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Importance of Cultural Ecosystem Services for Cultural Identity and Wellbeing in the Lower Engadine, Switzerland

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Abstract: Current climate and environmental changes have brought unprecedented rates of change to mountain ecosystems. These changes are impacting the provisioning of ecosystem services. Despite the increase in academic publications on ecosystem services, research on cultural ecosystem services (CES) and their availability in mountain regions has largely been neglected. Here we analyse how important different CES are for inhabitants and visitors in the Lower Engadine region (Switzerland). We use questionnaires and maps to identify the most important CES for individual and collective wellbeing as well as their geographical location in the region. We had 48 participants in this study of which 28 grew up in the Lower Engadine. Our results show that the most important (i.e., 'Highly important') CES are: 'The view of mountains, rivers or glaciers'; the presence of plants typical for the region, for example Fire Lily and Edelweiss (i.e., *Lilium bulbiliferum* subsp. *croceum*, *Edelweiss-Leontopodium alpinum*); 'Hiking'; 'Local customs'; 'Watching large mammals'; and the importance of 'Terraces for traditional Agriculture activities'. Results from the spatial analysis show that identical geographical locations in the Lower Engadine provide multiple CES and bring health benefits to the users.

Keywords: mountain regions; climate change; environmental change; cultural ecosystem services; human wellbeing

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1. Introduction

Recent human activities and their impact on the environment and climate have brought us out of the Holocene into the Anthropocene Epoch [1,2]. Rapid changes in our climate and environment cause ecosystems in mountain regions to change at an unprecedented rate, with direct drivers such as land use change, species exploitation, climate change, pollution, and alien species invasions [3–5]. Recent climate change is placing high mountain regions and their ecosystems at particular risk due to reductions in the temperature vertical gradient and a potentially decreased cooling effect of aerosols [6]. Local communities in mountain areas are closely connected to nature and have a lower adaptive capacity, and they are particularly vulnerable to climate change [7]. Nonetheless, indirect drivers of environmental change, such as demographic, economic, and institutional change, armed conflicts, and epidemics, are also impacting mountain areas by underpinning changes of cultural and societal values [3,5]. Furthermore, these indirect drivers, such as political conflicts and other societal limitations can intensify distance to (food) markets, inaccessibility to town facilities and infrastructure or clean water, and healthcare [8–10]. In the past 50 years, mountain regions have experienced significant land use change and land intensification increase (i.e., intensified

agriculture) [11,12]. This has altered the loss of biodiversity and played a key role in ecosystem change, which has, in turn, affected the delivery of ecosystem services [13].

Ecosystem services (ES) can be defined as compounds of nature that are directly enjoyed, consumed, or used to maintain or enhance a good quality of life and human wellbeing [14–16]. ES can be divided into four categories: (a) provisioning (e.g., timber, fuelwood, freshwater, agriculture, and mountain pastoralism); (b) regulating (e.g., the local climate and microclimate, carbon sequestration and storage, and protection from and moderation of extreme events—landslides, erosion and other geomorphological processes); (c) supporting (e.g., providing a habitat for many species, serving as climate change refugia, and preserving the world's genetic diversity); and (d) cultural (e.g., aesthetic, spiritual or recreational benefits, and stewardship of nature) (MEA 2005). It is known that, historically, the livelihoods of local populations in the mountains highly depended on provisioning services visible through pastoralism, traditional agriculture or hunting [5,17,18]; hence, some ecosystem services, such as provisioning and regulating were more often assessed [19,20].

Mountain landscapes across the globe also offer attractive ecosystems and landscapes bringing us closer to a sense of place and peace, local community and individual identity, spiritual values, processes of healing and connectedness with nature [21], and, therefore, attention has recently shifted towards cultural ecosystem services (CES) [17].

