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Cultural ecosystem services in mountain regions: Conceptualising conflicts among users and limitations of use

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ABSTRACT

Mountain landscapes provide a variety of cultural ecosystem services (CES), but recent developments such as land-use and climate changes, population growth or urbanization seem to lead more frequently to conflicts among users or restrict the use of natural resources. An enhanced understanding of such conflicts and limitations may improve decision-making and management of mountain landscapes and maintain high levels of CES supply. However, conceptual and empirical research on identifying and evaluating conflicts and limitations of use in qualitative, quantitative and spatial terms as well as interdependencies in socio-ecological systems (SES) is still rare, and suitable methods are underdeveloped. Therefore, this paper elaborates the outcomes of an expert workshop and presents eleven case studies related to different CES and various contexts to conceptualise conflicts and limitations of CES use in mountain regions, complemented by assessment approaches to facilitate their identification and management. Using a multidimensional framework, we find that conflicts were mostly related to socio-economic changes and an increasing recreational use, whereas limitations of use greatly depended on accessibility and legal issues. Our findings contribute to the advancement of research on CES and are particularly useful for landscape management and decision-making to develop sustainable solutions and maintain CES in mountain landscapes.

1. Introduction

Mountain environments are highly important for the provision of cultural ecosystem services (CES) (Tenerelli et al., 2016), which are usually defined as the non-material benefits originating from human interactions with ecosystems (Fish et al., 2016). In addition to recreational opportunities, aesthetic landscape enjoyment and inspiration (Oteros-Rozas et al., 2018; Pastur et al., 2016; Schirpke et al., 2018a, 2017), mountain landscapes offer many less commodified CES, such as national identity, landscape memory, therapeutic forests, heirloom traditions, rituals, and spirituality (Robbins and Berkes, 2000; Sarmiento and Cotacachi, 2019). In addition to the positive effects on physical and mental health (Bryce et al., 2016; Willis, 2015), for numerous mountain locations, CES have become an important economic factor for place branding and the generation of significant income from tourism (Haller et al., 2020; Schirpke et al., 2019b). However, recent developments seem to lead more frequently to conflicts among users or restrict the use of natural resources. Population growth, urbanization (Dickinson and Hobbs, 2017), land-use changes that modify ecosystems for more food, fibre, or energy production (Cumming et al., 2014) as well as climate change (Berrouet et al., 2018) alter socio-ecological systems (SES) in mountain regions. Resulting landscape changes may threaten the provision of CES and provoke conflicts among different landscape uses and related values, for example, between agricultural and touristic use

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(Bender and Haller, 2017), or between traditional use and market-driven land use (Starrs, 2018).

A major source of conflicts is the growing demand for outdoor recreation (Guo et al., 2010), which leads to an increasing frequency of recreational use, causing conflicts among recreational user groups (Needham and Rollins, 2005; Scolozzi et al., 2015), or with non-recreational users, such as forest managers, hunters, and pastoralists (Wilkes-Allemann et al., 2015). Higher visitation rates also lead to more waste, air and noise pollution, and negative visual impacts, as well as trampling and, thus, disturbance of the environment, which causes conflicts with conservation interests (Barros and Pickering, 2017; Gundersen and Vistad, 2016; Marion et al., 2016). This also applies for emerging recreational activities (e.g. downhill-mountain biking, riding fat-bikes) which are often carried out off-road and may affect sensitive ecosystems (Monz and Kulmatiski, 2016; Törn et al., 2009).

While the investment into tourism development aims to foster the local economy, it substantially alters the SES of mountain areas (Geneletti and Dawa, 2009). Indigenous groups and isolated mountain villages can be particularly affected (Díaz et al., 2019), including protected areas and other public reserves, such as national parks or ecological reserves (Sarmiento et al., 2015). Social changes including social integrity, lifestyle, and values may result in alterations of CES and related values along with impacts on the long-term economic viability of communities (Carter and Beeton, 2004; Wilson et al., 2018). This is also the case of massive investments in winter tourism in remote valleys to counteract rural depopulation (Huber et al., 2020). Those investments, however, are mostly accompanied by irreversible landscape changes by affecting natural site conservation (Sarmiento and Hitchner, 2019).

Hence, mountain landscapes need to be carefully managed, accounting for socio-cultural values of mountain communities, to assure CES provision in the long term, but CES have long been underrepresented in research on ecosystem services due to difficulties in their assessment (Bryce et al., 2016; Dickinson and Hobbs, 2017). Scientists and decision makers need to account for the multidimensional relationships between human well-being, nature as well as cultural and societal values to capture related benefits as well as to understand underlying mechanisms and drivers of change (Satz et al., 2013). Consequently, limited attention on CES weakens the development of effective management strategies and policies for assuring the provision of crucial ecosystem services (Hølleland et al., 2017; Plieninger et al., 2015). Decision-making and management needs require an enhanced understanding of underlying interdependencies between elements of the SES under scrutiny to avoid undesired side effects such as excluding beneficiaries from CES use or losing less commodified CES. Therefore, identifying and evaluating conflicts between various user groups as well as factors that restrict landscape use in qualitative, quantitative, and spatial terms is a prerequisite (Needham and Rollins, 2005; Olander et al., 2018). However, conceptual and empirical research on such complex issues is still rare, and suitable methods are underdeveloped. This is exacerbated by recent trends in recreational activities, lack of data, and limited understandings of the dependencies and interactions between CES and the different elements of related SES (Muhar et al., 2018).

Thus, to facilitate a better shared understanding, this paper aims to conceptualise and illustrate conflicts and limitations of CES use in mountain regions, as defined in Box 1. We analyse eleven case studies and elaborate on the outcomes of an expert workshop using a multidimensional framework. We also collect assessment approaches to support the management of conflicts and limitations of CES use. We discuss our results in light of recent developments and general recommendations for landscape management and decision-making.

2. Materials and methods

2.1. Methodological approach

Following Hugé and Mukherjee (2018), we applied several steps of a nominal group technique (NGT) exercise to address two research questions in three different phases (Fig. 1): (1) generating ideas and workshop preparation; (2) sharing and discussing ideas at the workshop; and (3) distilling the outputs of the workshop. In the following, we describe each phase and each step in detail.

2.1.1. Phase 1: Generating ideas and workshop preparation

2.1.1.1. Defining research questions. Based on recent literature and ongoing projects, the need to address conflicts and limitations related to CES use became evident. Accordingly, the following two research questions were identified:

Q1. What are conflicts and limitations of CES use in mountain regions?

Q2. How can we assess these conflicts and limitations of CES use?

2.1.1.2. Identifying a suitable location. The International Mountain Conference (IMC) in Innsbruck (Austria) was deemed a suitable location for bringing together experts from different disciplines. The conference was largely built on interactive workshops with flash talks, common discussions, and public poster exhibitions.

