or polluted water) that had occurred over a period of time. The respondents were also asked to state whether any specific attributes of the forests (eg forest type, condition, management activities, etc) also affected the forest–water relationships.

Results

Respondent attributes and perceptions of the relationship between forest and water quantity and quality: Responses were analyzed for descriptive statistics, including Pearson's χ^2 test to calculate the independence between perceptions and respondents' characteristics, including: gender, role within the CFUG, and duration of the CFUG roles (0–10, 11–20, 21–30, and >30 years). A probability value of 0.05 was used to determine significance.

Of the total respondents interviewed ($n = 150$), 76% were male, and 24% were female. The majority (71%) identified agriculture as their primary occupation, a typical lifestyle of the mid-hills. At the time of interviewing, about 83% of the respondents were active CFUG members, while the remaining 17% served on the CFUG executive committee.

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TABLE 2 Community forest users' group perceptions of the forests' effects on water quantity and quality.

Perceived effect of forests on water quantity (%), $n = 150$	Perceived effect of forests on water quality (%), $n = 150$				Total %
	Water quality diminishes	No effect	Not sure	Water quality improves	
Water quantity decreases	5	23	6	3	37
No effect	0	7	1	2	10
Not sure	0	1	7	1	9
Water quantity increases	0	20	9	15	44
Total %	5	51	23	21	100

About half (49%) of the respondents had been CFUG members for 11–20 years, and nearly a third (32%) had been CFUG members for 21–30 years.

Regarding water use, 83% of the respondents used river or stream water, 9% used wells or ponds, while 8% had multiple sources of water for agricultural and domestic use. A very large proportion (94%) said that the quantity of water had decreased, with over 82% and 18% indicating that the decrease had occurred in the past 10 and 20 or more years, respectively. Interestingly, earlier studies around this time reported increased forest cover in the study area, particularly due to the success of pine plantations and CFUG activities (Gautam et al 2002, 2004a). Additionally, only 20% of the respondents said that the water quality had diminished, with 80% and 17% of those considering this to have occurred in the past 10 and 20 or more years, respectively. A large majority (69%) said that water quality had remained unchanged.

As evident from Table 2, the results showed that 44% of the respondents perceived the forests to contribute to increased water quantity, and 37% perceived the forests to contribute to decreased quantity. Moreover, of those who thought that forests decreased water quantity, a vast proportion (96%) said that it was the effect of pine plantations in the area.

When cross-tabulations were conducted between respondents' views and their characteristics, there were no significant relationships among gender, occupation, and roles within the CFUG. However, perceptions of forest effects on water were influenced by the duration of membership in a CFUG, such that the respondents with longer CFUG experience were significantly more likely to perceive forests as contributing to increased water quantity ($\chi^2 = 17.56$, df $= 9$, $p = 0.041$).

Discussion

Changing CFUG perceptions of forest–water relationships as an opportunity for evidence-based policymaking

The public perception is that forests improve environmental quality (Maraseni and Cadman 2015), including water availability (Kaimowitz 2005; Calder et al 2007). This is also evident from the results of this survey, as the largest proportion of the respondents (44%) considered that forests increase water quantity, which is the dominant viewpoint within broader Nepalese society and forest policymakers as discussed earlier. The belief that forests improve water availability has also been documented in other parts of the mid-hills of Nepal (Gurung 1989; Adhikari et al 2015).

The tendency of experienced CFUG members to consider forests as contributing to increased water quantity is notable. While this is consistent with the views of Nepalese society, the situation is an example, as pointed out by Calder (2005: 29–62), wherein the deep-rooted collective intellect denies acceptance of an alternative notion that contradicts the historically acquired wisdom about forest–water relationships. However, it is expected that reforesting degraded landscapes revives disturbed hydrological conditions due to improved rainfall absorption by the soil (Scott et al 2005; Ilstedt et al 2007; Bonnesoeur et al 2019), which can occur following years of forest development under low disturbance (Bonell et al 2010; Ghimire, Bruijnzeel, et al 2014). Thus, it is reasonable that the afforestation and reforestation activities continue to form part of the strategies to mitigate flood and landslides, or conserve soil and water, in line with the Soil and Watershed Conservation Act 1982, despite evidence against the ability of the forests to reliably deliver those results (Calder 2005). This inherent trust of the authorities in traditional methods of catchment management, including tree planting, has also contributed to the failure of more sustainable systems catering to local needs and interests (eg the end of decades-old ropeway in the mid-hills; Gyawali and Dixit 2010). This is because the traditional methods of catchment management, entailing excessive mechanization of the catchment landscape, provided suitable conditions for the government's forestry officials to exercise power and influence.