It has been known that non-material services (i.e., CES) contribute to our physical and mental wellbeing [22,23] through their aesthetic, recreational, educational, cultural, and spiritual aspects of human experience. Still, there is a lack of scientific research on CES in mountain regions in terms of their spatial and temporal distribution [12,17,24]. Since approximately 20% of the world's population lives in mountain regions and many tourists visit them, it is essential to understand the availability and demands for CES and their relationship to our wellbeing [17,24]. For example, Tugjamba et al. [25] investigated the importance of CES for Mongolian nomadic herders in the Khentii mountain range and found out that heritage, cultural sites, and aesthetic values of the mountains were associated with spirituality, in particular, Shamanic and Buddhist practices important for wellbeing. Recently, Schirpke et al. [21] mapped an essential symbolic species in the European Alps that is an essential part of the cultural identity of several nations living in this mountain range. Another study investigated the importance of CES for Utawallu indigenous people in the Andes and how their biocultural heritage could be used for conservation purposes [26]. It is known that the loss of cultural identity in relation to the impacts of environmental and climate change can pose significant challenges for our wellbeing (both physical and mental), and this has been related to a concept known as 'Ecological grief' [27–29]. Furthermore, Schirpke et al. [30] have investigated the importance of CES linked to mountain lakes in the Alps and their relation to our wellbeing, and found out that aesthetic and spiritual values and education are the most important. Another study, from the Mt. Kilimanjaro region, has shown hiking (i.e., a recreational CES) to be important in recovery processes for cancer patients, giving them a sense of personal strength, closure, and control [31]. Similarly, veterans who participated in the same endeavour experienced self-determination and inner strength and more active coping with stress and social support [32]. The evaluation of CES in mountain regions could also help us to better understand complex relationships between humans and nature [14,17,23,33]. Still, very little emphasis has so far been placed on how CES impact human wellbeing. There have been only a few studies looking at both physical and mental wellbeing, which is surprising as CES contribute to both [14,34].

Therefore, we hope that this study contributes towards a better understanding of which CES are in the highest demand, and what is their availability in the Lower Engadine, and how these services are important for wellbeing. The novelty of this research is that, to the best of our knowledge, this is the first study that has investigated the demand for CES and their spatial distribution in the Lower Engadine. This can lead towards accurate and just conservation policies that will aim to preserve local knowledge and enhance stewardship of nature in order to safeguard the wellbeing of inhabitants and visitors in this region [35,36]. Although, this study does not aim to show a direct causal link between wellbeing and CES in the Lower Engadine

region, we do aim to show different pathways of those connections. As empirical research on CES in the Lower Engadine is still lacking, we are aiming to answer the following questions: (1) What is the demand for, and the importance of, different CES in the Lower Engadine and their relation to human wellbeing? (2) What are the hotspots of different CES in the region?

2. Study Area

Our research area was the Lower Engadine, the easternmost part of Switzerland in the canton of Grisons. It is the largest canton in Switzerland, covering an area of 7105.2 square kilometres (Figure 1). The canton has international borders with Italy, Austria, and Liechtenstein. Its southern part is formed by the upper reaches of the Inn River, after which the Engadine is named. The Lower Engadine is climatically classified as an inner-Alpine dry valley. Considering recent climate change, mountain ecosystems are prone to glacier melting, avalanches, changes in hydrological systems, soil erosion, landslides, and the rapid loss of habitat and genetic diversity [37]. Switzerland's only official National Park is situated in the southwestern part of the Lower Engadine. The Lower Engadine has approximately 7000 inhabitants. The main economic sectors of Grisons are the primary sector, including agriculture, forestry and Alpine transhumance pastoralism, and the tertiary sector, specifically tourism. The Lower Engadine has a long history of pastoralism and agriculture that goes back into prehistoric times [38–42]. Over time, a highly sophisticated vertical system of seasonal resource use developed, which combined agriculture in the valleys with the use of mountain pastures [39]. Visible traces are features such as irrigation channels, ancient tracks and paths, hay hauls, and—most strikingly—agricultural terraces (now used as meadows) on the northern slope of the Inn valley, which are much better preserved than in other inner-Alpine valleys [42]. Local inhabitants often say that the Lower Engadine is a best-kept secret with a distinctive Romansh culture that is deeply imbedded in the cultural identity of its inhabitants.