2.1.1.3. Selecting participants. To reach experts in ecosystem services and/or mountain issues, the workshop call was distributed through

Box 1

Definitions

Conflicts are diverging interests between two or more different beneficiaries or stakeholders with opposing opinions, principles, or perceptions. Conflicts may arise between CES beneficiaries and other beneficiaries or stakeholders (e.g. forest managers, hunters, farmers, herders, residents, tourism industry, nature conservationists, industries and enterprises, public entities, and land owners), as well as between different beneficiary groups of CES (e.g. hikers vs. bikers).

Limitations are restrictions of use, which may exclude (potential) beneficiaries from the use of CES, permanently or temporarily. Limitations can be caused by environmental processes (e.g. weather, natural hazards) or can be driven by governance decisions resulting from past conflicts (e.g. access regulations in protected areas).

Beneficiaries are any person or group whose well-being is positively influenced by CES, through active or passive consumption, or through simple appreciation resulting from the awareness of these services (Nahlik et al., 2012).

Stakeholders are any individual, group, corporation, organization, or system that can affect or is affected by the services provided by ecosystems (Hein et al., 2006).

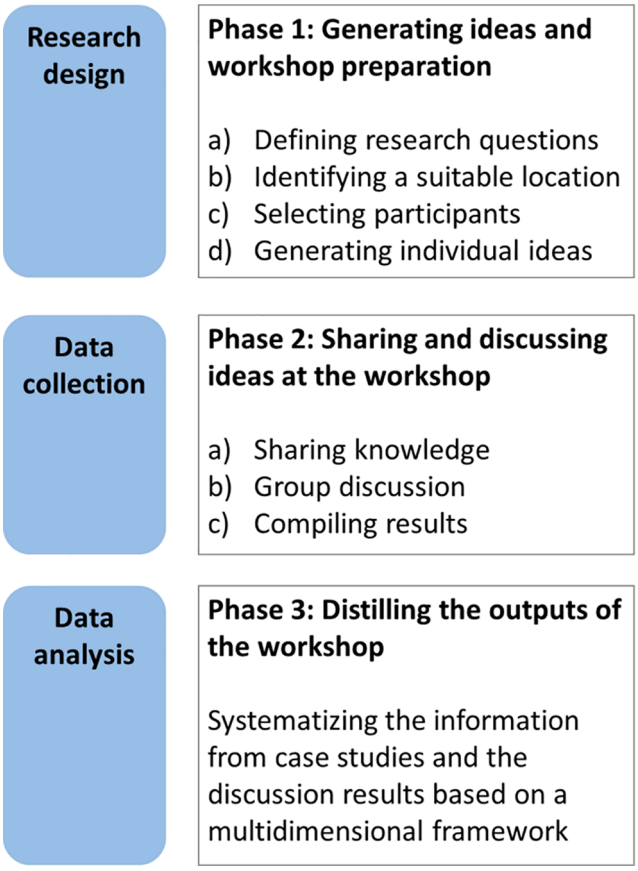

Fig. 1. Conceptual steps based on a typical nominal group technique (NGT) exercise, modified from Hugé and Mukherjee (2018).

various channels, including the Ecosystem Services Partnership (ESP) or the Mountain Research Initiative (MRI). In the call for contributions, the aim of the workshop was presented together with a description of the research background and the main research questions. Interested participants could submit an abstract explaining their contribution to the questions based on own case studies. The workshop organizers evaluated the abstracts and accepted contributions based on their relevance for answering these research questions.

2.1.1.4. Generating individual ideas. Before the workshop, the organizers sent detailed information on the research questions to all participants. The participants were asked to reflect on the questions and to prepare ideas and issues related to the two research questions based on their expertise and case studies. Moreover, the participants prepared a flash talk as well as a poster to share their experiences.

2.1.2. Phase 2: Sharing and discussing ideas at the workshop

2.1.2.1. Sharing knowledge. In the first part, participants shared knowledge from case studies in three-minute flash talks. To highlight various issues related to conflicts and limitations of CES use, these presentations reported new findings from fieldwork and data analysis from different mountain regions. This part had a duration of about 45 min.

2.1.2.2. Group discussion. The second part aimed at generating and grouping ideas in an open discussion. Participants discussed one of the two research questions in two different groups. The group discussing the first question collected their ideas using a simple mind map. The second group collected and discussed a variety of approaches to assess CES in qualitative or quantitative terms, using sticky notes to collect methods and tools. Facilitators ensured that everyone took part in the discussions and stimulated the grouping of the ideas. This step lasted 45 min.

2.1.2.3. Compiling results. In a final plenary discussion, the main results of each group discussion were shortly presented to the other group. The results of both groups were then combined by placing together the sticky notes onto the mind map. During this step, all participants could integrate and highlight the importance of the various ideas. The plenary discussion lasted 30 minutes. After the workshop, the discussion continued in small random groups during a dedicated poster session with the posters prepared by the participants for at least another 45 minutes. At this occasion, participants discussed also in more detail specific issues related to the individual case studies.

2.1.3. Phase 3: Distilling the outputs of the workshop

All collected ideas from the mind map and the sticky notes were digitized. As the workshop participants stated that there is a need for a theoretical framing of the discussed research questions, we developed a multidimensional framework, based on existing frameworks, to assess and conceptualise conflicts and limitations of CES use in mountain regions. We used this framework to analyse and systematize the results of the workshop discussions as well as the case studies.

2.2. Multidimensional framework

To assess conflicts and limitations of CES use, as outlined in Box 1, we used a multidimensional framework embedded in a mountain SES (Fig. 2), which is based on other frameworks such as Berrouet et al. (2018), Bretagnolle et al. (2019), Torralba et al. (2018), and Ostrom (2009). A multidimensional framework that addresses the complexity of SES is an adequate tool to identify changes in each variable and the direction of change (Ferrara et al., 2016). As CES are co-produced by human-nature interactions (Fish et al., 2016), conflicts and limitations may arise from four sources within the SES as well as from external factors:

- *Social system*: The social system comprises social, economic, political, and cultural assets and represents the demand for CES (Muhar et al., 2018). Conflicts may arise between the social system and CES use, as different stakeholders may have different interests in how to use the ecological system (Needham and Rollins, 2005). The distribution of power within the social system is critical (Felipe-Lucia et al., 2015), including gender relations, cultural minorities, and social classes, as these may lead to unfair outcomes, limiting the use of specific CES. Socio-economic changes that are reflected in the landscape often affect the provision of CES or may even lead to a loss of CES (Lasanta et al., 2018; Schirpke et al., 2017; Starrs, 2018; Huber et al., 2020), causing conflicts and limitations with CES beneficiaries and users.
- *Governance*: Public and private actors of the social system aim through governance processes at regulating human-nature interactions to meet the demand for goods and services (Loft et al., 2015). Consequently, socio-economic and political decisions influence the type of land use and environmental management can improve or reduce the capacity of ecosystems to contribute to CES supply (Fish et al., 2016; UNU-IAS et al., 2014). If governance does not explicitly address CES, for example, due to lacking information or knowledge (Loft et al., 2015), decisions or management may cause conflicts and limitations (Hølleland et al., 2017; Satz et al., 2013).
- *Ecological system*: The mountain landscape contributes to CES supply by its environmental assets such as climate, topography, land cover, and biodiversity (UNU-IAS et al., 2014). Natural conditions may generate limitations on CES use, in particular, in high-elevated areas (Schirpke et al., 2019a). Human use highly affects the ecological system and shapes cultural landscapes, for example, through specific

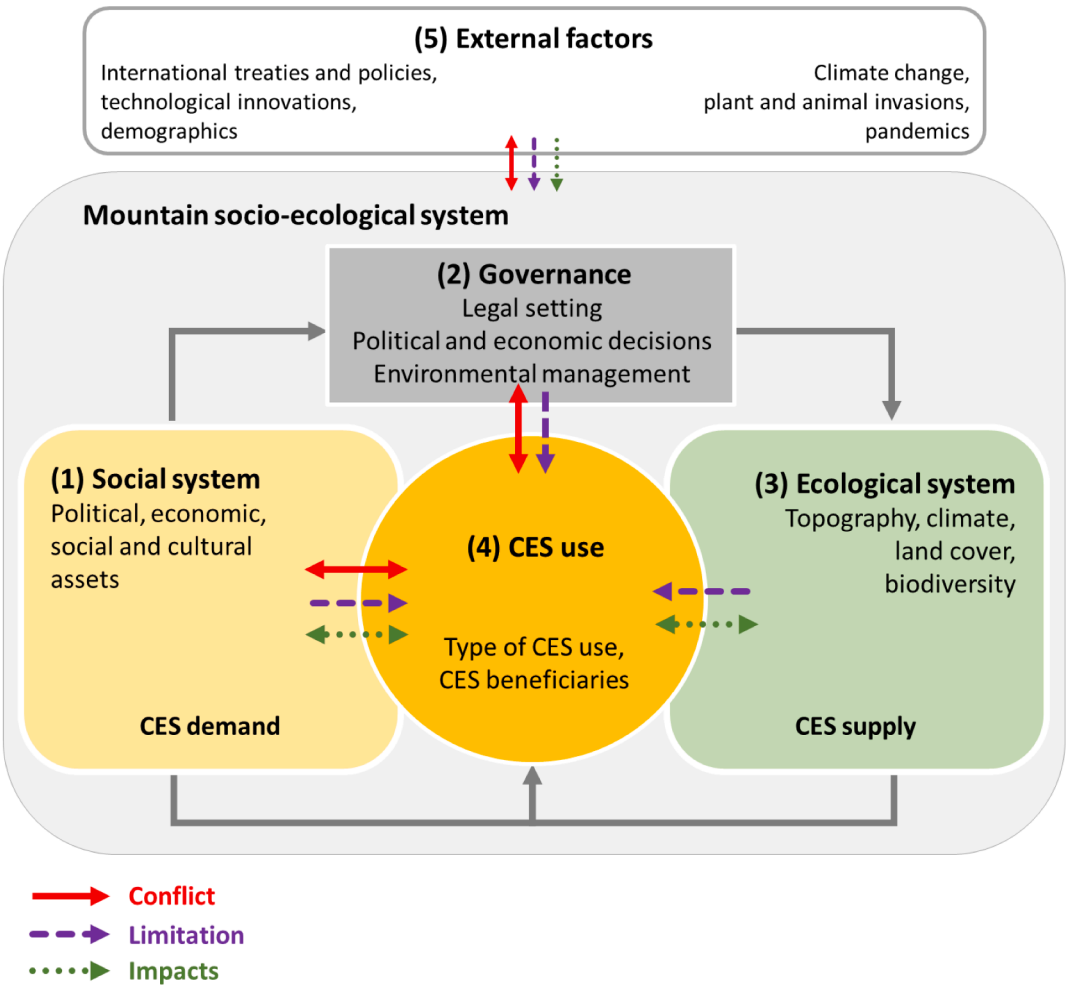

Fig. 2. Multidimensional framework used for identifying conflicts and limitations of CES within regional socio-ecological systems (SES). Conflicts and limitations of CES can originate from four sources within the regional SES: (1) social system; (2) governance; (3) ecological system; and (4) CES use. Grey arrows represent the linkages between the social and the ecological system. Conflicts arise from interactions between at least two beneficiaries/user groups/actors (red arrows). Purple arrows (dashed) indicate the direction of limitations that reduce the use of CES. Additionally, (5) external factors influence the regional SES and may be an additional source of conflicts and limitations. Potential impacts on mountain SES from CES use, socio-economic or environmental changes may generate further conflicts and limitations of CES use (green dotted arrows).

agricultural practices (Egarter Vigl et al., 2016; Lasanta et al., 2018; Schirpke et al., 2017; Starrs, 2018).

- *CES use:* Conflicts can include two or more different user groups of CES (Bogardus, 2012; Scolozzi et al., 2015), but they can affect also farmers or hunters (Wilkes-Allemann et al., 2015). An increasing CES use may also have negative impacts on the ecological system (Barros and Pickering, 2017; Gundersen and Vistad, 2016) or the social system (Geneletti and Dawa, 2009) and may lead to new conflicts or limitations of use.
- *External factors:* Mountain SES are further embedded into national/global SES, which may generate conflicts and limitations if, for example, socio-economic interests or land-use policies diverge from those of the regional SES (UNU-IAS et al., 2014; Valipour et al., 2014). In addition to international socio-economic, demographic, and technological developments, external factors include environmental changes such as climate variations occurring at the global level.

Additionally, socio-economic (e.g. tourism development, land-use change) or environmental processes (e.g. climate change) may cause impacts on CES supply and may lead to conflicts between different beneficiaries or stakeholders as well as to limitations of use. CES use may also generate impacts on the environment (e.g. overuse, disturbance of wildlife) or reduce the quality of CES permanently or temporarily (e.g. overcrowding, noise, pollution).

