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# Ordering 'wilderness': Variations in public representations of wilderness and their spatial distributions

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ABSTRACT

Wilderness has recently re-emerged as a key landscape quality in the public debate in Europe, experiencing renewed appreciation in terms of tourism and nature conservation. At the same time, wilderness has turned into a critical matter of conflict, calling for a better understanding of the public's varied views on wilderness and the spatial localisation of areas of potential conflict. In this paper, we explore the plurality of existing public wilderness representations combining qualitative evidence from 21 semi-structured interviews with quantitative data from a large-scale questionnaire survey (n = 858) conducted in the region of South Tyrol in the Central Alps. This is complemented with a GIS-based approach to quantify and map the geographic coverage of the different representations of wilderness. Our study reveals three distinct public wilderness representations, i.e. '*Area with no human impact*', '*Remote and large area*', and '*Area where nature can self-develop*', differing in terms of selection and weighting of wilderness attributes. The translation of wilderness representations into maps shows clear differences in spatial distribution, location, and extent of areas with high wilderness quality across the three representations. We further demonstrate the added value of our approach by comparing the results with a standardised, expert-based approach on wilderness quality mapping, finding that the extent of areas of high wilderness quality significantly varies depending on whether the mapping is based on experts' or public's representation of wilderness. We therefore conclude that recognising public wilderness representations and their plurality is fundamental for identifying areas of potential conflict and sustainably managing wild landscapes.

## 1. Introduction

Wilderness is a key landscape quality, which gained increasing attention in Europe in recent years. Not only has wilderness re-emerged in the nature conservation community as a guiding concept, informing nature protection and restoration agendas at the national and EU level (European Commission, 2013; Jones-Walters & Čivić, 2010), but has also been increasingly taken up by the tourism industry. Travel brochures, leisure magazines and outdoor programs increasingly advertise and commodify wilderness as a main tourism attraction and central component of tourists' activities (Sæþórsdóttir & Saarinen, 2016). Similarly, an increasing number of protected areas have adopted the term 'wilderness' for reasons of place branding and marketing (Øian, 2013).

With groups as varied as nature conservationists and tourist agencies raising claim to wilderness in Europe, each supporting different uses, the respective areas can be important sites of conflict. The research community has recognised this particular potential for conflict for some time. Taking inspiration from Nash's famous saying that what is "one man's wilderness is another's roadside picnic ground" (Nash, 1967, p.1), several studies have examined variations in perception and attitudes towards wilderness (e.g. Vistad & Vorkinn, 2012; Larkin & Beier, 2014). What this research shows is that wilderness cannot easily be separated from non-wilderness, but is best represented as a gradient or continuum (Lesslie & Taylor, 1985). Projects to map variations in wilderness clearly reflect this in that wilderness quality is typically quantified along a spectrum of varying human modifications from least to most wild areas (Aplet, Thomson, & Wilbert, 2000; Carver, 1996).

At a more fundamental level, however, it is not only perceptions and

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attitudes that may differ, but also people's understanding of what wilderness is and where it can be located. Qualitative research on wilderness has shown that different culturally constructed representations of wilderness can exist (Øian, 2013; Sæþórsdóttir & Saarinen, 2016). Yet, existing mapping efforts tend to suppress such variation in favour of condensed maps based on expert-based judgments (e.g. Carver, Tricker, & Landres, 2013; Radford, Senn, & Kienast, 2019). This tendency is also reflected in the 'European Parliament Resolution on Wilderness in Europe' that was adopted in 2009. Aware of the myriad of existing definitions of wilderness, it called for the development and implementation of a standardised definition for effectively protecting and restoring remaining wilderness areas across a wide range of geographically and culturally different places in Europe (Wild Europe, 2012). Taking this standardised definition into account, European wilderness was mapped on the basis of an expert-informed Geographic Information Systems (GIS) model (Kuiters et al., 2013). Other efforts at wilderness mapping have taken people's varying perceptions and attitudes into account, yet equally refrained from accepting multiple definitions and thus pre-selected wilderness attributes on which people's preferences were assessed (Carver, Comber, McMorran, & Nutter, 2012; Carver, Evans, & Fritz, 2002). So far, previous research has sought, with few exceptions (Flanagan & Anderson, 2008; Kliskey, 1994; Larkin & Beier, 2014), to represent the spatial distribution of wilderness on a single map. However, to account for and spatially define areas of potential conflict, particularly such fundamental ones such as those based on varying definitions of wilderness, it is necessary to find ways to reconcile the competing demands of a participatory approach emphasising plurality and public involvement on one hand, with a more pragmatic, policy-oriented approach requiring parsimonious representation on the other. Is it possible, then, to account for plurality in people's wilderness representations and make potential conflicts spatially localisable while escaping relativism?