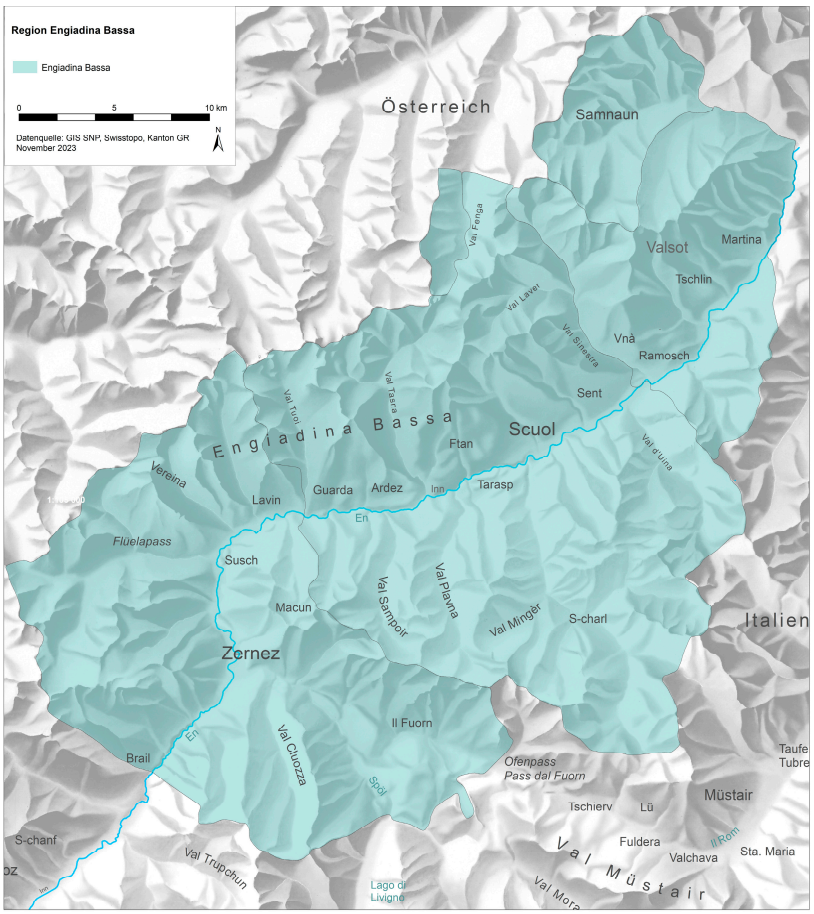

Figure 1. The Lower Engadine region in southeastern Switzerland.

3. Methods

This research is based on an evaluation of different CES in the Lower Engadine using Millennium Ecosystem Assessment CES categories as a baseline [15]. Here we use a mixed-methods research approach; both qualitative and quantitative. Firstly, prior to the start of our research and fieldwork, in 2017 we gave a presentation in Ramosch explaining this project to the local community. We used this communal gathering to design the questionnaire together with members of the local community in order to assess the importance of CES in terms of individual and community wellbeing. In the questionnaire, we used both closed and open questions. Closed questions were designed based on the selection of pre-determined response options (i.e., Likert scale questions) being classified as "Unimportant", assigned as 1, to "Very important", assigned as 5. Originally, the questionnaire was designed in German (i.e., the Lower Engadine region is a German and Romansch speaking area), and afterwards translated into English. To obtain data on geographical locations that are linked to CES, we asked participants to mark on the map or to name the geographical location of places where they find a given service most enjoyable. This survey included both local inhabitants and visitors.

Data were collected by circulation of both an online and a paper version of the questionnaire, plus printed maps of the region. Paper questionnaires were distributed in Scuol, Ramosch, Tschlin, Tarasp, and Vnà in August 2017. Snowball sampling was used in order to reach a higher number of participants. In addition to paper-based questionnaires, we also distributed online questionnaires with sub-questions where participants could refer each particular CES to geographical locations. Online questionnaires were sent out in 2018 and remained open until the end of that year. Secondly, after gathering the results, we conducted descriptive statistics. Furthermore, we used machine learning, specifically k-means clustering, to explore the spatial distribution. K-means clustering was selected due to its effectiveness in identifying inherent patterns and simplifying complexity within our dataset. This method is particularly adept at revealing natural groupings among the studied variables, providing clear insights into the underlying structure of the data [43]. K-means clustering was preferred for its computational efficiency and ease of interpretation [44]. To understand whether there is any correlation between different CES, we applied the Spearman correlation test, which is known to be a robust method for ordinal data [34,45,46]. To undertake exploratory spatial analysis, geographical locations of different CES were georeferenced in ArcGIS (released version 10.8.2).

4. Results

In total we obtained 48 responses, including both paper and online questionnaires. In terms of social and cultural variables, we had 23 females and 25 males, and therefore gender representation was quite homogeneous (Figure 2). In terms of age groups, the highest representations were of people aged between 17–36 (31%) and 37–52 (29%). The lowest representation was of the youngest generation, aged 1–16 (4%), followed by the oldest age group 72–90 (9%) (Figure 2). Participants in the oldest group were all males. In terms of the respondents' residency status, 41 had lived in the Lower Engadine for more than six months. Out of the 48 participants in this survey, 28 had grown up in the region.