2.3. Conference workshop

A workshop on "Cultural ecosystem services - conflicts and limitations" was organized at the International Mountain Conference (IMC) 2019 on 09 September 2019 in Innsbruck (Austria) by two researchers, one from the University of Innsbruck and the other from the University of Trento (Italy). The aim of the workshop was to discuss the two research questions with researchers working on CES in mountain regions. Eleven researchers from various research disciplines (anthropology, ecology, ecological economy, geography, sociology), including the organizers, and coming from six different countries (Austria, France, Italy, Mexico, Spain, USA) participated in the workshop (Table S1 of the supplementary material). All participants were familiar with the underlying concepts and could therefore concentrate on developing the issues raised. Although the research questions were rather broad, this allowed collecting a greater variety of experiences and ideas. In addition to group discussions, results from case studies were shared.

2.4. Case studies

The participants presented experiences related to conflicts and limitations of CES based on eleven case studies (Table 1, Fig. 3). Six case studies focused on the European Alps, two on the Andes, one on the Trans-Mexican Volcanic Belt, and two on mountain ranges worldwide. Seven case studies focused at the local level, three at the regional level, and one at the national level. The case studies were located in different climate regions such as tropical, semi-arid, and temperate zones and extended over large elevational ranges. Therefore, a variety of landscapes was covered, ranging from lower-elevated cultural mountain landscapes dominated by forest, grassland, settlements, and arable land up to high-mountain landscapes with glaciers, rocky and barren land, and alpine grassland. The case studies addressed a variety of CES including outdoor recreation, aesthetic values, spiritual values, and biocultural heritage. Most studies involved and targeted stakeholders as well as related beneficiaries.

3. Results

3.1. Examples of conflicts and limitations of CES use

The group discussions and the case studies provided various examples of conflicts and limitations of CES use (Table 2). According to the definitions in Box 1, we distinguish between conflicts and limitations. In the following, we use the IDs indicated in Table 1 to refer to the case studies.

3.1.1. Conflicts of CES use

Conflicts originating from the *(1) social system* were mainly linked to socio-economic changes. Economic and political decisions such as land-use change, tourism development, or land conservation were major underlying drivers, which caused conflicts with traditional landscape use and related CES. These included the need to maintain microrefugia for biocultural heritage (C10) or a marginalization of certain user groups, such as pastoralists, which provoked conflicts with other user groups (C9). Aesthetic values, cultural identity, history, sense of place, landscape memory, etc., were affected by landscape changes not only due to agricultural intensification (C9, C10), but also when mountain communities shifted their economic focus from agriculture to tourism (C7). While tourism infrastructures were created to sustain the local economy, yet bringing more tourists to 'pristine' spots and environmentally sensitive areas (C4, C5), conflicts between users or between different uses have increasingly been recognized by both residents and tourists (C1).

Such changes in the social system may be reflected in *(2) governance* through land-use policies. Moreover, governance may be a source of conflicts due to unclear legal settings, formal vs. informal rules or the distribution of rights (C2, C5). An example is the expansion of illegal settlements on the outskirts of Mexico City. It is a delicate issue for the local government, especially when it comes to nature conservation areas and natural parks, as it is the case in Los Dinamos. Besides the irregular legal situation, it is affecting landscape values, like natural and aesthetic values, and the perception of safety by the local community and visitors of the park (C2).

Conflicts arising directly from *(4) CES use* were related to an increasing or changing demand for outdoor recreation, which had various impacts (Fig. 4). Increasing numbers of recreational users provoked conflicts among different CES user groups, for example, hikers vs. bikers (C1). Such conflicts occurred mainly when too many people carried out recreational activities at the same time and place (C1, C2), leading also to overcrowding and overuse (C6). Spatial expansion of recreational activities such as ski mountaineering or mountain biking, caused ecosystem degradation or disturbance of wildlife (C1, C3). In addition, touristic infrastructure and measures had negative impacts on biodiversity and ecosystems (C2). For example, in glacier ski resorts, geotextiles are exposed on ski slopes to increase albedo and hence reduce ablation. This measure is crucial as a method of snowfarming, but there are also safety issues when pylons are solely fixed into the ice. However, geotextiles are not only altering living conditions for cryobiota (mainly microbially dominated), but also release large amounts of plastic fibres due to abrasion (C4). Such environmental impacts from CES (over)use caused conflicts with landowners, foresters, hunters, nature conservationists, public entities, etc.

Finally, *(5) external factors* that influence the mountain SES can cause conflicts. On the one hand, conflicts were caused by socio-economic changes (C9); on the other hand, new technologies (e.g. E-Bikes) may create new CES user groups, getting into conflict with other user groups.

3.1.2. Limitations of CES use

Limiting factors arising from the *(1) social system* included infrastructural constraints, such as fences, walls, poorly developed public roads, or insufficient transportation services (C2, C7). Such constraints may also concern capacity constraints, which limits the number of people who can benefit from CES at a certain time. For example, mountain huts have limited space for overnight stays, and some managers of the huts restrict access with an early-booking policy (e.g. in Austria, C6), some with a lottery system, and some via pricing. Security constraints were further important, for example, in regions that are politically instable (C10) or where people are afraid of being attacked or robbed (C2).

Legal constraints, arising from *(2) governance*, prohibited or limited access for recreational purposes or pastoral use. For example, the core zone of protected areas or winter rest zones should not be used for recreational activities for the protection of wildlife (C3, C5). Such constraints often aimed to protect biodiversity through access or use regulations (C5, C6, C8). Access rights, primarily determined by land ownership (private or public), may also exclude specific types of uses (C9, C11) or are related to entry fees or travel fees, for example, mountain tourism in Bhutan.

Limitations related to the *(3) ecological system* originated from extreme weather conditions, avalanches, or floods (C6) as well as rock fall due to thawing permafrost (e.g. in the Alps in spring and summer; C6, C7). Most of such limitations are not permanent and may not affect all users equally, if personal constraints, such as the physical condition of a person, do not allow them to reach remote locations or to use difficult/steep trails (C6).

Furthermore, *(5) external factors* can provoke limitations of CES use. For example, higher temperatures increase frequency and intensity of natural hazards, affecting accessibility and CES use in high-mountain areas (C7).

3.2. Assessing conflicts and limitations of CES use

Workshop participants collected possible approaches to assess conflicts and limitations of use during the group discussion. In addition, the case studies applied different methods, which were attributed to the four dimensions of the framework. These included different data collection methods, various mapping techniques, and social assessment approaches (Table 3).

To capture conflicts and limitations of use arising from the *(1) social system*, it was important to gather stakeholder perceptions as well as the variety of landscape values (questions 1 and 2 of Table 3). Accordingly, assessment approaches included various social-sciences methods such as interviews, surveys, group discussions, stakeholder workshops, or content analysis (C1, C2, C5, C6, C7, C11) to gather information on conflicts in qualitative terms.

