Ecosystem Services 50 (2021) 101335

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Community perception of ecosystem services from commercially managed forests in Bhutan

Jigme Wangchuk [a,*], Kinley Choden [a], Robin R. Sears [b,d], Himlal Baral [d,e], Dawa Yoezer [a], Kelly Tobden Dorji Tamang [a], Thinley Choden [a], Norbu Wangdi [c], Shacha Dorji [a], Dorji Dukpa [a], Kaka Tshering [a], Cheten Thinley [a], Tashi Dhendup [a]

[a] Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER), Lamai Goempa, Jakar, Bumthang 32001, Bhutan
[b] Harvard Forest, Harvard University, 324 North Main St, Petersham, MA 01366, USA
[c] Royal Society for Protection of Nature, Kawajangsa, Thimphu, Bhutan
[d] Center for International Forestry Research (CIFOR), Situ Gede, Sindang Barang, Bogor 16115, Indonesia
[e] School of Ecosystem and Forest Sciences, University of Melbourne, Parkville, VIC 3010, Australia

ARTICLE INFO

Keywords:
Forest management units
Ecosystem services
Qualitative assessment
Forests perception
Bhutan

ABSTRACT

Given the direct dependence rural communities have on forests, understanding ecosystem services can empower communities and align stakeholders to define priorities and objectives for the sustainable management of forest resources. In this qualitative study on the forest ecosystem services in Bhutan, we assessed community awareness and perceptions of local forest ecosystem services, identified their top priorities, and evaluated how they have changed over time. The study focused on state reserve forest areas designated for commercial timber production, formally known as forest management units (FMU). We held focus group discussions separately with women and men associated with five FMUs in the central belt of the country. Participants identified 45 ecosystem services, with soil productivity, freshwater, timber, fresh air, construction stone, carbon sequestration, spiritual value, pollination, and local weather regulation comprising the most highly valued services critical to local livelihood and well-being. Participants felt that forest ecosystem services have been generally declining over the past decade in the FMUs and identified a need for forest restoration activities to improve their delivery. We recommend that state forest entities conduct an awareness campaign to empower communities with the conceptual framework and globally recognized concepts to advocate for their needs related to forests. We also recommend that biophysical and economic studies be conducted in these areas to seek evidence for causal linkages between natural resource use and the status of ecosystem services. This study contributes to a growing literature on ecosystem services in Bhutan and provides a basis for future studies to understand how management activities can impact the delivery of critical services.

1. Introduction

1.1. Forests and people

Forests provide a wide range of benefits to human societies, collectively known as ecosystem services. Forests are critically important at the global scale for their role in the carbon cycle (Hicks et al., 2014; Price and Apps, 1996) and mitigation of global warming (Arora et al., 2012). They provide ecological services at the watershed scale, such as regulation of water cycle and soil conservation, and habitat for local flora and fauna (Band et al., 2001; Band, 2010; FAO, 2013). At the local scale, forests directly support rural livelihoods through the provision of ecosystem services for sustenance and commercial use (Bhatta et al., 2015), provide a sense of place and identity (Cooper et al., 2016), and hold cultural and spiritual values (Allison, 2019). Recognition and appreciation of diverse forest ecosystem services at all scales is essential

* Corresponding author.
E-mail addresses: jwangchuk@uwice.gov.bt (J. Wangchuk), kchoden@uwice.gov.bt (K. Choden), robin.sears@aya.yale.edu (R.R. Sears), H.Baral@cgiar.org (H. Baral), dyoezer@uwice.gov.bt (D. Yoezer), kelly@uwice.gov.bt (K.T.D. Tamang), thinleyc@uwice.gov.bt (T. Choden), nwangdi@rspnbhutan.org (N. Wangdi), sdorji@uwice.gov.bt (S. Dorji), ddukpa@uwice.gov.bt (D. Dukpa), ktshering@uwice.gov.bt (K. Tshering), cthinley@uwice.gov.bt (C. Thinley), tashid@uwice.gov.bt (T. Dhendup).

https://doi.org/10.1016/j.ecoser.2021.101335
Received 22 March 2020; Received in revised form 16 June 2021; Accepted 28 June 2021
Available online 8 July 2021

to motivate their conservation and sustainable management (Cooper et al., 2016).

The condition of mountain forest landscapes is of particular concern given that land use and forest conditions in upper watersheds can have a significant impact on natural and human-modified ecosystems and human settlements lower down (Måren et al., 2014; Rinzin et al., 2009). Deforestation and forest degradation on mountain hillside can easily lead to the loss of soil and water regulating services that trees normally provide by slowing overland flow after rainfall or snowmelt, resulting in sediment loads in waterways (Arias et al., 2011) and flooding of downstream communities (Sharma et al., 2009). Thus, sustainable management in sloping landscapes is critical for the entire watershed.

Defining appropriate forest management objectives and plans depends on the understanding and appreciation of the values held by a multitude of actors, including local forest users, commercial operators, and government authorities. It depends on a system of forest governance that acknowledges and balances the diverse human interests to capitalize on those services, in monetary ways or otherwise. The governance system should clearly define access rights and management goals, with a system of checks and balances that ensures equity in decisions that shape the management goals, planning, and implementation. Finally, sustainable management of mountain forests requires accountability for all forest actors, with consideration for the impacts of their actions at multiple scales.

In cases where forest governance is centralized, and where decision-makers and forest operators are not directly dependent on the local forest, access rights, management planning, and implementation are limited for local communities. This is particularly important where residents depend directly on the forest to meet their welfare needs. In this case, there should be a mechanism by which their concerns are incorporated into the management plans.

1.2. Forest management unit as a forest production type

All forests in Bhutan are governed by principles of sustainable forest management under the Forest Act 1995, which gives governing entities a mandate to improve forest conditions and ecological services and to harvest timber and non-wood forest products (NWFP) without compromising future use. The vast majority of forestland is under the jurisdiction of the central government, with only 12 hectares under private forest management (FRMD, 2020). Much of the public forestland is protected from degradation under different categories of protection, where the focus is non-consumptive use and management to maximize regulating, supporting, and cultural ecosystem services. In protected areas, resource extraction is largely limited to NWFP for household consumption and timber for local house construction.

On public forestland designated for resource production, management structures include community forest, where forest governance is shared between a community management group and the local forest office (Bruggeman et al., 2016; Prasad, 2015); local forest management areas of state reserved forest, managed by local communities to meet local timber needs; and forest management units (FMU) and working schemes, where the forests are actively managed for commercial timber production and governed by the national forest authority, the Department of Forests and Park Services (DoFPS) (Bruggeman et al., 2018; DoFPS, 2018; FRMD, 2020).

In this paper we focus on this latter category, the FMU and working schemes, which are designated as per the Forest Resources Potential Assessment (FRMD, 2013) conducted by the DoFPS, based primarily on commercial timber stocking and accessibility. The working scheme is a forest area designated ad hoc for commercial timber production to complement and respond to urgent and specific timber needs (Bruggeman et al., 2018) and can be considered as a precursor to FMU status. In this paper, the term FMU encompasses the working scheme.

The silvicultural systems in FMUs include patch selection in broadleaf forest and group selection in mixed conifer forest (SFED, 2016). Forest management planning for FMUs is conducted by the DoFPS, while harvest and marketing are executed by the state logging company, the Natural Resources Development Corporation Limited (Dhital, 1997).

As of 2019, Bhutan had 21 FMUs covering a total area of 198,407 hectares located across 13 of the 20 districts in Bhutan (FRMD, 2020). They are largely located in the temperate mid-elevation zone of Bhutan because these cool temperate broadleaf and mixed conifer forests contain significant stocks of accessible commercial timber, as compared to the sub-tropical hardwood forests at lower elevations and to the ecologically sensitive and inaccessible conifer forests in higher elevations.

Reports suggest that 22 percent of Bhutan's forest production area had degraded forest cover (WMD, 2017) and that deforestation was prominent in the underdeveloped eastern and southern districts (Bruggeman et al., 2016). Forest areas are lost to the installation of electric transmission lines in rural areas, and for the expansion and establishment of stone quarries to meet construction demands (WMD, 2017).

There are some concerns that the timber stock from FMUs is inadequate to meet the increasing demands from economic growth and urbanization in Bhutan (WMD, 2017). The high demand puts pressure on forest management authorities to allocate the maximum annual allowable cut, which, despite being based on forestry best practices, has not been well tested for ecological integrity. In addition to the high demand for timber, the integrity of the forests in FMUs, particularly in the broadleaf forest, is threatened by regeneration failure (Covey et al., 2015; Darabant et al., 2007; Norbu, 2002; Rai et al., 2014).

The ongoing expansion of the rural network of farm roads and forest roads increases access to the FMU areas, and there are concerns about illegal resource extraction. Communities located within the boundaries of and adjacent to FMUs are allowed to harvest a limited amount of timber and NWFP to meet subsistence needs according to the management plan (Moktan et al., 2009).

1.3. Forest ecosystem services assessment

At the root of fair forest governance, including equitable access and benefit-sharing, and of sustainable forest management is the clear understanding of the forest ecosystem itself and of people's relationship to it. One framework for gaining insight on both of these dimensions is the concept of ecosystem services (MEA, 2005; Baral et al., 2017). This globally recognized framework defines a typology of ecosystem services found in natural ecosystems, categorized as provisioning, regulating, cultural, and supporting services. The identification, quantification, and valuation of ecosystem services at local and national levels can help decision-makers prioritize conservation and resource management efforts (Wundera et al., 2008; Zilberman et al., 2006) and identify needs in clarifying and strengthening governance and access rights to resources.