Respondents in this study answered questions regarding different CES, valuing them on a scale from unimportant to highly important *(Unimportant = 1; Less important = 2; Draw = 3; Important = 4; Highly important = 5).*

The CES with the highest frequency (F = 32) of *'Highly important'* service was 'The view of mountains, rivers or glaciers'. The second highest important CES was the presence of plants typical for the region, for example Fire Lily and Edelweiss (i.e., *Lilium bulbiliferum* subsp. *croceum, Edelweiss-Leontopodium alpinum*) (F = 30). *'Highly important = 5'* services that follow are related to 'Hiking' (F = 24); 'Local customs' (F = 23); 'Watching large mammals' (F = 21) and the importance of 'Terraces for traditional Agriculture activities' (F = 20). The less important or unimportant services were 'Fishing' (F = 28) and 'Hunting' (28); followed

by 'Kayaking/rafting' (F = 27); 'Designing sculptures' (F = 26); 'Composing music' (F = 25); 'Writing poems' (F = 23); and 'Camping' (F = 22).

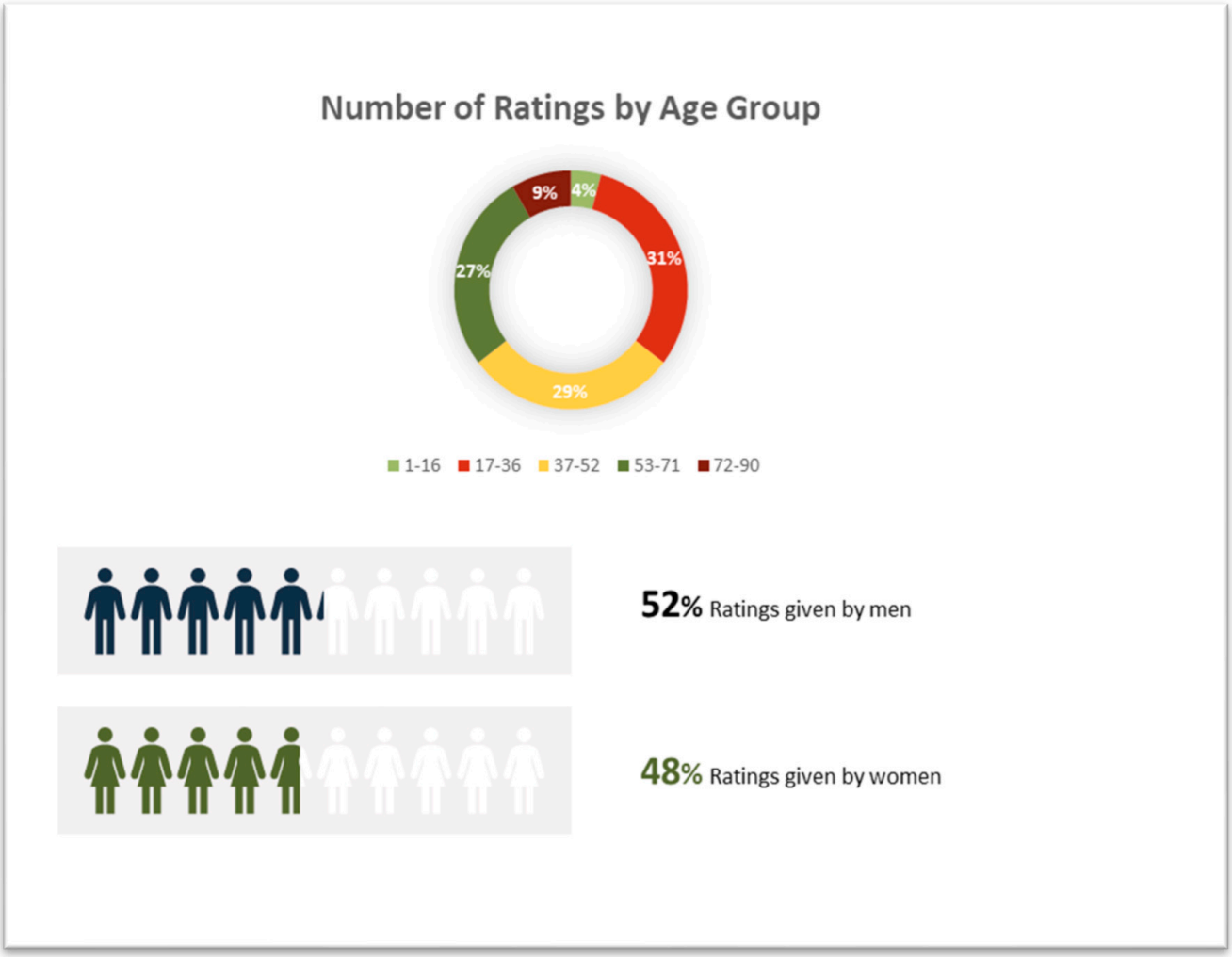

Figure 2. Age and gender groups.