(2) Governance needs information on environmental quality and desirable levels of use (questions 3 and 4 of Table 3), which may be derived from various assessment approaches such as trade-off analysis, system dynamics modelling (C8), stakeholder workshops (C1), and

Table 1
Overview of case studies. Further details are presented in Table S2 of the supplementary material.

ID	Key issues addressed	Location	Elevation range [m a.s.l.]	Area [km^2]	Mountain range	Landscape/ ecosystem type	CES addressed	Stakeholders and/ or beneficiaries targeted	Scale	References
C1	Identifying and locating major conflicts	Kleinwalsertal (Austria)	1086–2536	96.9	European Alps	Cultural mountain landscape (settlements, forest, grasslands, rocky and barren areas)	Outdoor recreation, nature observation, research and education, aesthetic experience, natural heritage, symbolic inspiration, cultural landscape value	All stakeholder groups, beneficiaries (visitors, residents)	Local	https://www.gde-mittelberg.at/Natur-bewusst-erleben
C2	Evaluation of social values and management challenges	Los Dinamos, Mexico City (Mexico)	2400–3850	30	Trans-Mexican Volcanic Belt	Natural park in suburban landscape (forest, settlements)	Outdoor recreation, ecotourism	Beneficiaries (visitors)	Local	Kovács, B. et al.
C3	Identifying potential conflict zones between ski mountaineering and wildlife	Tyrol (Austria)	465–3798	12,640	European Alps	Cultural mountain landscape (settlements, agricultural land, forest, grasslands, rocky and barren areas)	Outdoor recreation	Stakeholders (NGOs in nature conservation)	Regional	Jäger et al. (2020)
C4	Analysing and mitigating the consequences of geotextiles on glacial surfaces used for snow farming	Glacier ski resorts (Austria)	~2600–3300	N/A	European Alps	Glacier	Outdoor recreation	Stakeholders (managers of glacier ski resorts, public administration), beneficiaries (visitors)	Local	Sattler and Weisleitner (2019)
C5	Identifying challenges and chances related to mobile wooden houses	Eisenwurzen (Austria)	~200–2,300	5904	European Alps	Forest	Outdoor recreation, aesthetic values	Stakeholders (public administration, tourism industry, managers of protected areas, small and medium enterprises, land- and forest owners), Beneficiaries (visitors)	Regional	Kister et al. (2019)
C6	Capturing the influence of mountaineering on alpine nature and analysing welfare benefits of CES	Tyrol (Austria)	1650–3768	22	European Alps	High-mountain landscape (glacier, permafrost, rocky and barren areas, alpine pastures and meadows)	Aesthetic values, outdoor recreation	Beneficiaries (visitors)	Local	https://www.uibk.ac.at/geographie/agef/projects/hight/
C7	Analysing changes in accessibility, landscape pattern and actual supply of aesthetic values since the beginning of tourism	Sölden (Austria)	1285–3768	466.8	European Alps	Cultural mountain landscape (settlements, forest, grasslands, rocky and barren areas)	Aesthetic values	N/A	Local	Schirpke et al. (2019a)
C8	Using systems thinking and causal loop diagrams to address and to anticipate	Protected areas (global)	N/A	N/A	N/A	Protected areas	Outdoor recreation	Stakeholders (managers of protected areas), beneficiaries (visitors)	Local	Scolozzi et al. (2019)

(*continued on next page*)

Table 1 (*continued*)

ID	Key issues addressed	Location	Elevation range [m a.s.l.]	Area [km^2]	Mountain range	Landscape/ ecosystem type	CES addressed	Stakeholders and/ or beneficiaries targeted	Scale	References
	environmental problems around the enjoyment of CES									
C9	Analysing the relationship between pastoralism and natures' contribution to people	Grasslands (global)	N/A	N/A	N/A	Various grassland types	Learning and inspiration, physical and psychological experiences, supporting identities	N/A	National	Dean, G. et al.
C10	Analysing changes in landscape transformation and conservation effectiveness	Uchucay reserve (Ecuador)	900–3200	220	Andes	Tropical montane cloud forests, agricultural land, pastures	Spiritual values, biocultural heritage and microrefugia	Stakeholders, beneficiaries (residents, visitors)	Local/ regional	Donoso and Sarmiento (2020); Minga et al. (2019); Sarmiento and Cotacachi (2019)
	Analysing erodibility risk, accessibility, landscape pattern and migration trends for conservation	Paute River basin (Ecuador)	1600–2250	6419		Dry interandean forest, montane shrub, tropical montane forests, orchards and pastures				
	Assessing aesthetic values and spiritual dimension of conservation in the watershed	Imbakucha (Ecuador)	2250–4000	150.7		Dry interandean forest, montane shrub, tropical montane forest, agriculture and pastures				
C11	Assessing regional conservation strategies along the urban–rural continuum	Shullcas River subbasin (Peru)	3580–5557	155	Andes	High-mountain landscape (grassland, rocky and barren areas, glacier)	Spiritual values	Stakeholders	Local	Haller and Córdova-Aguilar (2018)

scenario analysis. The definition of an acceptable impact is controversial, and it requires not only qualitative and quantitative data, but also a map of processes underlying the interventions and the impacts, for example, reinforcing demand of accessibility and economic benefit (C8). This includes a strong social component in terms of asking 'Access for whom?'. Recreational activities in mountain areas can be accessible for elderly people, people with special needs, female groups, or children of all ages; but eventually, it will take a greater effort for the management to build the necessary infrastructure.

To address/identify/explore conflicts and limitations of use that involve the *(3) ecological system*, mostly spatial analysis methods (C3) were used to identify and map potential impacts on ecosystems or species (question 5 of Table 3). Such analyses were based on or integrated by field surveys to collect vegetation samples or to measure specific environmental parameters (C4, C10).

A detailed assessment of conflicts originating from *(4) CES use* requires mixed methods. On the one hand, high-resolution mapping using GPS-tracking (C3, C6) or on-site observations (C2) can provide information on potential conflict zones (questions 6 and 7 of Table 3). To address impacts on values or acceptable levels of use (questions 8 and 9 of Table 3), social-sciences methods such as interviews, surveys, group discussions, and stakeholder workshops were mostly used (C1, C2, C5, C6).

4. Discussion

4.1. Conflicts and challenges related to changing socio-economic conditions

It is widely acknowledged that CES may be generated by specific uses of the landscape – for example, traditional farming activities have shaped cultural landscapes with a high level of cultural identity (Davies et al., 2016; Nahuelhual et al., 2014; Sarmiento, 2018) – which are important to the local population and attractive for visitors (Plieninger et al., 2015). This means also that CES are vulnerable to land-use changes resulting in, for example, loss of cultural identity or aesthetic values (Hanaček and Rodríguez-Labajos, 2018; Zoderer et al., 2016). In line with these studies, our results indicate that changing environmental and socio-economic conditions have considerable impacts on CES, leading to conflicts among different types of users, restrictions of use or even a loss of CES. Similarly, declining pastoral activities have caused a loss of CES, such as local traditional knowledge, that is, how to use limited resources and deal with climatic and other uncertainties (e.g. diseases, extreme events such as fire or floods), while pastoralism modified the landscape to better accommodate human needs in the past (Starrs, 2018).