In some cases, people with deep experiential knowledge of forest use and management in Nepal assign an "emotional affection" to the trees on account of the perceived benefits of forest development (Karn et al 2017) that apparently impedes scientific forest management. Again, while this attitude of "experienced" forest users and managers in Nepal broadly aligns with the perceptions of the CFUGs with sustained forestry experience in this study, the views also suggest a need to apply caution in interpreting forest–water relationships, particularly in relation to the role of pine species in catchment water availability. This is because catchment water yield is affected by a host of biologically mediated and anthropogenic factors related to forest use and management, as shown by a number of studies in the broader mid-hills region (eg Gilmour et al 1990; Bonell et al 2010; Ghimire et al 2013) and elsewhere in the tropics (eg Zwartendijk et al 2017). Importantly, the hydrological effects

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in the forested catchments are further uncertain, with successional change leading to alterations in forest structure and composition, for example, broadleaf species integrating with pine plantations in parts of the mid-hills, including the study area (Gilmour et al 1990; Gautam and Webb 2001; Paudyal and Sapkota 2018).

Nevertheless, over a third of respondents (37%) perceived the forests to decrease water quantity, while a much smaller fraction (15%) perceived forests to improve both water quantity and quality. A vast proportion of the respondents believed pine trees reduced water quantity, which is supported by limited scientific evidence in the mid-hills. For example, the planted pine forests contribute to reduced dry season flows due to their higher evapotranspiration (Baral 2012; Ghimire, Lubczynski, et al 2014) and lower soil hydraulic conductivity (Ghimire et al 2013) as compared to the natural broadleaf species. Similar effects on water yield due to pine and broadleaf species have also been reported in other parts of the world, including North America (Swank and Miner 1968; Swank and Douglass 1974) and Japan (Komatsu et al 2008). The study in Japan further suggested converting coniferous forests into broadleaf forest to increase water yield, as reportedly done by some local governments. However, the results are not uniform, as species respond in different ways to site conditions. For example, a mixed beech–spruce stand used up more water than a spruce-only stand in Norway (Schume et al 2004), whereas the water use by *Eucalyptus* varied with soil type in India's dry zones and used no more water than the deciduous natives (Calder et al 1993). Likewise, evaporation by the broadleaf and pine forests was similar in Japan (Komatsu et al 2007), while the age of *Eucalyptus regnans* was significant in affecting water use in Australia (Vertessy et al 2001). Importantly, local perceptions of pines are not consistent, as one participant with over 25 years of CFUG experience in Balthali village opined, "the pines have made our dry barren hills (*sukkha rukho danda haru*) look greener—much better than before." This also suggests that more studies on pines' effects on local water availability are needed.

Yet, it is unclear whether forest–water relationships or perceptions of them will remain the same or change as the rural economies of the mid-hills transition to market-based systems, due to, for example, outmigration (Jaquet et al 2016; Sunam and McCarthy 2016; Ojha et al 2017) and reduced agricultural productivity (Maharjan et al 2013; Paudel et al 2014). Similar circumstances elsewhere are predicted to cause further increases in forest cover, for example, in India (DeFries and Pandey 2010).

Conclusion

This study shows a perception gap of forest–water relationships in Nepal, particularly among the members of the CFUGs, forest policymakers, and broader Nepalese society. The broader societal perception that forests increase water availability, and the perceptions of the forest policymakers that focus essentially on tree planting reflect cultural beliefs and traditional practices. Conversely, CFUG perceptions, which are largely founded on lived experience in forest use and management, are more discerning: Only 44% of respondents considered forests to increase water quantity, while 37% considered that forests reduced it. These respondents also disliked pine forests due to the alleged role of the species in causing the reduction.

We consider that the mismatched perceptions of forest–water relationships described here pose challenges to the management of Nepal's mid-hills catchments in 2 major ways: (1) They impede collective action (ie the development of widely acceptable catchment management plans); (2) the cultural interpretation of these relationships obstructs, or at least delays, the integration of scientific evidence into forest policymaking processes. This is despite CFUG perceptions that align more closely with the scientific evidence showing that forest development in catchments reduces water yield overall.

Thus, while the overall shortage of knowledge on forest–water relationships in the broader mountainous region underscores the need for increased scientific research, the divergent views on these relationships offer opportunities for adopting more inclusive research methods to concurrently integrate science with the perceptions held by the various sections of the Nepalese society. This is particularly important in view of expanding community forestry practices and the ongoing debate on scientific forest management.

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