Studies show that globally important ecosystem services such as carbon sequestration and storage in developed countries appear to be in recovery while the developing countries have on balance lost global ecosystem services, especially through land conversion (Davidson, 2017; FAO, 2015). This is not the case in Bhutan, where forest cover remains steady and the country is carbon neutral (Yangka et al., 2018). Assessment of ecosystem services is crucial for developing and implementing integrated sustainable management plans for land use systems, watersheds, and mountain ecosystems, and for recognizing the local community as a key stakeholder (Baral et al., 2017; Hofer and Zingari, 2003). Much of the research on ecosystem services focuses on the biophysical and economic aspects of ecosystems (Greiner, 2017; Vitousek et al., 1997; Wangai et al., 2016). A rough and preliminary ecosystem services valuation in Bhutan suggested that 94 percent ($14.5 billion y^{-1}) of the country's total natural capital was contributed by forests (Kubiszewski et al., 2013). Other valuation assessments have been made in Bhutan, including one using the Integrated Valuation of Ecosystem Services and Tradeoffs model (WWF, 2017) and another using The Economics of Ecosystems and Biodiversity (UWICER, 2018), conducted

at the scale of a single watershed and focused on only a few targeted services. More direct studies in Bhutan have shown that timber species are used by local communities for building structures and scaffolding, flag poles, and fencing. Leaf litter is employed as cattle bedding, which is later used in agricultural land as farmyard manure (Sargent et al., 1985) and fresh leaves provide fodder for cattle (Roder et al., 2003). Wild edibles including mushrooms, fruits, and wild vegetables, and medicinal plants and minerals are enjoyed locally and provide income opportunities (Namgyel, 1996). Critically, fuelwood is collected for cooking and heating from these forests (Dick and Yonten, 1995).

Constraints to quantifying ecosystem services and their economic value include the lack of fine-scale biophysical data and measurement of ecological dynamics for many of the country's ecosystems. Furthermore, these economic assessments illuminate only part of the socio-ecological system of forests and people. Information on the links between forests and rural livelihoods, culture and food, and livelihood security help to orient landscape and resource management planning. A first step is to assess the relative importance of ecosystem services through qualitative research with local communities, which costs little yet yields information that can help to prioritize management decisions and more robust assessment studies (Baral et al., 2017; Måren et al., 2014; Meijaard et al., 2013; Moutouama et al., 2019; Scholte et al., 2015; Zhang et al., 2015).

Through participatory rural appraisal methods, centered on place-based analysis, the perceptions, beliefs, and understandings of local residents may be identified and compared across political districts and ecosystems (Brown, 2013; Mikusiński and Niedziałkowski, 2020). Qualitative studies conducted directly with local residents can help identify the needs and priorities of local communities for conservation and management of ecosystems. Some local assessments in Bhutan have been made using this approach (Dorji et al., 2019; Kandel et al., 2018; Tshering et al., 2015; Wangchuk et al., 2019), and results suggest that local people today and for generations have depended directly on provisioning, regulating and cultural services.

Due to the direct dependence of rural communities on forests, mechanisms that support local forest governance can strengthen forest management. This has been shown in Bhutan by the successful governance schemes of community forests (SFD, 2010) and local forest management areas (SFED, 2016). FMUs are governed entirely by public agencies, but since people living within and adjacent to FMUs areas have some rights for access and use of forest resources (Moktan et al., 2009), we pose the question of whether local communities could also share in the governance of the FMUs, a topic that has yet to be explored in Bhutan. In this paper, we report on an assessment of the importance of the FMU areas to local communities in Bhutan to provide a basis for analyzing this question.

1.4. Objectives of this paper

In this paper, we report on community perceptions of the forest ecosystem services provided by FMUs and whether and how they have changed over time. The findings of this study can be applied to multiple areas of forest governance and management. First, local awareness of the importance of local forests can help adjacent communities to appreciate how management, or even lack of management, can impact the provisioning ecosystem services, and subsequently the community's well-being. Second, local perceptions of the status of ecosystem services in FMUs, including the perceived impact of logging events, can help inform forest operators and planners on outcomes of management implementation. The information can help forestry entities to integrate the ecosystem services concept and directly address community needs in revising and implementing forest management plans.

2. Methods

2.1. Study area

This study was conducted in eight communities located within or adjacent to five FMUs[1] in central and eastern Bhutan (Table 1). A total of 21 FMUs existed in Bhutan at the time of this study (Fig. 1), all located in the bands of mid-elevation temperate forests. We selected five FMUs in similar forest types (dominated by broadleaf and mixed conifer) (Fig. 1) in consultation with local forest offices, and associated villages were identified in discussion with the local forest office and village representatives. Where an adjacent village had few households, we invited neighboring villages to participate. Livelihoods in the villages were mainly based on agriculture, livestock, and forest products, all of which heavily depend on forest ecosystem services. Given that timber harvest is the main management objective for all FMUs, though the species might be distinct, we cautiously suggest that these five are representative of FMUs in general in terms of management goals and general types of ecosystem services these forests provide locally.

2.2. Study design and tools

Field work was conducted from April 2017 to January 2018, during the months when rural communities have fewer farm activities. We conducted two focus group discussions (FGD) (Bloor et al., 2001; Morgan, 1997) with villagers associated with each of the five FMUs, one with women, the other with men. Each FGD consisted of 10 participants. We used purposeful and chain sampling (Dodge, 1955; Govindaraju, 2006) to select 10 women and 10 men in villages proximate to FMUs and having residence there for more than 10 years (2006–2016) at the time of the study. The residency requirement was applied to inquire about perceived changes in ecosystem services through their observation and experiences. The age and occupation of the participants varied in each group.

We consider gender as a factor that might account for differences in perceptions and thus elected to conduct separate discussions with women and men because in rural households and communities in Bhutan there are clear gender roles, with each having distinct interactions with the forest (Choden, 2017). For example, household chores such as the collection of water, firewood, dyeing, and cooking are largely performed by women and girls, while the harvesting of timber, construction, and ploughing are performed by men and boys. Separate gender group discussions allowed all participants to share ideas and bring out issues of common interest, thereby acquiring independent gender perception (Nyumba et al., 2017; Elias, 2013; Green et al., 2003; Kitzinger, 1994; Krueger, 1994; Richardson and Rabiee, 2001). In a systematic review of research papers reporting on ecosystem services, Yang et al. (2018) found that less than one percent of the studies treated gender differences. Likewise, Cruz-Garcia et al. (2017) found that only five out of 49 case studies on ecosystem services considered gender dimensions.

2.3. Focus group discussion procedure

The FGDs were centered on three main questions: (1) what are the ecosystem services provided by nearby forest areas?, (2) what are the top priority ecosystem services?, and (3) how has the availability of these ecosystem services changed in the past decade? Each FGD was led by a facilitator from the research team, and the event lasted no more than two hours. All proceedings were conducted orally and facilitators

[1] One of these is officially designated as a "working scheme", which is a forest area designated for commercial timber production to complement and respond to urgent and specific timber needs. A working scheme can be considered as a precursor to FMU status, and thus we consider it under FMU in this paper.

Table 1
General information on forest management units under study and associated villages.

District	Name of FMU/Working Scheme	Year established	Total FMU area (ha)	Predominant forest types	Name of participating village (Number of associated villages)	Number of associated households	
						Inside FMU	Outside FMU
Mongar	Lingmethang	1996	10,571	Broadleaf Chirpine	Jangdung (6)	76	30
Trashigang	Khaling-Kharungla	1995	7,265	Broadleaf Mixed conifer	Kurichilo (4)	289	
Lhuentse	Rongmanchhu	2007	6,401	Broadleaf Mixed conifer	Budur Kupinesa (2)	181	202
Trongsa	Chendebji	1996	7,852	Mixed conifer Broadleaf	Chendebji Drangla (5)	87	
Zhemgang	Kekhar Working Scheme	2009	2,460	Broadleaf	Kekhar (1)		56

Source: Lingmethang Forest Management Plan 2008; Khaling-Kharungla Forest Management Plan 2009; Rongmanchhu Forest Management Plan 2018; Chendebji Forest Management Plan 2018; Chendebji Forest Management Plan 2018; DoFPS, 2018.