Despite the wide-ranging negative effects of increasing demand for outdoor recreation on social structures and landscape use (Kohler et al., 2017; C7), a controlled development may have positive effects on

Fig. 3. Case study details: a) touristic landscape (C1); b) natural park in proximity to Mexico City (C2); c) ski mountaineering in a pristine winter landscape (C3); d) glacier covered by geotextiles (C4); e) mobile wooden home (C5); f) people around a mountain hut (C6); g) high-mountain landscape in Austria (C7); h) chamois in a national park in Italy (C8); pastoralism in the European Alps (C9); j) Interandean landscape in the Uchucay Community Reserve (C10); k) Cordillera Huaytapallana (C11); and l) location of case studies (IDs refer to the case studies; see Table 1). Photos by Uta Schirpke if not indicated differently.

mountain SES. Particularly in remote areas, where people often abandon agri-pastoral activities, value creation through local timber products can help to support the local economy and restore CES (C5, C6). In most tropical mountains, declining traditional agricultural activities and decreasing forest cover have caused a loss of CES, such as sacred foods, inspiration, and mythology (Sarmiento, 2012). The important preservation of biocultural heritage in traditional practices is suddenly replaced by mechanized agriculture, monocultures, and invasive exotic species (C10). These have changed the essence of the original farmscape into a globalized agro-industrial setting, in most cases catering to the 'hungry' tourist that goes to the mountains for a flair of authentic values, including food hubs, heirloom varieties, and ancient recipes that prompt their tourism experiences (C10; Sarmiento, 2018, 2012). Linking tourist food consumption to the local extensive agricultural production that supports the CES supply in mountain areas could be a sustainable management solution (C6). Furthermore, in pastoral systems, traditional governance systems are often overlooked, even though there is strong evidence to support that land governance is a cultural issue (Davies et al., 2016).

4.2. Conflicts and impacts from increasing recreational use

In line with other studies (e.g. Geneletti and Dawa, 2009; Huber et al., 2020; Pickering and Hill, 2007), our results indicate that an increasing or changing demand for outdoor recreation has important effects on SES in general, and on biodiversity, ecosystems as well as on related provisioning and regulating ecosystem services in particular. The case studies pointed out that various recreational activities were carried out off-road and affected sensitive environments (C1, C3, C5), which is also reported by other studies (e.g. Monz and Kulmatiski, 2016; Newsome and Davies, 2009; Törn et al., 2009). Other examples are paragliding and snowmobiling affecting the nesting of golden eagles (Chamberlain et al., 2016), rock climbing with negative impacts on snail communities (McMillan et al., 2003), and winter sports causing stress in wild animals (Arlettaz et al., 2015). It is well recognized that recreational activities in general may lead to the degradation of soils and plant species (Pickering and Hill, 2007), but effects of emerging recreational trends (e.g. downhill-mountain biking, fat-bikes) are often not yet understood and barely managed (Monz and Kulmatiski, 2016). This may

Table 2
Conflicts and limitations of CES use mentioned during the group discussion (indicated with 'D') or in the case studies (indicated by IDs, see Table 1). The examples are attributed to different possible sources of conflicts or limitations of the multidimensional framework and are not listed in any order of importance.

Source	Conflicts	Limitations
(1) Social system	Agricultural intensification (C9, C10) Socio-economic change (C9) Financial interests (C4) Social relationships (power distribution) (D) Perception of status (D, C9) Stakeholder interests (D, C1, C8) Demographic development (C9, C10)	Roads and paths (C2, C6, C7) Tourism infrastructure (D, C2) Transportation (C2) Safety/security (D, C2, C6) Financial constraints (D)
(2) Governance	Land-use policies (D) Laws, legal system (formal/informal), property/use rights (D) Type of governance (traditional vs formal) (D)	Land ownership (D Access rights/fees (D, C11) Regulations (e.g. biodiversity conservation) (C5, C6, C8)
(3) Ecological system		Weather conditions (D, C6) Natural hazards (C2, C6) Topography (C6, C7) Dangerous animals (D)
(4) CES use	New recreational trends (C3) Spatial and temporal expansion (C1, C3) Different user groups of CES with conflicting interests (D, C1, C2, C6) Restriction of traditional practices (D, C9, C10) Landscape change (C7) Ecosystem degradation (C5, C6, C8) Overuse, e.g. extensive mushroom picking, trampling (C6, C8) Overcrowding (D, C1, C8) Pollution (C4, C5)	
Sources	Conflicts	Limitations
(5) External factors	Market conditions, e.g. putting pressure on traditional farming or on tourism (C9) Economic exploitation of resources, e.g. extractive industries (D) Technological innovations, e.g. E-Bikes (D)	Climate change (C7)

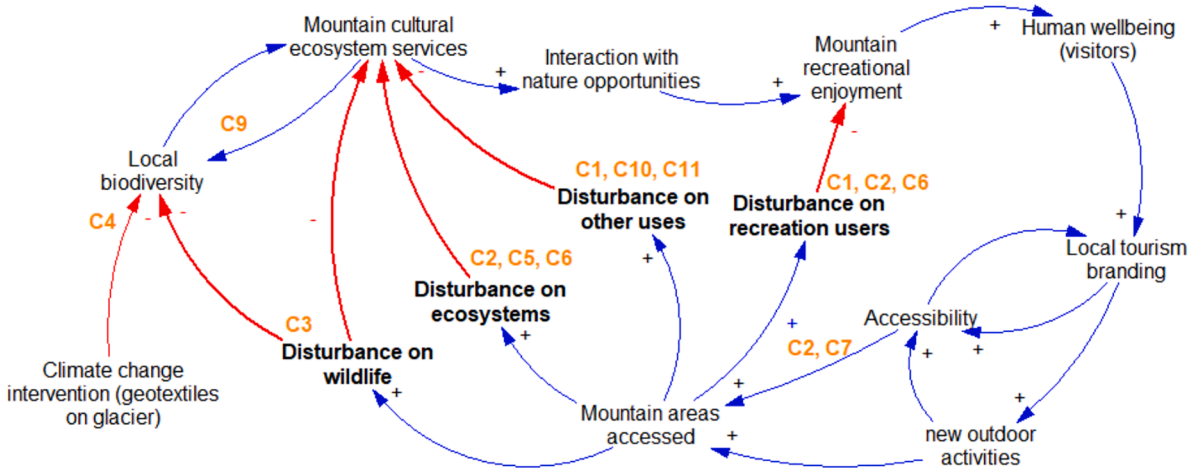

Fig. 4. Causal loop diagram indicating various consequences of an increase in accessibility to mountain areas. Bold text highlights different types of disturbance, identified from the case studies (IDs refer to the case studies; see Table 1). Red arrows indicate negative impacts or a decrease; blue arrows represent positive effects or an increase.

lead to new conflicts, for example, between recreational users and nature conservationists (C3, C5).