If we split these results by demographics, for the oldest generation the *'Highly important service = 5'* was 'Looking for flowers', which received a 100% response rate. Another *'Highly important = 5'* service for the elderly generation was 'Refreshes my mind', answered with a 75% rate. Equally important was 'Learning about archaeology and/or history', 'Climate change and recent landscape changes' (e.g., decline in glaciers, debris flow, rockfalls, etc.). Furthermore, 'Terraces' and 'Talking to neighbours' were highly important for 50% of the respondents in this group. The service 'Visiting museums' was rated as *'important = 4'* for 75% of the elderly group. In the least important category (i.e., *Unimportant = 1*), the elderly group responded with 100% for 'Fishing', 'Kayaking/rafting' and 'Hunting'. This was followed by a 75% response rate for 'Biking', 'Collecting mushrooms/berries', and 'Composing music'.

For the middle-aged group *'Highly important = 5'* CES were 'Local customs' and 'Typical plants (e.g., Fire Lily = *Lilium bulbiliferum* subsp. *croceum* and Edelweiss = *Leontopodium alpinum*) with both accounting for 64% of respondents in this age group. For CES that are *'Important = 4'*, the highest response rate was received for 'Talking to neighbours' (73%), 'Cooking' (64%), 'Hiking', 'Refreshes my mind', 'Let me distance myself from modern comfort', 'Traditional clothing/costume', 'To live and enjoy on campsites or in huts', and 'Biking' (all with 55% of respondents).

The youngest generation found the *'Highly important service = 5'* to be 'Watching big mammals', 'Determining plants', 'Bird watching', 'Watching the night sky', 'Cooking', 'Fishing', 'Hunting', and 'Skiing', all with a 50% response rate. For the same age group, '*Important services = 4'* replied with a 100% rate were: 'Visiting restaurants/enjoying local food in the region', 'Swimming', and 'To live and enjoy on campsites or in huts'. *'Important = 4'* services assigned by 50% of the youngest generation were 'Biking', 'Kayaking and rafting', 'Ski touring/cross-country skiing', and 'Free climbing'. Interestingly, 'Talking to neighbours' is equally important for the youngest and the oldest generations of participants in this study. Furthermore, 50% of the participants in the youngest age group answered that it is highly important for them how the Lower Engadine helps to 'Understand my family's culture and history', whereas participants in other age groups did not attribute a high importance to this question.

Regarding gender, the most important service (i.e., *'Highly important = 5'*) for both women and men was 'The view of mountains, rivers or glaciers' with 61% and 75% response rates. An interesting result was that for men, the service 'Climate change and recent landscape changes (e.g., decline in glaciers, debris flow, rockfalls, etc.)', had a response rate of 64% that was much higher than for women (35%). The second service in the rank of importance (i.e., *'Important = 4'*) was 'Talking to neighbours' for women and men with 70% and 60% response rates, respectively. The most unimportant CES for the two gender groups was 'Hunting' and 'Fishing', with similar response rates of 61% for women and 56% for men. The frequency distribution figure by gender to different CES is provided in the Supplementary Materials.

The Spearman's Rho correlation test between age and CES shows the highest positive, statistically significant correlation ($p < 0.405$) to a 0.01 significance level, for the service 'Looking for flowers' (Table 1). Although correlation tests cannot tell us what specific age group was statistically significant to a particular CES, we know from the correlation matrix that the oldest age group (72–90) in this survey consider 'Looking for flowers' the most important service, responding with a 100% rate. The K-means clustering enabled us to draw more nuanced conclusions about the relationships between different CES and demographic variables. The highest negative correlation was for 'Taking part in guided hikes' (e.g., National Park) ($p < -0.476$; Table 1 and Figure 3).

Table 1. Spearman's Rho correlation between CES and age.