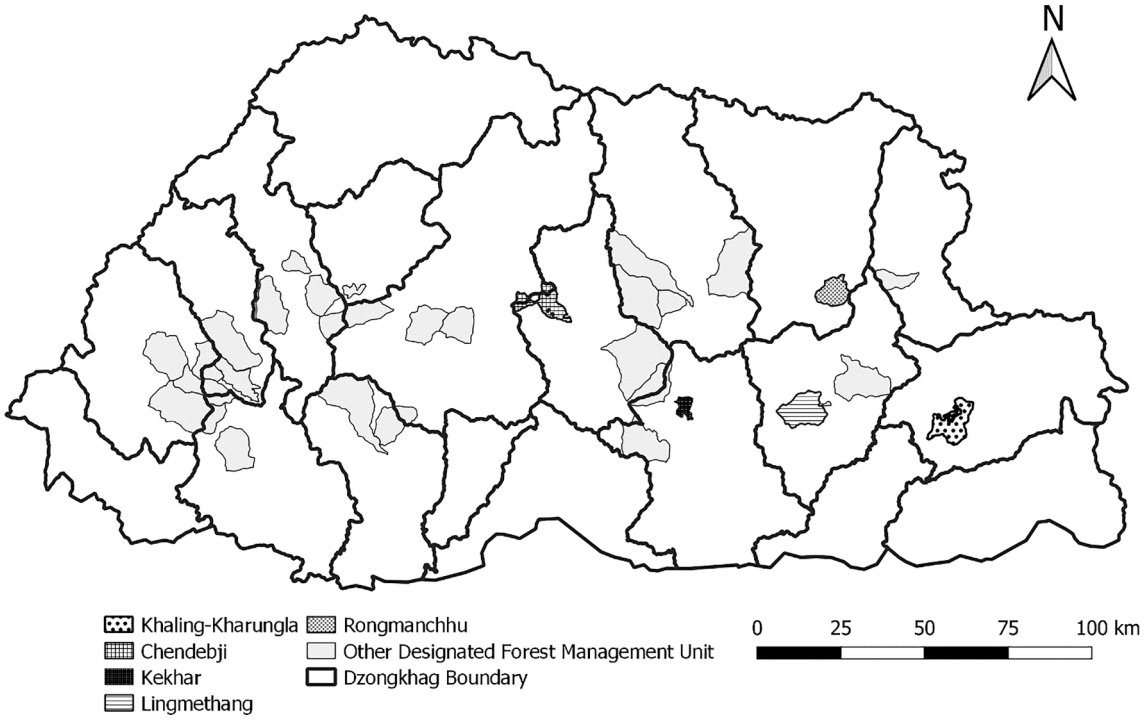

Fig. 1. Map showing FMUs and study area in central and eastern Bhutan.

used local vernacular terms as far as possible to ensure that participants followed the discussion. The group facilitator ensured that all group members contributed in the discussion to validate the group's opinion rather than allowing only a few local members to dominate (Van Oort et al., 2015). Discussions were recorded with participants' consent and later transcribed for analysis.

After an introduction to the study topic and purpose, participants were requested to list the ecosystem services availed from the local forests. Probing questions and analogies were used by the discussion facilitator to help participants expand their thinking to intangible benefits when these were not forthcoming in the discussion.

The participants were asked to identify and rank the top five services of the whole pool most important to that community, and to justify their prioritization. Then they were asked to report on perceived trends in the availability of the prioritized ecosystem services over the past decade (2006–2016). They were presented with a Likert scale from highly decreased, decreased, no change, increased, to highly increased (Cáceres et al., 2015). Finally, the participants were asked to share ideas on measures that could be taken to improve the provision of forest ecosystem services in the future.

2.4. Analysis

The unit of study is the FMU, not the village, and analysis is based fully on the information generated in the FGD. Both quantitative and narrative analyses were carried out using written notes and the discussion transcripts, allowing for the identification of ecosystem services, which were categorized *post hoc* according to the MEA (2005) and TEEB (2010) frameworks. Services were identified and ranked, and trends were defined based on group agreement. At the end of each FGD event, the facilitator introduced the internationally recognized categories to participants in an effort to provide them with a tool for discussion with other communities and stakeholders.

3. Results

3.1. Ecosystem services identified by the communities

Forty-five ecosystem services were identified across all sites and groups. These were categorized into provisioning (21), regulating (11), habitat/supporting (5), and cultural (8) services (Table 2). In all FGD but

Table 2
Ecosystem services identified by community members in ten focus groups (five per gender) with descriptions of indicators and the perceived importance. Ecosystem services are presented based on MEA and TEEB categories.

Ecosystem Category	Identified ES	Nos of times mentioned		Indicators of ES	Perceived importance
		Women	Men		
Provisioning Services *Raw materials*	Timber	5	5	Quality and harvestable trees	Timber stock at harvestable age
	Fuel wood	5	5	Volume of fuel wood	Stock available and obtained from forests
	Construction stone	5	5	Quality and quantity	Quality and stock available in forest
	Bamboo	4	3	Amount collected	Stock available
	Sand/clay	2	1	Amount collected	Stock available
	Wood burr	0	2	Quality collected	Burr production for making bowl
	Fiber (Pulp for paper/ broom)	5	0	Harvestable amount	Variety of plants for fiber
	Leaf litter	5	5	Amount collected	Stock available for cattle bedding and farm manure
	Dye plants	4	0	Quality and quantity collected	Variety and quantity of plants for dyeing
	Incense material	2	1	Number of species and amount	Stock available for household uses and spiritual offering
	Essential oil (lemongrass, resin)	1	1	Amount harvestable	Harvestable area of essential oil
Food/forage	Limestone	1	0	Quality and quantity collected	Stock available for consumption, used in chewing betel nut
	Fodder trees	5	5	Number of fodder species	Forage production for cattle
	Wild fruits and vegetables	5	5	Quantity of fruits/vegetables collected	Provision of food for household consumption and sale
	Edible insects	0	2	Amount of insect collected	Provision of protein
	Bush meat	0	2	Number of species	Provision of protein
	Tea leaves	2	2	Amount collected	Provision for household consumption
	Fish	1	2	Amount collected	Household consumption
Fresh water	Fresh water	5	5	Number, quality, and quantity	Household consumption, irrigation, and livestock
Medicinal resources	Medicinal plants	5	3	Number of species and harvestable amount	Plants for biomedical values
	Medicinal/holy spring water	3	2	Number of sources, quality, and quantity	Therapeutic values
Regulating services *Local climate and air quality*	Fresh air	5	5	Total forest area and concentration of pollutants	Provide oxygen for living and trees absorb carbon dioxide
	Local weather regulation	4	3	Quantity and quality of crops affected	Provision of regular rain for cropping
	Shade	4	1	Area of forest coverage	Trees provide shelter and shade for cooling
	Pollution control	3	0	Amount of pollutant in the air	Forest intercept chemical released in soil and water
Carbon sequestration and storage	Carbon sequestration	4	4	Amount of carbon in the air	Carbon dioxide captured by forest stored in the form of biomass
Waste water treatment	Wastewater treatment	3	0	Amount of clean water	Forest and soil absorb waste and provide clean water
Moderation of extreme events	Flood regulation	5	5	Number of flood incidences	Vegetative cover control flood
Erosion prevention and maintenance of soil fertility	Control land erosion	1	0	Area of degraded land/forest	Forest acts buffers for land erosion and improve soil productivity
Biological control	Biological reproduction	1	0	Increase or decrease flora and fauna	Maintain diversity of plants and animals
	Biological control	4	1	Increased or decreased yield	Control pest and disease
Pollination	Pollination	4	4	Number pollinators species	Maintain pollinators population for plant production
Habitat/supporting services *Habitat for species*	Soil productivity	5	5	Quantity and quality of forest products and crop harvestable	Forest maintains soil productivity for growth of food and regulation
	Habitat for plants and animals	3	5	Increased or decreased wild species	Provide home to plants and animals
Maintenance of genetic diversity	Maintain genetic diversity	5	1	Number of diseased species	Acts as the storehouse for maintaining genetic diversity
	Nutrient cycling	2	0	Quantity of biomass and crop yield	Diversity of forest plants and animals recycle nutrients enhance crop productivity
	Wild animal diversity	4	3	Number of variety species	Maintain food chain
Cultural services *Recreation, mental and physical health*	Picnic spot	0	1	Number of visitors	Forest provide recreational spots
Appreciation and inspiration for culture art and design	Traditional monuments and architectures	3	4	Number of visitors	Forest provide sites for traditional monuments
	Aesthetic values	3	0	Number of visiting guests	Offers scenic beauty
Spiritual expression and sense of place	Spiritual values	3	4	Number of followers	Provides spiritual and religious sites for well-being
	Birth guardian deity	4	4	Number people diseased and died	Provides sacred sites for reverence
	Local deity/spirits	5	5	Area of proximity forest increased or decreased	Provides sacred sites for deities
	Pilgrimage site (Dhakini meditation site)	1	2	Number of visitors	Harbors forest caves for meditation
Tourism	Tourism	2	2	Number of sites and visitors	Recreation and ecotourism purposes

one (with Lingmethang), 30 or more ecosystem services were identified. In Kekhar, the working scheme, while it is the smallest forest area and most recently designated, participants identified the most ecosystem services with 35. At all sites, both gender groups easily identified provisioning services used commonly for their livelihoods, such as timber (frequency of mention = 8), bamboo (8), fodder (9), and wild fruits and vegetables (10). Perhaps due to their intangible nature, regulating services were recognized with difficulty, and sometimes only after a brief explanation with analogies and probing questions by the facilitator. The emphasis on provisioning services suggests that people most strongly associate forest value directly related to their daily practices.

There was a total concurrence among all communities and genders for 11 services, of which seven were provisioning: timber, fuelwood, fodder trees, wild food, leaf litter, construction stone, and freshwater. Supporting, regulating, and cultural services recognized by all were soil productivity, fresh air, flood regulation, and local deities. An additional three were mentioned in four of the five communities for each gender (birth guardian deity, carbon sequestration, pollination). These ecosystem services are all fundamental to farming livelihood and rural life. Four ecosystem services were mentioned only once: limestone (used in betel quid), picnic spots, erosion control, and biological reproduction.

At almost all sites, women identified more ecosystem services than men (Table 3a); only for cultural services did the men's tally surpass the women's (Table 3b). Women identified nine unique ecosystem services, while men identified four (Fig. 2). The top two for women, fiber plants and dye plants, could be construed as gendered goods since women traditionally use these in their households.