The spatial expansion of recreational activities is also notable across landscapes. People increasingly use nearby mountain locations for outdoor recreation due to decreasing recreational opportunities in lowland regions and foothills (Dickinson and Hobbs, 2017). However, mountain areas located in proximity to urban agglomerations are often visited by day-trippers (Schirpke et al., 2018b), which can cause considerable negative side effects such as noise and air pollution or crowding (C1, C8). Such issues are increasingly causing conflicts, which require the development of new management strategies and governance solutions, including access restrictions (C1; Scuttari et al., 2019).

Tourism development often requires measures to improve the touristic infrastructure and may lead to landscape changes through, for example, construction of ski slopes where the terrain is modified mechanically (C7). This not only has negative effects on soil properties (Pintaldi et al., 2017), but also on other CES, such as aesthetic values (Schirpke et al., 2013). Impacts related to new practices for providing recreational opportunities, however, are not yet sufficiently studied and understood. For example, covering glaciers with geotextiles to prevent losses of snow masses due to ablation are a major source of plastic pollution affecting cryobiota (Sattler and Weisleitner, 2019). It is still unclear if those fibres and particles are hampering macrozoobenthos living in glacial rivers, but they could also possibly have effects in terms of a manifestation in melted water. This applies not only to the case study in Austria (C4), but also to all glacier ski resorts in Europe using geotextiles to reduce ablation. Similarly, there is an urgent need to examine trade-offs between increasing tourism and water quality and

Table 3
Examples of methods and data types to address strategic questions for managing conflicts and limitations of CES use, collected during the group discussion (indicated with 'D') or indicated in the case studies (indicated by IDs, see Table 1).

	Strategic questions for management of CES	Methods	Data
(1) Social system	1. How many types of values are recognized in the area? 2. What are the perceptions of different users with respect to other uses? (e.g. indifference or conflict about sharing space or about the quality of the experience)	Citizen science projects (D) Content analysis of local newspaper articles (C11) Content analysis of narratives (D) Participatory mapping (C8) Interviews and surveys (individuals and groups) (C1) Stakeholder workshop (C1, C5) Monetary valuation (travel-cost, willingness to pay) (D)	Economic data (benchmarks, surveys) (D) Social media data (D) Historical data from interviews with elderly residents, photos, maps, demography, LTSER sites (long-term monitoring) (D) Socio-demographic data (D)
(2) Governance	3. What are the common references regarding long-term environmental quality levels? 4. What are the desirable levels of accessibility for different users?	Trade-off analysis (D) System dynamics modelling (C8) Review of quality definitions and standards (e.g. mass tourism vs. 'slow tourism') (D) Scenario analysis (accessibility, impacts) (D) Risk assessment (dis-services) (D) Stakeholder workshop (C1)	Sustainability indicators (D) Biodiversity indicators (D) Environmental data (C1) Socio-demographic data (D)
(3) Ecological system	5. What are the impacts of each type of use on the interested ecosystems?	Ecological modelling (C3) Spatial (overlap) analysis (C3) Geostatistical analysis (C7) Viewshed analysis (C7) Time-series analysis (C7) Laboratory experiments (C4) On-site observations and measurements (C4) Vegetation sampling (C10)	Biodiversity indicators (D) Data from field observations and measurements (C4) Land use/cover data (C7) Digital elevation model (C7) Drones, air-borne satellite imagery (D)
(4) CES use	6. How many types of uses and users are present in the same area? 7. What are actual or potential spatial and temporal overlaps between different uses? 8. What are the impacts of each type of use on the potential value for other uses? 9. What are the maximum levels of accessibility for different uses/users in the different sensitive areas?	Interviews and surveys (individuals and groups) (C1, C2, C5, C6) Focus group discussion (C5) Temporal analysis (C3) On-site observations (C2) Content analysis of pictures and photos (C6) GPS-tracking (C6) Trade-off analysis (C11) Meta-analysis (C9) Participatory mapping (D) Stakeholder consultation (C1)	GPS data (smartphone; GPS-tracking devices; data from sport- or health-related self-management-devices, such as sport clocks or providers) (C3, C6) Big data (ethnographic research using computer data and science) (D) Numbers of users from counting stations (C3)

quantity of mountain rivers, which has significant impacts on downstream populations. For instance, Magdalena River in Los Dinamos (Mexico) has the highest value of contamination in proximity of food stalls, trout ponds, and increased numbers of visitors, which is affecting the needs of the population in the southwest of Mexico City (Jujnovsky et al., 2017).

4.3. Limitations of CES use originating from accessibility and legal settings

Similar to other categories of ecosystem services, accessibility is crucial to spatially link ecosystems with beneficiaries (Ala-Hulkko et al., 2016; Syrbe and Grunewald, 2017), as it enables or prevents the use of many CES (C2, C5, C6, C7, C11). However, it became clear during the discussions that accessibility may include different aspects and that researchers need to define what they mean by this term. Participants carrying out research in the European Alps associated accessibility mainly with whether a location can be reached, that is, whether the necessary infrastructure is provided (Koppen et al., 2014; Tenerelli et al., 2016), whereas participants from other places instead associated it with safety and security (Santarém et al., 2020). In line with our findings, perceived accessibility can vary due to the personal and sociocultural background (Koppen et al., 2014) (e.g. while local people decided against recreational activities because of extreme weather conditions or feared to be robbed, tourists did not perceive the situation as dangerous (C1, C2)).

Legal issues seem to be an important factor in the identification of limitations of CES use. Land ownership (private or public) primarily determines accessibility (Graves et al., 2017), but the official management authority of the landscape may not be identical to the user groups who effectively manage it and who may have limited or no legal rights. Consequently, informal governance systems are often in conflict with formal governance systems (Davies et al., 2016; Hanaček and Rodríguez-Labajos, 2018). Moreover, legal right of access may differ from people's perceived right of access, which is influenced by landscape attributes as well as their sociocultural background (Koppen et al., 2014). In certain regions, mainly emerging or developing countries, we must also consider customary laws. These can be challenging to understand for users and managers outside of the corresponding communities, but it is crucial for preventing conflicts and for the conservation of local traditions (Acosta-Jiménez and Gutiérrez-Yurrita, 2015).