CES	Spearman's Rho 'Age' Correlation Coefficient
Looking for flowers	0.405 **
Reading and/or writing	0.397 **
Skiing	−0.379 **
Swimming	−0.434 **
Kayaking/Rafting	−0.381 **
Biking	−0.469 **
Sun bathing	−0.295 *
Fishing	−0.327 *
Taking part in guided hikes (e.g., national park)	−0.476 **

** Correlation is significant at 0.01 level (two-tailed). * Correlation is significant at 0.05 level (two-tailed).

Figure 3. Spearman's Rho correlation matrix.

Spearman's Rho correlation between different CES and the participants who grew up in the Lower Engadine (or were just visitors) showed the highest positive correlation for the service 'Let me distance myself from modern comfort' ($p < 0.307$). The highest statistically negative correlation was calculated for the service 'Specialties and old recipes remind me of my childhood' ($p < -0.629$), both on a 0.01 significance level (Table 2 and Figure 3). The second highest statistically negative correlation was for 'The region helps me understand my family's culture and history'.

Table 2. Spearman's Rho correlation between CES and 'growing up location'.

CES	Spearman's Rho 'Did You Grow up in the Region?' Correlation Coefficient
Fishing	−0.306 *
Hunting	−0.439 **
Let me distance myself from modern comfort	0.307 *
The Lower Engadine landscape awakens childhood memories	−0.472 **
The region helps me understand my family's culture and history	−0.603 **
Specialties and old recipes remind me of my childhood	−0.629 **
Singing in a choir is part of the culture of the Lower Engadine	−0.419 **
To live and enjoy on campsites or in huts	−0.286 *

** Correlation is significant at 0.01 level (two-tailed). * Correlation is significant at 0.05 level (two-tailed).

5. Spatial Analysis

To answer our second question (what are the hotspots of different CES in the region?), we georeferenced the location of several special services. Unfortunately, not all participants answered the questions assessing the geographical location for each service. Therefore, here we show CES that received the highest number of responses (i.e., exact geographical locations) in our survey. We used ArcGIS 10.8.2 to geo-reference the locations of individual CES. Services that were attributed the most to exact geographical locations in our questionnaires were 'Enjoying the view of mountains, rivers or glaciers' (24 geographical locations), 'Hiking' (21 geographical locations), and 'Looking at flowers' (19 geographical locations). Our results show that many of the services are available at the same locations, such as Ardez, Valsot, Sent, Val Sinestra, Tarasp, and Ftan (Figure 4—for place names compare Figure 1), making those places more desirable to visit for Lower Engadine inhabitants and visitors.