3.2. Prioritization of forest ecosystem services

Ten ecosystem services were ranked in the top five priorities across FMUs and genders (Table 4). With the exception of one focus group, there was total congruence among villages and genders that the number one priority service from these forests is soil productivity. Fresh water provision and timber were ranked second or third by all communities, and fresh air and construction stone filled the fourth and fifth ranking spots. Other services in the top five but mentioned with low frequency were carbon sequestration, pollination, local weather regulation, spiritual values, and birth guardian deity.

Participants perceived soil productivity as the foundation for local livelihoods, necessary for general human well-being, and as support for provision of all other ecosystem services. They suggested that due to its role in cycling nutrients, the forest is critical for maintaining soil productivity, which is vital, especially for yields of timber, fuelwood, and forest-based fodder. They linked forest soil productivity to their agricultural fields nearby, indicating that farmers replenish the nutrients in their field soils with leaf litter, topsoil, and humus collected from the nearby forest. They suggested that the forest also retains soil minerals.

The freshwater provisioning service of forests was cited as essential for survival as it supplies clean and safe drinking water for household consumption, livestock use, and crop irrigation. Uses of freshwater also have a strong association with culture, spiritual well-being, and satisfaction of the local community. For example, participants mentioned that their day always starts by offering freshwater on the altar with prayers to purify the obscuration of all sentient beings. Stream water is used to power prayer wheels constructed over streams with the intent to accumulate wisdom and merit and to purify negativities.

All focus groups of both genders ranked timber from the forest as a high priority. Wood resources are used for house and livestock shed construction, furniture, and fuelwood. Communities also attributed the regulation of fresh air, carbon sequestration, and prevention of soil erosion to the presence of live trees in the forest.

Fresh air was ranked fourth by nine groups and first by one. Participants suggested that fresh air is crucial for their own health and growth, and their animals. The women's group from Chendebji prioritized fresh air first, suggesting that it is the most important life-supporting service. They cited the deteriorating air quality in the locality attributed to dust created by road construction and increasing vehicle movement, and to indoor woodsmoke, both of which they said poses risks to the health and hygiene of the local community. They suggested that the presence of forest vegetation filters these air pollutants. One participant rationalized her choice this way: "*When I use fuelwood to make fire for cooking, smoke accumulates in the kitchen. By then I have difficulty in breathing, irritation in my eyes, and suffocation becomes evident. Therefore, I rush out of the house with great relief, and as I inhaled fresh air, I felt that I had escaped a gunpoint.*" In this case, the participant sees the fresh air provided by the forest as an antidote to the health risk posed by indoor air pollution.

The women's group in Lingmethang linked carbon sequestration to the provision of fresh air and ultimately to mitigating the deleterious effects of rising levels of carbon dioxide in the atmosphere. They reasoned that developmental activities in their locality and from the neighboring industrialized countries have a negative effect on ecosystem health in the long run. They suggested that forests can neutralize carbon emission, which ultimately contributes to the well-being of living organisms.

Construction stone was ranked fifth by six groups. Stones of roughly 10 cm by 20 cm found in the forests proximate to their settlements on the soil surface are collected and used in various structural projects, such as for house construction, terracing fields for soil stabilization, and as fencing material to protect crops from wild animals. Participants also stated that stone plays an important role as the basis for soil formation. Participants felt that construction stone is abundant compared to other ecosystem services, so it was ranked low out of the top five.

A diversity of cultural services of forests were highlighted by all groups with all mentioning the important presence of local deities that look after the people's well-being (Table 2). However, only the men's group from Chendebji prioritized the spiritual values of the forest in the ranking exercise, and notably in two ranked positions (Table 4). They specified that the local forest is believed to be the abode of the deity that gives swift birth and prosperity and that the spiritual value of the forest is influential in the general well-being of the community. These spiritual services of forests are valued for maintaining peace and prosperity in the locality, and communities conduct rituals to gain permission from local deities for their use of forest resources.

3.3. Perceived trends of the prioritized ecosystem services

All ten of the priority ecosystem services were perceived by at least some groups to have declined over the past decade (2006–2016) (Table 5). The most urgent concerns were for timber, freshwater, and fresh air. They believed that these declines were due to increasing pressure on timber supplies and pollution of water and air from nearby growth and developmental activities, including road building and infrastructure construction, and by the intrusion of outsiders who extract these resources. Participants suggested that in the past, timber,

Table 3
Counts of ecosystem services: (a) number of ecosystem services identified by study area and gender, and (b) number of times ES are mentioned in each category, by gender (b).

(a) Study area	Women	Men	Total
Khaling-Kharungla	29	24	32
Rongmanchhu	23	28	35
Lingmethang	24	19	26
Chendebji	30	23	35
Kekhar	35	24	37
Total			45
Total in common			32
(b) ES category			
Provisioning	64	57	
Regulating	37	25	
Supporting	19	14	
Cultural	20	21	

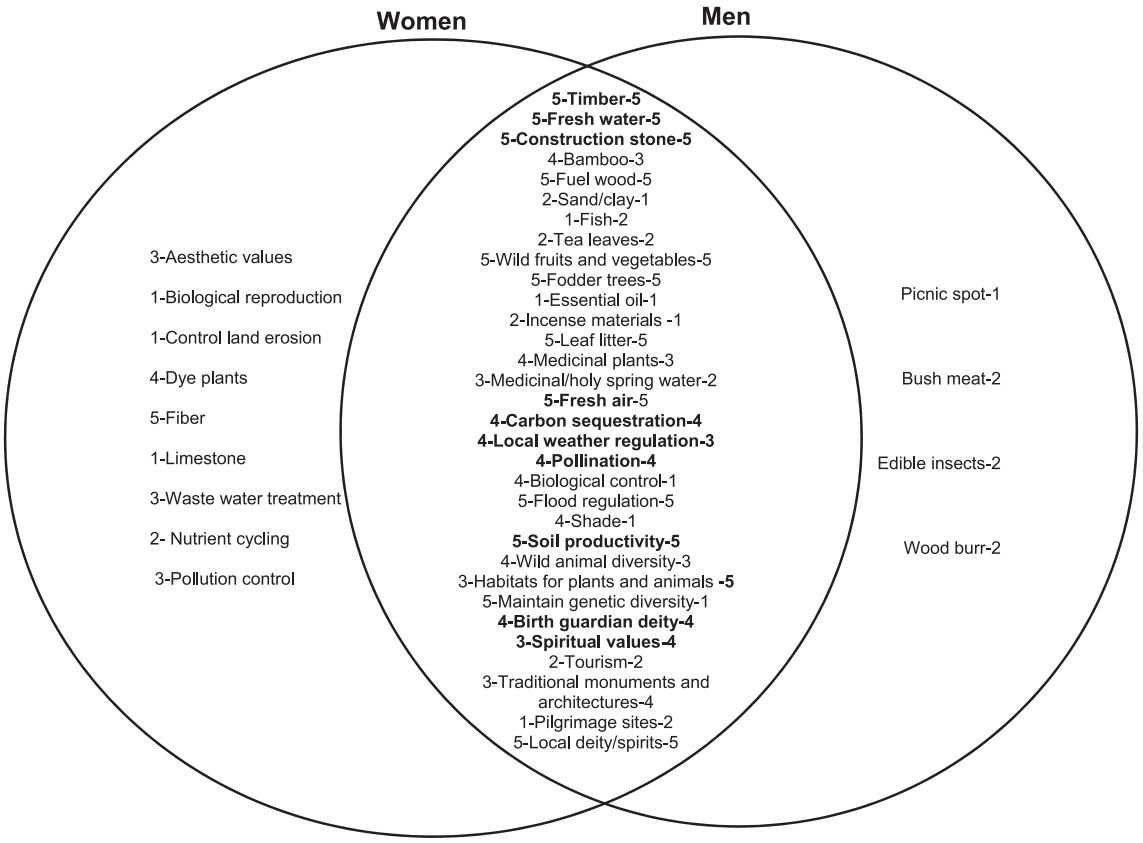

Fig. 2. Ecosystem services identified by the men and women, indicating common preferences and variations. Bold in the text represents prioritized ecosystem services while the number represents frequency of ecosystem services identified by men and women group in their localities.

Table 4
Ranking of top five ecosystem services by the five participating communities based on focus group discussion, disaggregated by gender.

Location	Gender	Ecosystem services ranking				
		First	Second	Third	Fourth	Fifth
Chendebji	Female	Fresh air	Soil productivity	Freshwater	Timber	Construction stone
	Male	Soil productivity	Freshwater	Timber	Birth guardian deity	Spiritual values
Kekhar	Female	Soil productivity	Freshwater	Timber	Fresh air	Pollination
	Male	Soil productivity	Freshwater	Timber	Fresh air	Local weather regulation
Khaling-Kharungla	Female	Soil productivity	Freshwater	Timber	Fresh air	Construction stone
	Male	Soil productivity	Timber	Freshwater	Fresh air	Construction stone
Lingmethang	Female	Soil productivity	Freshwater	Timber	Fresh air	Carbon sequestration
	Male	Soil productivity	Freshwater	Timber	Fresh air	Construction stone
Rongmanchhu	Female	Soil productivity	Timber	Freshwater	Fresh air	Construction stone
	Male	Soil productivity	Timber	Freshwater	Fresh air	Construction stone

fuelwood, fodder trees, and construction stone were readily available in nearby forests but that now they must travel long distances to find them. In addition to excessive demand for timber, the removal of immature trees and the poor regeneration of broadleaf species were perceived to drive the decline in timber supply to local communities. Some groups reported having seen quality hardwood timber go to waste due to poor planning for its disposal and sale.