Legal restrictions can prevent overuse, and, therefore, these restrictions help preventing conflicts between differing user interests (Gundersen and Vistad, 2016). For example, in many European countries, high-mountain or forest areas should have free public access, but public authorities or forest owners may impose restrictions of access for forest protection or health and safety reasons (Bauer et al., 2004). Moreover, free public access may cause conflicts with respect to liability questions in case of accidents, that is, roads that were constructed for economic use (forest management) are also used for recreation (e.g. in Austria, C5). Legal restrictions can often be seen as a result of a shared understanding of the limitations of use by individuals for the benefit of a social welfare-oriented goal; that is, distributional justice aiming at a fair distribution of benefits to the variety of social groups (Chaudhary et al., 2018), also considering rights of disposal (C5).

4.4. Managing conflicts and limitations of CES use

The degree to which non-monetary aspects are developed and integrated in local legal settings is decisive to maintain CES, as known values and benefits are often a motivation to maintain the specific landscapes (Plieninger et al., 2015). Cultural knowledge, history, identity, sense of place, and landscape memory are particularly important aspects often under risk due to socio-economic changes (e.g. tourism development), amenity migration, or land-use changes (Robbins and Berkes, 2000; Sarmiento and Cotacachi, 2019). If the legislation is not recognizing such values, management planning can directly or indirectly put indigenous and local communities or recreationalists at a disadvantage, such that their needs and preferences will not be addressed. This can be a potential reason for underlying or emerging conflicts (Bogardus, 2012). Therefore, all stakeholders need to be considered when addressing CES, as the most vulnerable groups are often overlooked or excluded during environmental management decisions (Martinez-Alier, 2014). Our results illustrate a high variety of available and actually employed qualitative and quantitative methods to assess non-monetary values, which are difficult to capture due to their (subjective) value (see also, e.g. Bryce et al., 2016; Fish et al., 2016). Only in the case of outdoor recreation might monetary values be applicable – if related to tourism (e.g. Schirpke et al., 2019b).

The knowledge about current trends in CES use and local value systems, as well as an enhanced understanding of the interdependencies of conflicts and limitations of use, represent an initial step for the management and the anticipation of possible consequences of interventions – for example, as illustrated in C8 or by visualizing different scenarios and their consequences (Nahuelhual et al., 2014). Conflict management in CES can consist of controlling or limiting negative impacts between different uses as well as favouring measures with positive effects on the environment and ecosystem services through legal and policy measures (Wilkes-Allemann et al., 2015). A common approach is limiting impacts between different types of users, for example, regulating the type of visitors in sensitive areas (e.g. 'no-bike trails', C1) or the period of access (e.g. no access during winter, C3). These types of interventions, however, are considered to have a low potential to permanently change the dynamics of complex problems, since they do not change the system structure or the feedback (Meadows, 1999). Moreover, they may provoke other undesired consequences, such as an increase in wildfires due to changes in ecosystems after excluding grazing activities (Lasanta et al., 2018), or a decline in aesthetic values (C7). The pressure exerted by an increasing number of users could therefore weaken the effectiveness of the rules or lead to exceptions, such as adjustments in the maximum number of people who can access the area, resulting in a drift to low performance (Pejic Bach et al., 2014). Nonetheless, these types of interventions can be enhanced if based on a systemic understanding of the problem(s) and on information feedback in order to calibrate the interventions and adapt them over time to changing conditions or variable external pressures. For example, supporting extensive livestock farming is most effective against the increasing frequencies of wildfires due to changes in biomass as a consequence of excluding grazers (Lasanta et al., 2018).

There are different types of evaluation that can create these informative feedbacks (Table 3). The most promising types of intervention are those that create new informative feedback loops (Lopes and Videira, 2017), delivering information to a place where it has not gone before and therefore causing people (such as beneficiaries and stakeholders of different sub-systems) to behave differently (Wilkes-Allemann et al., 2015). Such an intervention may consist of sharing and co-defining the desired values (both social and ecological) with the beneficiaries and stakeholders in order to define the compatible 'desired level' of access, use, uptake, and conservation (Willis, 2015). This may include making people aware of the role of extensive farming in the provision of ecosystem services (other than food) (C7; C9; Lasanta et al., 2018; Nahuelhual et al., 2014). The answers to strategic questions reported in Table 3 may provide such fundamental information. Further research should therefore examine the use of causal loop diagrams, which may be effective tools for sharing hypotheses, explaining causal relationships, and exploring the current and potential dynamics (C8). According to such a paradigm, all dynamics in ecological and social systems are ultimately embedded into causal feedback loops, and all decisions are part of a balancing feedback loop, generally depending on the difference (gap) between a current state and a desired state.

Finally, the question of who is managing activities is not always as easy to answer. Many traditional agricultural systems, as well as outdoor activities, like rock climbing, have a kind of self-organization, which has been developed throughout its history and includes its own values established by the respective community (Bogardus, 2012). When the national or local government, the private sector, tourism projects, or NGOs intervene, it can provoke unforeseen consequences, such as biodiversity loss due to grazing exclusion (Davies and Hatfield, 2007).

5. Conclusions

This study greatly relies on the outcomes of an expert workshop, including experiences from (partly ongoing) case study research, and may therefore not address all possible aspects and variables related to the research questions. The intention was instead to emphasize the importance of identifying and managing conflicts and limitations of CES use in mountain areas and to point out the complex interactions in SES, which may be useful for future research. Our findings illustrate that conflicts and limitations of CES use may arise from different dimensions, including social and ecological systems as well as governance and CES use. Changes in land use are a major driver of changes in CES supply, but the increasing demand for recreational use has also wide-ranging effects on the mountain SES. The collected assessment approaches suggest that more inter- and transdisciplinary approaches are needed to support a better understanding of complex relationships. However, currently, social sciences – particularly anthropology, critical biogeography, and political ecology – are still underrepresented in the transdisciplinary application of mountain studies (i.e. montology).

To support more inter- and transdisciplinary approaches, applying systems thinking may be one promising option, as it facilitates cross-cutting and integrating of different kinds of data on social dimensions and natural processes in complex, adaptive mountainscapes, in the process of developing sustainable management (Sarmiento et al., 2019). Accordingly, we need to discover which key feedback loops are driving the dynamics in systems associated with relevant and important CES, as well as where and how to intervene. Effective initiatives should target the 'leverage points' that can help transforming systems towards desirable and sustainable behaviour; these are often not very visible and require the strengthening of specific feedback loops.

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.

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Appendix A. Supplementary data

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