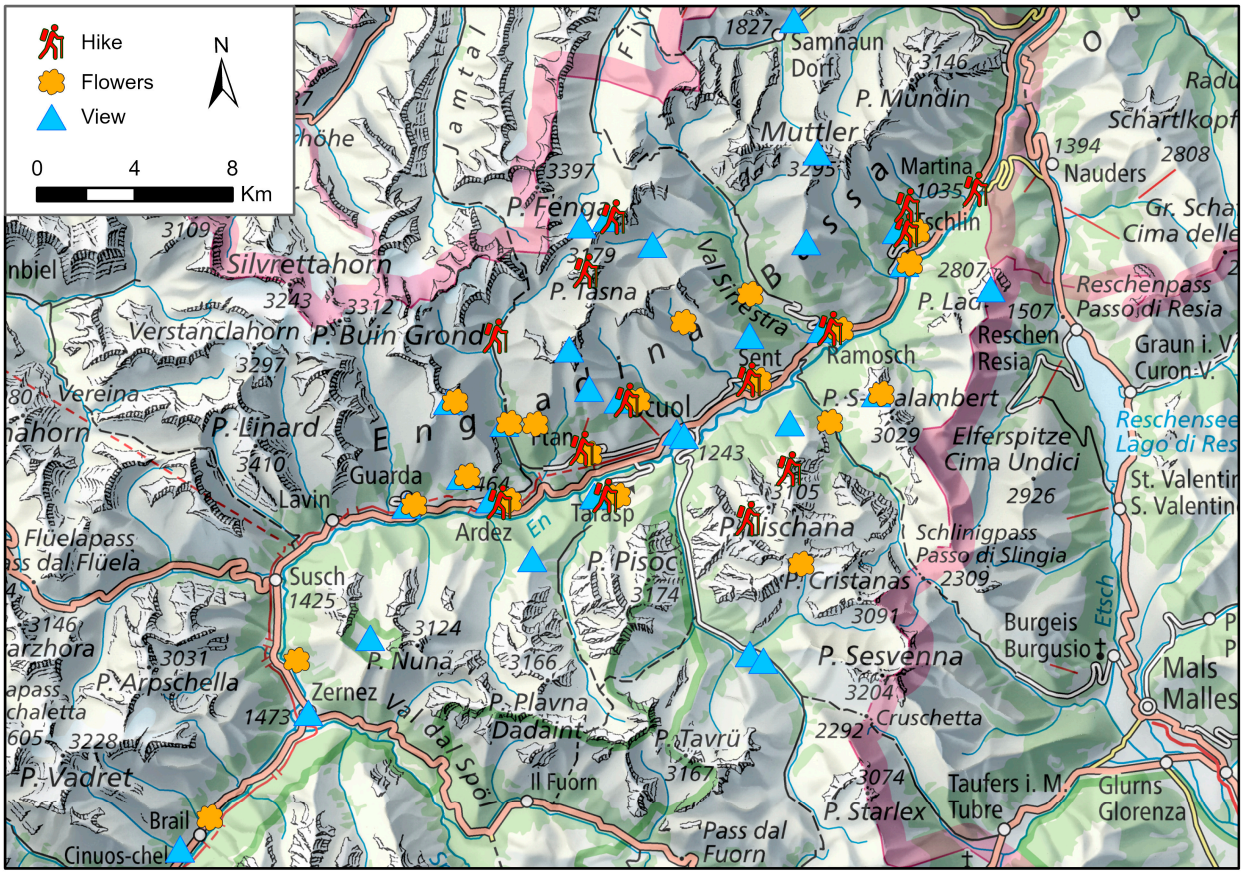

Figure 4. Spatial analysis of CES: 'Enjoying the view of mountains, rivers or glaciers'; 'Hiking' and 'Looking at flowers'.

6. Discussion

Culture ecosystem services are important non-material benefits of nature that have been receiving recognition in research in recent decades. However, their contribution to wellbeing in the face of rapidly changing climate, ecosystems, and landscapes is still not well enough explored or understood across different spatial and temporal scales [14,33].

In mountain regions, traditional and more isolated communities are very much dependent on cultural ecosystem services, as they are essential not only for their survival, but an important part of community and individual identity [47]. Yet, very little emphasis has so far been placed on how the demand for particular CES impacts human wellbeing locally and regionally [14,30,48]. It has been known that physical activity and recreation have various benefits for human physical wellbeing, such as lower mortality, improved

cardiovascular health, for example Japanese 'forest bathing', helping to control diabetes and securing better cognitive performance [49–51].

The benefits of hiking and trekking in mountain landscapes have been known for years [52,53] and they have become very popular over recent years. Our results confirm that hiking is one of the most important services in the Lower Engadine and it is equally important for all age groups, except for the elderly. Furthermore, hiking could offer participants meaningful experiences in nature that can distract us from a technology-centred lifestyle and encourage environmentally conscious behaviour [54,55]. Our results for the service 'Let me distance myself from modern comfort' are in line with those previous findings showing that being in the mountains and nature reduces stress and improves our wellbeing [56]. The highest and the second highest statistically negative correlations between people who did not grow up in the region were calculated for the services 'Specialties and old recipes remind me of my childhood' and 'The region helps me understand my family's culture and history', showing how the Lower Engadine's landscape and heritage is imbedded in personal and community identity that is a common theme for the local population in mountain regions [25]. Hopefully, environmentally conscious behaviour can be further altered as many recreational activities were highly valued by the younger generation such as skiing and swimming, fishing, biking, free climbing, kayaking, and rafting. Correlation analysis showed statistically significant negative correlations between age and skiing, swimming, kayaking/rafting, and biking, respectively. Our results are in contrast to previous findings, where for example Alpine skiing was important for the older population and showed higher levels of physical health, and contributed to better self-valuation, healthy aging, and a better quality of life (e.g., social interactions and cardiovascular health) [57]. Hence, our results confirm spatial heterogeneity of CES and present a venue for new research on how to make nature and activities in nature more accessible and appealing for the elderly and people with disabilities [14,58,59]. From the point of view of environmental justice, we must strive to make nature accessible to elderly or people with disabilities and different genders who have not been in the mountains or forest for a very long time, and are no longer able to engage in activities they used to enjoy or were beginning to enjoy [14,60]. These groups are very often deprived of nature and are not able to enjoy specific aspects of nature or activities due to a lack of accessibility [58]. Furthermore, as we live in the Anthropocene, we are aware that CES in mountain regions will be affected by climate change seasonally [7,61]. The impact of climate change on winter recreational activities, such as skiing, will be predominantly negative due to the loss of snow [29,62]. On the other hand, other recreational activities such as hiking and swimming will be very popular in the summer season [30,59] and they will offer the opportunity to escape urban heat islands. Still, these increased visits to mountainous regions could add to the already existing stress on vulnerable mountain ecosystems and potentially create a positive climate change feedback.