Participants in all groups indicated a decline in the provision of freshwater. They attributed the trend to the extraction of timber from the forest, increasing water demand from local growth and development, and, in one of the men's groups, the installation of concrete structures at the water source. In this latter case, participants expressed concern that the concrete structure absorbs water from the ground and evaporates quickly. They believe it may change the water course underground, contributing to the decline of water discharge downstream.

Improvements in the forest's cultural services of spiritual value and birth guardian deity were noted by the men's group in Chendebji. They suggested that people's fear of retribution from the deities if the forest is disrespected helps to protect the forest in the deity's mountain landscape.

3.4. Threats and management recommendations

Participants identified key threats to the priority services and especially to those on which they directly depend for their livelihoods, such as timber, freshwater, and NWFPs. Threats they cited were unsustainable forest resource exploitation, soil disturbance from logging operations, cattle grazing, and climate change. They expressed concerns that these threats to the forest ecosystem services critical to meet their daily needs will result in resource scarcity in their locality and ultimately

Table 5
Direction and strength of perceived changes in the priority ecosystem services in the past decade, with the number of groups mentioning, by gender. The scale represents the strength of change, with negative representing decrease, zero as no change, and positive as an increase in availability and quality.

Trend	Women					Men				
	−2	*−1*	*0*	*+1*	*+2*	*−2*	*−1*	*0*	*+1*	*+2*
Habitat/Supporting services										
Soil productivity		3	2				4	1		
Provisioning services										
Freshwater		4			1	1	4			
Timber	1	4					5			
Construction Stone		3					2	1		
Regulating services										
Fresh air		4	1				4			
Carbon sequestration		1								
Pollination		1								
Local weather regulation							1			
Cultural Services										
Spiritual and religious value									1	
Birth and guardian deity										1

impact their well-being. They shared that the lack of public awareness about the linkages between forest-based activities and their own well-being results in both unsustainable collections of forest resources and inadequate knowledge with which to advocate for their own needs.

In response to the decline of ecosystem services, local communities identified a suite of management interventions that could help to bolster them (Table 6). These range from biophysical interventions, such as planting trees, to building local governance empowerment and raising awareness of the spiritual nature of the forest. Key among options for regulating resource use is to revise and regulate access to forest resources by all users, including people coming from outside of the FMUs. They advocated for empowering their own communities through ownership and management of their local forests through community forestry. To address issues related to the spiritual value of the forests, they suggested raising awareness about making regular offerings of prayers to the local deities and spirits. The groups broadly suggested that freshwater quality and quantity in the locality can be improved by planting more trees and creating community-based water user groups.

Table 6
Perceived ecosystem services management intervention by local communities.

Priority ecosystem services	Perceived threats	Management interventions
Timber	Deforestation, resources exploitation, regeneration failure	Revise and strict regulation of resources supplies Establish community-based water user groups Create awareness Local people empowerment through resources ownership and management Plantation Prevention of forest fire Revering and regular offerings of prayers to deities and spirits
Freshwater	Deforestation, resources exploitation, regeneration failure, climate change	
Construction stone	Resource exploitation	
Fresh air	Deforestation, resources exploitation, lack of awareness, climate change	
Pollination	Deforestation, resources exploitation, lack of awareness, climate change	
Local weather regulation	Deforestation, resources exploitation, lack of awareness, climate change	
Soil productivity	Deforestation, resources exploitation, soil erosion	
Carbon sequestration	Deforestation, resources exploitation, Lack of awareness, climate change	
Spiritual values	Lack of awareness	
Birth guardian deity	Lack of awareness	

4. Discussion

Our study revealed a wide range of forest ecosystem services valued by forest-dependent communities in eastern and central Bhutan. Ecosystem services provided by forests in Bhutan are recognized as indispensable for local livelihoods and as a central pillar of the cultural and economic well-being of the country (Sears et al., 2018). The communities in this study revealed greater awareness and concern for provisioning and cultural services than for supporting and regulating services, a pattern that has been found in other studies in the region (Dorji et al., 2019; Paudyal et al., 2018). This trend might reflect a lack of conceptual knowledge of ecological and biophysical processes by rural residents (Sagie et al., 2013; Iniguez-Gallardo et al., 2018). Literate community members participating in the study did mention regulating services and their importance, thus suggesting that some education about ecological and earth sciences could raise the general awareness of the breadth of services provided by natural ecosystems.

Our findings suggest an influence of gender on the perception and prioritization of ecosystem services in these rural communities. Women and men's focus groups identified 34 services in common out of 45 in total, and women consistently identified more services than men, except for cultural services. Women also identified nine unique services while men had four. Empirical research shows that women are more likely to recognize and value regulating services, while men tend to emphasize provisioning services (Kalaba et al., 2013; Martín-López et al., 2012; Oteros-Rozas et al., 2014). This was not the case in our study, where women identified more services in both categories. In concordance with Martín-López et al. (2012), we found that women identified more ecosystem services than men, but by our analysis the gender differences cannot be explained by embedded socio-culture values and prescribed gender roles, as they are elsewhere (Fortnam et al., 2018; Rocheleau and Edmunds, 1997). We suggest, rather, that the disparities here reflect women's relationship to the forest being based on a more diverse set of needs and interests than men's.

The other factors that may have an even stronger influence on local people's perceptions of ecosystem services than gender are the availability of a resource, people's knowledge of it, their ability and skill in accessing it, and their usage of it (Iniguez-Gallardo et al., 2018; Jones et al., 2016; Zoderer et al., 2016). For example, essential oils from lemon grass and limestone were mentioned only by the communities where these resources exist. One women's group felt that freshwater service was increasing due to an increase in their access to water brought about by the installation of a water piping system directly from the forest source to the village. This supports the notion that local communities recognize ecosystem services when both the potential service from nature (stock) and the demand by the beneficiaries (flow) exist (Jones et al., 2016). The concept of a socio-ecological system, where nature and

society meet, can help to provide an accounting of the stocks and flows of ecosystem services.

Of note is that the participants around the Kekhar working scheme, which is the most recently designated and smallest FMU in the study, identified the most services. This heightened familiarity with the forest services may be due to the communities' better access to the forest area prior to its more recent formal designation as a working scheme. Restrictions imposed by a formal FMU status may eventually erode the perceptions of the importance of the forest, as villagers turn elsewhere to meet their needs.

The provision of freshwater was of serious concern to the men from Lingmethang, who attributed it to two things: the evaporative rate of concrete water storage structures and the extraction of timber from upstream local forests. The perceived decline of water availability from FMUs could be attributed to the gradual removal of trees and small deforestation events, but confirming this hypothesis will require detailed qualitative and controlled studies. While there is no doubt that forests regulate water flow from upstream to downstream through water retention and flow regulation, and that water quality from the intact forest is better in the undisturbed forest compared to the deforested area (Qazi et al., 2017), there is considerable debate around the causal links between the quality of forest cover and freshwater provision (Gilmour, 2014). The impact of tree removal or deforestation on water provision depends on the initial forest condition, the intensity and scale of the disturbance, and a host of other factors (Molina et al., 2012; Goeking and Tarboton, 2020). Studies have shown that forest stand removal can increase water yield initially, but that in the longer term, with the regeneration of trees, water yield decreases and stabilizes (Moore et al., 2005). A study in northeast India, with similar mountain ecosystems to these in Bhutan, revealed that annual baseflow of water in the undisturbed montane oak forest had a higher yield compared to a deforested area (Qazi et al., 2017).

The status of belief systems can also influence the perception of ecosystem services. In this study, services associated with animistic and shamanistic beliefs were perceived as important across the communities. Worship of *Yul lha* and *Btsen* – the deity of a place – in sacred peaks, mountains, rivers, lakes, and trees are found in numerous localized forms (Pommaret, 1994; Phuntsho, 2013). The protection or wrath afforded by these deities can affect people through floods, drought, good or bad harvest, and success and failures. Setting aside sacred sites for the deities and performing rituals and other forms of worship are made by residents to ensure harmony with these deities (Phuntsho, 2013). Beliefs of supernatural protection and penalties assure the protection of these sacred places through restriction of access for development or extractive activities. These sacred places in the landscape serve as important reservoirs for ecosystem services, as they have been shown to be more intact in contrast to adjoining non-sacred places (Ormsby and Bhagwat, 2010).

The Forest Act 1995 mandates that Bhutan's public forests are managed for a sustainable supply of both commercial and subsidized rural timber through sustainable logging and management for multiple ecosystem services. Nevertheless, local perceptions of the forest sites under study were that the ecosystem services from these FMUs were largely declining. The perceived decrease of ecosystem services by local communities is a cause for concern since the changes affect not only the ecosystem integrity but also the socio-political and economic advancement of the local communities and the entire nation (Dawson and Martin, 2015). The forest management plans for FMUs prescribe silvicultural systems designed chiefly to ensure sustainable supply of timber to meet public demands through annual harvest limits and assisted regeneration after harvest. Nevertheless, study participants related a decline in their own access to forest resources through excessive harvest of productive timber by local and neighboring residents and the logging company, all of whom have legitimate rights to claim trees in the FMU (DoFPS, 2017). Study participants suggested that increasing unplanned public and private demand, even if lawful, coupled with incidences of pests and disease and forest fires, have caused a decline in their own access to timber resources. This calls attention to the need for comprehensive evaluation of the effectiveness and suitability of the existing management plans and their implementation, access rights, and harvest strategies for these forest areas. Others have made similar calls for validation studies in Bhutan (Chaudhary et al., 2017; Dorji et al., 2019; Sears et al., 2018) and across the eastern Himalayas (Chettri et al., 2010).

Community perception of the declining timber quantity and forest quality are congruous with reports that almost a quarter of Bhutan's production forests are degraded (WMD, 2017), and that deforestation is especially prevalent in the eastern and southern districts of the country (Bruggeman et al., 2016). Over-harvest of forest resources can be attributed in part to higher timber demand from Bhutan's rapid socio-economic progress and urban development (Walcott, 2009). Bhutan's forest ecosystems are also vulnerable to forest fires, especially with a drying climate in the region (Vilà-Vilardell et al., 2020). Green technologies, including wood processing innovations that increase production yields, and sustainable forest management are necessary to ensure these outcomes. Bhutan's commitments to maintaining at least 60 percent forest cover and to remaining carbon neutral (or negative) in perpetuity are also positive developments (Yangka et al., 2018).

Participating communities felt that the productive capacity of FMU forests could be enhanced and forest ecosystem services degradation could be reduced by strict enforcement of forest access and management rules, increasing public awareness and engagement on issues related to ecosystem services, and increasing people's participation in local forest management planning processes. Participants' call for improved and decentralized management of the FMUs suggests that they feel that they should share in the governance of those forests.

5. Conclusions

Our research is the first to look specifically at community perceptions of ecosystem services in commercially managed public forests in Bhutan, and as such can serve as a pilot for future studies that focus on other parts of the country and other forest types. This study, in which community members identified a total of 45 ecosystem services provided by publically managed forests, supports the notion that local forests in Bhutan support community livelihoods and well-being through the provision of ecosystem services (Dorji et al., 2019; Sears et al., 2018; Tshering et al., 2015). Participants identified a close association between the forest and spiritual well-being, expressing a belief that they are blessed by the spiritual elements of forests with multiple ecosystem services. While no specific patterns of gender-differentiated recognition of services were detected in the services identified, women identified more ecosystem services than men, including more unique services, indicating perhaps women's greater reliance on or at least perceived dependence on forest services.

In this study, we considered gender and association with a specific FMU as two factors that could influence people's perceptions about forest ecosystem services. Other influential social, cultural, and economic factors that could be considered in future research include participants age, level of education, livelihood activities, and degree of spirituality (Moutouama et al., 2019; Zhang et al., 2014). We also limited the scope of our study to five out of the 21 FMUs in the country, and only in mid-elevation forests in central and eastern Bhutan.

We recommend that the perceptions of forest ecosystem services expressed in this study should be taken as hypotheses to be tested empirically through biophysical and economic assessments. Services such as timber, freshwater yield, and soil productivity can be assessed empirically, which could help to identify causal links between management activities and the actual status of the forest ecosystems and can help to test people's perceptions (Sears et al., 2018). Should the results of empirical studies not measure up to targets defined in the forest management plans, adjustments can be made in future management

planning and activities. We also recommend educational outreach to villagers about the concept of ecosystem services and assessment practices to prepare them to contribute to their oversight of public forests. Given the widespread use of the ecosystem services conceptual framework, and Bhutan's efforts to assess the value of ecosystem services nationally, it is empowering for nature-dependent villagers to understand this way of thinking.

Empowered with knowledge about the importance of forests, and the impacts of resource extraction on the forest, community members can serve as the public eye to keep watch over the forest, exercising at least informal local governance over these forests. Knowledge about their own dependence on forest resources can help local people to be self-advocates for their continued access to the forest resources. In short, knowledge about their forests can strengthen local people's participation in the sustainable management of Bhutan's forests.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The people's perception study on ecosystem services in FMU was a component of the Sloping Lands in Transition-Bhutan project, a collaborative research program carried out between UWICER and the Center for International Forestry Research with funding assistance from the Republic of Austria. Participants across all study areas gave their best to present their perception of ecosystem services, and we are grateful for their contribution to improving our understanding of the importance of Bhutan's forest. We would like to thank all the participants from the FMUs and management of Territorial Forest Divisions from Bumthang, Mongar, Trashigang, and Zhemgang for delegating the FMU officials for facilitating the FGD successfully in respective localities. We would also like to express our sincere gratitude to the anonymous reviewers for their valuable feedback and guidance on the manuscript that helped improve the manuscript immensely. We are grateful for the selfless contribution from Mr. Jamyang Tenzin, currently affiliated with the Bhutan Tiger Center, Gelephu, and Mr. Karma Wangdi from UWICER, who were instrumental in assisting in the field work and co-moderating during the FGD. We also acknowledge the CGIAR research program on Forests, Trees and Agroforestry for making this article available to all by sponsoring CIFOR's payment of the journal's open access fee.

References

Allison, E., 2019. Deity citadels: Sacred sites of bio-cultural resistance and resilience in Bhutan. Religion 10 (4), 1–17. https://doi.org/10.3390/rel10040268.

Arias, M.E., Cochrane, T.A., Lawrence, K.S., Killeen, T.J., Farrell, T.A., 2011. Paying the forest for electricity: a modeling framework to market forest conservation as payment for ecosystem services benefiting hydropower generation. Environ. Conserv. 38 (4), 473–484. https://doi.org/10.1017/S0376892911000464.

Arora, P., Luhach, J., Sharma, M., Chaudhry, S., 2012. Mitigation of Climate Change and Role of Forest Management: A short review. Universal J. Environ. Res. Technol. 2 (4), 198–202.

Band, L.E., Tague, C.L., Groffman, P., Belt, K., 2001. Forest ecosystem processes at the watershed scale: Hydrological and ecological controls of nitrogen export. Hydrol. Process. 15 (10), 2013–2028. https://doi.org/10.1002/(ISSN)1099-108510.1002/hyp.v15:1010.1002/hyp.253.

Band, L., 2010. Forest ecosystem processes at the watershed scale: ecosystem services, feedback, and evolution in developing mountainous catchments. In: Geophysical Research Abstract. European Geoscience Union General Assembly 2–7 May, Vienna, Austria, p. 7150.

Baral, H., Jaung, W., Bhatta, L.D., Phuntsho, S., Sharma, S., Paudyal, K., Zarandian, A., Sears, R.R., Sharma, R., Dorji, T., Artati, Y., 2017. Approaches and tools for assessing mountain forest ecosystem services. Working paper 235. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Bhatta, L.D., van Oort, B.E.H., Stork, N.E., Baral, H., 2015. Ecosystem services and livelihoods in a changing climate: understanding local adaptations in the Upper Koshi, Nepal. Int. J. Biodiv. Sci. Ecosyst. Serv. Manage. 11 (2), 145–155. https://doi.org/10.1080/21513732.2015.1027793.

Bloor, M., Frankland, J., Thomas, M., Robson, K., 2001. Focus groups in social research. (Introducing qualitative methods). Sage Publications, London, UK, p. 120.

Brown, G., 2013. The relationship between social values for ecosystem services and global land cover: An empirical analysis. Ecosyst. Serv. 5, 58–68. https://doi.org/10.1016/j.ecoser.2013.06.004.

Bruggeman, D., Meyfroidt, P., Lambin, E.F., 2016. Forest cover changes in Bhutan: Revisiting the forest transition. Appl. Geogr. 67, 49–66.

Bruggeman, D., Meyfroidt, P., Lambin, E.F., 2018. Impact of land-use zoning for forest protection and production on forest cover changes in Bhutan. Appl. Geogr. 96, 153–165.

Cáceres, D.M., Tapella, E., Quétier, F., Díaz, S., 2015. The social value of biodiversity and ecosystem services from the perspectives of different social actors. Ecol. Soc. 20 (1), 62. https://doi.org/10.5751/ES-07297-200162.

Chaudhary, S., Tshering, D., Phuntsho, T., Uddin, K., Shakya, B., Chettri, N., 2017. Impact of land cover change on a mountain ecosystem and its services: Case study from the Phobjikha valley, Bhutan. Ecosyst. Health Sustainability 3 (9), 1393314. https://doi.org/10.1080/20964129.2017.1393314.

Chettri, N., Sharma, E., Shakya, B., Thapa, R., Bajracharya, B., Uddin, K., Oli, K.P., Choudhury, D., 2010. Biodiversity in the Eastern Himalayas: Status, Trends and Vulnerability to Climate Change. ICIMOD, Kathmandu.

Choden, T., 2017. Gender mainstreaming analysis and action plan. Ministry of Agriculture and Forests, Thimphu Bhutan.

Cooper, N., Brady, E., Steen, H., Bryce, R., 2016. Aesthetic and spiritual values of ecosystems: Recognizing the ontological and axiological plurality of cultural ecosystem services. Ecosyst. Serv. 21, 218–229. https://doi.org/10.1016/j.ecoser.2016.07.014.

Covey, K., Carroll, C.J.W., Duguid, M.C., Dorji, K., Dorji, T., Tashi, S., Wangdi, T., Ashton, M., 2015. Developmental dynamics following selective logging of an evergreen oak forest in the Eastern Himalaya, Bhutan: Structure, composition, and spatial pattern. For. Ecol. Manage. 336, 163–173. https://doi.org/10.1016/j.foreco.2014.10.006.