Physical activity can contribute to holistic wellbeing, contributing to emotional renewal in nature, showing mental health benefits noticeable through various psychological pathways such as improved self-concept, improved self-perception/identity, and improved confidence [63–66]. It is therefore essential not only to understand which recreational activities across different sociodemographic groups are important, but also what is the value of nature for different stakeholders and how this differs locally and regionally.

Nature and its benefits contribute positively to our mental wellbeing in many ways [63,67,68], through activities in nature that have been referred to as "wilderness therapy, ... wilderness adventure therapy, or also outdoor recreation therapy" [58,69–71]. Hence, our research shows that beside physical benefits of recreational activities in mountains, other CES such as aesthetic values, sense of place, inspiration, and local and traditional knowledge (i.e., traditional clothing and local costumes) contribute to wellbeing by reducing stress, through emotional and cognitive renewal, and by strengthening social relationships [54,69,71].

Most respondents from this research assigned a high importance to CES related to 'Terraces for traditional Agriculture activities' and 'Local costumes' such as to 'Cooking' or community identity related to biodiversity, and the identification of plant species that are particularly important for the Alps (e.g., Fire Lily, Edelweiss). Our results show the importance of a connection to nature of the local communities in order to preserve the cultural heritage, community identity, and landscape and traditional agricultural practices (i.e., 'Talking to neighbours', 'Learning about archaeology and/or history') in the Lower Engadine [72,73]. Previous studies have also shown that traditional agricultural practises (e.g., transhumance pastoralism) are essential for cultural identity and biodiversity preservation and restoration [74,75].

Our results from the spatial analysis are in line with previous studies showing that, in many cases, the same location or the same natural area can provide multiple CES and provide numerous health benefits [66,68,76,77].

An improved connectedness to nature can improve the interaction between humans and nature and strengthen our bond with nature, which promotes a better attitude towards environmental protection and leads to pro-environmental conservation strategies [67,78–80]. The results of this study point in this direction, as the younger generation from this region shows a clear interest in the landscape, mountain biodiversity, as well as in community and individual heritage (i.e., Traditional clothing/costume, Local customs, Terraces, The Lower Engadine landscape (terraces, pastures, etc.)). Hence, our findings show that there is great potential for future research to focus on the study of emotional dimensions of human connection to nature in order to create more understanding of the specific emotional connection between the younger generation and the landscape, as this will play a key role in creating equitable and just, sustainable management strategies, and nature-based solutions in climate change adaptation [80,81]. Another potential focus of future research could be on relational values within different stakeholder groups, including marginalised groups (i.e., people with disabilities) in the Lower Engadine [82–84].

7. Limitations

Our study has been limited by several factors. After the initial 'in person' survey, due to time constraints to organize another fieldwork to the Lower Engadine, we decided to use an online questionnaire. Possibly this decision limited elderly participants to join as they were not familiar with online surveys. Furthermore, the online survey showed a down side in participants' engagement in providing the correct geographical location for individual CES.

8. Conclusions

Our work shows the importance of diverse CES in the Lower Engadine for both residents and visitors. This study shows that it is an advantage to engage transdisciplinary research teams to develop key questions about the availability and demand of CES in order to understand the need for each service in mountain communities and across different socio-economic and socio-cultural groups, which could be beneficial for local NGOs and the Swiss National Park. Furthermore, this study contributes to a better understanding of which actors we can involve in climate change adaptation strategies and how we can connect local communities with local and national governments [85,86]. This can lead to the most transformative forms of adaptation possible: (a) with a future focus on research that involves different actors and an emotional connection to the landscape in mountain regions, and (b) with further investigation of relational values, we can empower local actors and marginalised groups (i.e., people with disabilities, women, people of different genders, the elderly). Transdisciplinary research and more education on environmental change for local communities will bring empowerment and different actors to the table, allowing them to share their knowledge and lived experience. Only such an approach will enable us to develop strategies for climate change adaptation and biodiversity conservation

that are equitable and just, leading towards a sustainable future and a better quality of life [34,87,88].

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12122156/s1.

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