Cruz-Garcia, G.S., Sachet, E., Blundo-Canto, G., Vanegas, M., Quintero, M., 2017. To what extent have the links between ecosystem services and human well-being been researched in Africa, Asia, and Latin America? Ecosyst. Serv. 25, 201–212.

Darabant, A., Rai, P.B., Tenzin, K., Roder, W., Gratzer, G., 2007. Cattle grazing facilitates tree regeneration in a conifer forest with palatable bamboo understory. For. Ecol. Manage. 252 (1-3), 73–83.

Davidson, M., 2017. Equity and the conservation of global ecosystem services. Sustainability 9 (3), 339. https://doi.org/10.3390/su9030339.

Dawson, N., Martin, A., 2015. Assessing the contribution of ecosystem services to human well-being: A disaggregated study in western Rwanda. Ecol. Econ. 117, 62–72.

Dhital. D.B., 1997. Forest Management in Bhutan. In: Heinemann, H.R and Sessions, J (eds.) Forest Operations in Himalayan Forest with Special Consideration of Ergonomic and Socio-economic Problems. Proceedings of the IUFRO/FAO seminar. Thimphu Bhutan, page 10-15.

Dick, J.H., Yonten, D.P., 1995. A Preliminary Sectoral Environmental Assessment and a Framework for Environmental Monitoring. Third Forestry Development Project, Khangma. Trashigang, Bhutan, Third Forestry Development Project (TFDP) Report.

DoFPS (Department of Forest and Park Services), 2017. Forest and Nature Conservation Rules and Regulations of Bhutan, (fourth edition). Ministry of Agriculture and Forests, Royal Government of Bhutan, Tashichho Dzong, Thimphu.

DoFPS (Department of Forest and Park Services), 2018. Forest Facts and Figures 2017. Department of Forests and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan, Thimphu, Bhutan.

Dodge, H.F., 1955. Chain sampling inspection plan, Indust. Qual. Contr. 11, 10–13. (originally presented on the program of the Annual Middle Atlantic Regional Conference, American Society for Quality Control, Baltimore, MD, February 5, 1954; also reproduced in Journal of Quality Technology 9, 139-142 (1997)).

Dorji, T., Brookes, J.D., Facelli, J.M., Sears, R.R., Norbu, T., Dorji, K., Cheteri, Y.R., Baral, H., 2019. Socio-cultural values of ecosystem services from oak forest in the eastern Himalaya. Sustainability 11 (8), 2250. https://doi.org/10.3390/su11082250.

Elias, M., 2013. Practical tips for conducting gender-responsive data collection. Biodiversity International, Rome.

FAO (Food and Agriculture Organization), 2013. Forest and water: international momentum and action. Food and Agriculture Organization of the United Nations, Rome.

FAO (Food and Agriculture Organization), 2015. Global Forest Resources Assessment; Food and Agriculture Organization of the United Nations: Rome, Italy.

Fortnam, M., Browna, K., Chaigneau, T., Crona, B., Daw, T.M., Gonçalves, D., Hickse, C., Revmatas, M., Sandbrook, C., Schulte-Herbruggen, B., 2018. The Gendered Nature of Ecosystem Services. Ecol. Econ. 159, 132–1125. https://doi.org/10.1016/j.ecolecon.2018.12.018.

FRMD (Forest Resources Management Division), 2013. Forest Resources Potential Assessment. Department of Forests and Park Services, Ministry of Agriculture and Forests, Royal Government of Bhutan.

FRMD (Forest Resources Management Division), 2020. Forest Facts and Figures-2019. Department of Forest and Park Services, Thimphu, Bhutan.

Gilmour, D., 2014. Forest and water: A synthesis of the contemporary science and its relevance for community forestry in Asia Pacific region. RECOFT – The Center for People and Forest, Bangkok, Thailand.

Goeking, S.A., Tarboton, D.G., 2020. Forests and Water Yield: A synthesis of disturbance effects on streamflow and snowpack in western coniferous forests. J. Forest. 1–21 https://doi.org/10.1093/jofore/fvz069.

Govindaraju, R., 2006. Chain Sampling. In: Pham, H. (eds.) Springer Handbook of Engineering Statistics. Springer Handbooks. Springer, London. https://doi.org/10.1007/978-1-84628-288-1_15.
Green, J.M., Draper, A.K., Dowler, E.A., 2003. Shortcuts to safety: Risk and 'rules of thumb' in accounts of food choice. Health, Risk and Society 5, 33–52.
Greiner, C., 2017. Pastoralism and land-tenure change in Kenya: The failure of customary Institutions. Develop. Change 48, 78–97.
Hicks, C., Woroniecki, S., Fancourt, M., Bieri, M., Garcia Robles, H., Trumper, K., Mant, R., 2014. The relationship between biodiversity, carbon storage and the provision of other ecosystem services: critical review for the forestry component of the international climate fund. UK, UNEPWCMC, Cambridge.
Hofer, T., Zingari, P.C., 2003. The multiple functions of forests in sustainable mountain development and the challenge of their management. Food and Agriculture Organization, Rome, Italy.
Iniguez-Gallardo, V., Halasa, Z., Briceño, J., 2018. People's perceptions of ecosystem services provided by tropical dry forests: A comparative case study in Southern Ecuador. Tropical Forests 95–113. https://doi.org/10.5772/intechopen.75081.
Jones, L., Norton, L., Austin, Z.P., Browne, A.L., Donovan, D., Emmetta, B.A., Grabowski, Z.J., Howard, D.C., Jones, J.P.G., Kenterg, J.O., Manley, W., Morris, C., Robinson, D.A., Short, C., Siriwardena, G.M., Stevens, C.J., Storkey, J., Waters, R.D., Willis, G.F., 2016. Stocks and flows of natural and human-derived capital in ecosystem services. Land Use Policy 52, 151–162.
Kalaba, F.K., Quinn, C.H., Dougill, A.J., 2013. The role of forest provisioning ecosystem services in coping with households' stresses and shocks in Miombo woodlands, Zambia. Ecosyst. Serv. 5, 143–148.
Kandel, P., Tshering, D., Uddin, K., Lamtshok, T., Aryal, K., Karki, S., Sharma, B., Chettri, N., 2018. Understanding socio-ecological interdependence using ecosystem services perspective in Bhutan, Eastern Himalayas. Ecosphere 9 (2), e02121. https://doi.org/10.1002/ecs2.2121.
Kitzinger, J., 1994. The methodology of focus groups: The importance of interaction between research participants. Sociol. Health Illn. 16, 103–121.
Krueger, R.A., 1994. Focus Groups: A Practical Guide for Applied Research, (2nd eds.). Sage Publications, Thousand Oaks, New Delhi.
Kubiszewski, I., Costanza, R., Dorji, L., Thoennes, P., Tshering, K., 2013. An initial estimate of the value of ecosystem services in Bhutan. Ecosystem Services 3, e11-e21. http://dx.doi. org/10.1016/j.ecoser.2012.11.004.
Måren, I.E., Bhattarai, K.R., Chaudhary, R.P., 2014. Forest ecosystem services and biodiversity in contrasting Himalayan forest management systems. Environ. Conserv. 41, 73–83. https://doi.org/10.1017/s0376892913000258.
Martín-López, B., Iniesta-Arandia, I., García-Llorente, M., Palomo, I., Casado-Arzuaga, I., García Del Amo, D., Gómez-Baggethun, E., Oteros-Rozas, E., Palacios-Agundez, I., Willaarts, B., González, J.A., Santos-Martín, F., Onaindia, M., López-Santiago, C., Montes, C., 2012. Uncovering ecosystem service bundles through social preferences. PLoS One 7 (6), e38970. https://doi.org/10.1371/journal.pone.0038970.
Meijaard, E., Abram, N.K., Wells, J.A., Pellier, A., Ancrenaz, M., Gaveau, D.L.A., Runting, R.K., Mengersen, K., 2013. People's perceptions about the importance of forests on Borneo. PLoS One 8 (9), e73008. https://doi.org/10.1371/journal.pone.0073008.
MEA (Millennium Ecosystem Assessment), 2005. Ecosystem and human well-being: synthesis. Island Press, Washington DC http://www.unep.org/maweb/documents/document.356.aspx.pdf.
Mikusiński, G., Niedziałkowski, K., 2020. Perceived importance of ecosystem services in the Białowieża Forest for local communities – Does proximity matter? Land Use Policy 97. https://doi.org/10.1016/j.landusepol.2020.104667.
Moktan, M.R., Gratzer, G., Richards, W.H., Rai, T.B., Dukpa, D., 2009. Regeneration and structure of mixed conifer forests under single-tree harvest management in the western Bhutan Himalayas. For. Ecol. Manage. 258, 243–255. https://doi.org/10.1016/j.foreco.2009.04.01.
Molina, A., Vanacker, V., Bathaza, V., Mora, D., Govers, G., 2012. Complex land cover change, water and sediment yield in a degraded Andean environment. J. Hydrol. 272–473, 25–35. https://doi.org/10.1016/j.jhydrol.2012.09.012.
Moore, R., Wondzell, S.S., 2005. Physical hydrology and the effects of forest harvesting in the Pacific Northwest: A review. J. Am. Water Resourc. Assoc. 41, 763–784.
Morgan, D., 1997. Focus Groups as Qualitative Research, Second, (2nd eds.). Sage Publications, Thousand Oaks, London, UK.
Moutouama, F.T., Biaou, S.S.H., Kyereh, B., Asante, W.A., Natta, A.K., 2019. Factors shaping local people's perception of ecosystem services in the Atacora Chain of Mountains, a biodiversity hotspot in northern Benin. J. Ethnobiol. Ethnomed. 15 (38) https://doi.org/10.1186/s13002-019-0317-0.
Namgyel, P., 1996. Beyond Timber—What Value of the Forest? A Rapid Rural Appraisal Study on Non-Timber Forest Products on the Nahi Gewog. Forestry Research Centre/ Bhutan German Integrated Forest Management Project, Occasional Paper No. 1. Wangdiphodrang, Bhutan.
Norbu, L., 2002. Grazing management in broadleaf forests. J. Bhutan Stud. 99–129.
Nyumba, T.O., Wilson, K., Derrick, C.J., Mukherjee, N., 2017. The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods Ecology and Evolution 9, 20–32. https://doi.org/ 10.1111/2041-210X.12860.
Ormsby, A., Bhagwat, S.A., 2010. Sacred forests of India: A strong tradition of Community-Based Natural Resource Management. Environ. Conserv. 37, 320–326. https://doi.org/10.1017/S0376892910000561.
Oteros-Rozas, E., Martín-López, B., González, J.A., Plieninger, T., López, C.A., Montes, C., 2014. Socio-cultural valuation of ecosystem services in a transhumance social-ecological network. Regional Environ. Change 14, 1269–1289.
Paudyal, K., Baral, H., Keenan, R.J., 2018. Assessing social values of ecosystem services in the Phewa Lake Watershed, Nepal. Forest Policy Econ. 90, 67–81.
Phuntsho, K., 2013. The History of Bhutan. Random House India.
Pommaret, F.,1994. "On local and mountain deities in Bhutan". "Le culte des montagnes sacrées dans l'aire tibétaine et tibéto-birmane", Paris, France. page.39-56.
Prasad, R., 2015. Community Forestry and Management of Forest Resources in Bhutan. In: Dutt A., Noble A., Costa F., Thakur S., Thakur R., Sharma H. (eds.) Spatial Diversity and Dynamics in Resources and Urban Development. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9771-9_25.
Price, D.T., Apps, M.J., 1996. The global carbon cycle and forest land use: past, present and future. In: Apps, Michael J., Price, David T. (Eds.), Forest Ecosystems, Forest Management and the Global Carbon Cycle. Banff, Canada, pp. 17–19.
Qazi, N.Q., Bruijnzeel, L.A., Rai, S.P., Ghimire, C.P., 2017. Impact of forest degradation on streamflow regime and runoff response to rainfall in the Garhwal Himalaya, Northeast India. Hydrol. Sci. J. 62 (7), 1114–1130. https://doi.org/10.1080/02626667.2017.1308637.
Rai, P.B., Darabant, A., Dorji, T., Sangay, D., Staudhammer, C., Gratzer, G.,, G., 2014. Effects of silvicultural openings, livestock grazing, understory competition and microsites on mixed conifer regeneration in western Bhutan. J. Renewable Natural Resourc. Bhutan 10, 146–160.
Richardson, C.A., Rabiee, F., 2001. 'A question of access'- an exploration of the factors influencing the health of young males aged 15–19 living in Corby and their use of health care service. Health Educ. J. 60, 3–6.
Rinzin, C., Vermeulen, W.J.V., Wassen, M.J., Glasbergen, P., 2009. Nature conservation and human well-being: An assessment of local community perceptions. J. Environ. Develop. 18, 177–202.
Rocheleau, D., Edmunds, D., 1997. Women, men and trees: Gender, power and property in forest and agrarian landscapes. World Dev. 25, 1351–1371.
Roder, W., Gratzer, G., Wangdi, K., 2003. Cattle grazing in the conifer forests of Bhutan. Mt. Res. Dev. 22, 7.
Sagie, H., Morris, A., Rofè, Y., Orenstein, D.E., Groner, E., 2013. Cross-cultural perceptions of ecosystem services: A social inquiry on both sides of the Israelie Jordanian border of the Southern Arava Valley Desert. J. Arid Environ. 97, 38–48. https://doi.org/10.1016/j.jaridenv.
Sargent, C., Sargent, O., Roger, P., 1985. The forest of Bhutan: A vital resource for the Himalayas. J. Trop. Ecol. 1, 265–286.
Scholte, S.S.K., van Teeffelen, A.J.A., Verburg, P.H., 2015. Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecol. Econ. 114, 6778. https://doi.org/10.1016/j.ecolecon.2015.03.007.
Sears, R.R., Choden, K., Dorji, T., Dukpa, D., Phuntsho, P., Rai, P.B., Wangchuk, J., Baral, H., 2018. Bhutan's forests through the framework of ecosystem services: Rapid Assessment in Three Forest Types. Forests 9, 675. https://doi.org/10.3390/f9110675.
SFD (Social Forestry Division), 2010. National strategy for community forestry: The way ahead. Department of Forests and Park Services. Ministry of Agriculture and Forests. Royal Government of. Kuensel Corporation Limited, Bhutan Thimphu, Bhutan, pp. 1–68.
SFED (Social Forestry and Extension Division), 2016. Forestry Field Manual for Bhutan: Silviculture and Other Forestry Operations, Second edition. Department of Forests and Park Services, Royal Government of Bhutan, Thimphu, Bhutan.
Sharma, E., Chettri, N., Tsering, K., Shrestha, A.B., Jing, F., Mool, P., Eriksson, M., 2009. Climate Change Impacts and Vulnerability in the Eastern Himalayas. ICIMOD, Kathmandu.
TEEB (The Economics of Ecosystem and Biodiversity), 2010. The Economics of Ecosystems and Biodiversity: mainstreaming the economics of nature: A synthesis of the approach, conclusions and recommendations of TEEB.
Tshering, K., Dema, K., Tshering, D., Dorji, P., 2015. Assessment of forest ecosystem services in Khaling Gewog, Bhutan. J. Agroforestry Environ. 6 (2), 41–44.
UWICER (Ugyen Wangchuck Institute for Conservation and Environmental Research), 2018. Factsheet: Implementation of Integrated Watershed Management to Benefit Maximum from Hydro-Power in Bhutan. UWICER, Department of Forest and Park Services, Royal Government of Bhutan.
Van Oort, B., Bhatta, L.D., Baral, H., Rai, R.K., Dhakal, M., Rucevska, I., Adhikari, R., 2015. Assessing community values to support mapping of ecosystem services in the Koshi river basin. Nepal. Ecosystem Services 13, 70–80.
Vilà-Vilardell, L., Keeton, W.S., Thom, D., Gyeltshen, C., Tshering, K., Gratzer, G., 2020. Climate change effects on wildfire hazards in the wildland-urban-interface – Blue pine forests of Bhutan. For. Ecol. Manage. 461, 117927 https://doi.org/10.1016/j.foreco.2020.117927.
Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M., 1997. Human domination of Earth' s ecosystems. Science 277 (5325), 494–499. https://doi.org/10.1126/science.277.5325.494.
Walcott, S., 2009. Geographical field notes: Urbanization in Bhutan. Geograph. Rev. 99 (1), 81–93.
Wangai, P.W., Burkhard, B., Müller, F., 2016. A review of studies on ecosystem services in Africa. Int. J. Sustain. Built Environ. 5, 225–245.
Wangchuk, J., Choden, K., Sears, R.R., Baral, H. 2019. Ecosystem Services from Forest Management Units in Eastern and Central Bhutan. Working Paper 248. Bogor, Indonesia, CIFOR.
WMD (Watershed Management Division)s, 2017. Drivers of Deforestation and Forest Degradation in Bhutan. Department of Forest and Park Services, Ministry of Agriculture and Forests.
Wundera, S., Engel, S., Pagiolac, S., 2008. Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. Ecol. Econ. 65, 834–852.
WWF (World Wildlife Fund), 2017. Valuing Ecosystem Services in Chamkharchhu Sub Basin: Mapping sediment using InVEST. World Wildlife Fund for Nature, Thimphu, Bhutan.

Yang, Y.E., Passarelli, S., Lovell, R.J., Ringler, C., 2018. Gendered perspectives of ecosystem services: A systematic review. Ecosyst. Serv. 31, 58–67.
Yangka, D., Rauland, V., Newman, P., 2018. Carbon neutral policy in action: The case of Bhutan. Climate Policy 19 (1), 1–16. https://doi.org/10.1080/14693062.2018.1551187.
Zhang, W., Kato, E., Bhandary, P., Nkonya, E., Ibrahim, H.I., Agbonlahor, M., Ibrahim, H. Y., 2015. Communities' perceptions and knowledge of ecosystem service. International Association of Agricultural Economists, Milan, Italy 212605.
Zhang, Y., Shidong, Z., Rongchao, G., 2014. Recent advances and challenges in ecosystem service research. J. Resourc. Ecol. 5 (1), 82–90. https://doi.org/10.5814/j.issn.1674-764x.2014.01.010.
Zilberman, D., Lipper, McCarthy, N., 2006. Putting payments for environmental services in the context of economic development. Agricultural and Development Economics Division. Food Agric. Org. United Nations, ESA Working Paper No, 06–15.
Zoderer, B.M., Lupo Stanghellini, P.S., Tasser, E., Walde, J., Wieser, H., Tappeiner, U., 2016. Exploring socio-cultural values of ecosystem service categories in the Central Alps: The influence of socio-demographic factors and landscape type. Reg. Environ. Change 16, 20332044. https://doi.org/10.1007/s10113-015-0922-y.