In this paper, we adopt an exploratory and descriptive approach to identify a limited number of public wilderness representations and combine this with spatial GIS models to translate each representation into maps. The approach allows a comparison of the spatial distribution of the different representations of wilderness and the identification of areas of potential agreement and disparity that are useful for conflict management and landscape planning. We demonstrate the added value of our approach by comparing it with a standardised, expert-based approach on wilderness quality mapping published in Radford et al. (2019), using research in the mountain region of South Tyrol located in the Central Alps.

## 2. Background

### 2.1. Wilderness representations

Despite the existence of legal definitions such as the US Wilderness Act (1964), wilderness is widely recognised as a socially and culturally constructed idea loaded with symbolic meanings and cultural values (Cronon, 1996; Nash, 1967; Oelschlaeger, 1991). Over the past decades, much research has been conducted on the multiple meanings and values people attach to wilderness, especially in the North American context (e.g. Cordell, Tatrant, McDonald, & Bergstrom, 1998; Johnson, Bowker, Bergstrom, & Ken Cordell, 2004). While great attention has been paid to identifying and reconciling a wide range of wilderness values (e.g. ecological, experiential, and symbolic values), these studies have often investigated meanings and values of wilderness in relation to a predefined wilderness such as legally designated wilderness areas in North America (Cole, 2005; Gunderson, 2006).

Unlike these studies, however, the present study does not concentrate on the ecological or human *meanings* and *values* people attach to a prescriptive definition of wilderness but explores *what* wilderness is for people and *where* it can be found (cf. Vannini & Vannini, 2016). Specifically, we focus on the mental representations that people hold of wilderness. People construct and use these mental representations as a form of subjective knowledge to make sense of the world in which they live (Sigel, 2012). Adopting a probabilistic view, we understand mental representations as fuzzy categories that are organised around a set of correlated, descriptive attributes (Medin, 2005). Here, we are specifically interested in non-evaluative and spatially identifiable attributes associated with wilderness that allow us to translate mental representations into visual maps.

Our focus on wilderness representations builds on previous qualitative research on wilderness in Europe (e.g. Wall-Reinius, 2012; Sæþórsdóttir & Saarinen, 2016), which argued that wilderness is not a 'real' and enduring condition, but that different representations of wilderness may exist depending on the socio-cultural environment in which a person or social group is living, and on their personal histories and experiences. Kirchhoff and Vicenzotti (2014) have further demonstrated that wilderness representations tend to vary over time and across different cultures.

### 2.2. Mapping wilderness

Over the past three decades, scholars have sought to develop various techniques and GIS applications to define wilderness in a spatially-explicit way (Carver and Fritz, 2016). To reflect the vagueness of the wilderness concept, most of these attempts make use of fuzzy spatial approaches to quantify and map wilderness along a continuum. Using expert-informed GIS models, these studies have generally mapped wilderness on the basis of a limited set of landscape attributes at a variety of scales, ranging from the local (e.g. Orsi, Geneletti, & Borsdorf, 2013) and national (e.g. Radford et al., 2019) to the continental (e.g. Kuiters et al., 2013) and global scale (e.g. Sanderson et al., 2002). Participatory mapping approaches, by contrast, have used multi-criteria evaluation (MCE) models to describe wilderness from the perspective of the general public (Carver et al., 2002, 2012). In these studies, however, participants were engaged to spatially define wilderness based on their perception and evaluation of a set of pre-selected wilderness attributes.

A third strand seen in the wilderness perception mapping literature, geographically represents perceptions of wilderness based on the Wilderness Purism Scale introduced by Hendee, Catton, Marlow, and Frank Brockman (1968). The Wilderness Purism Scale is frequently used to cluster users of wilderness areas according to attitudes expressed towards certain features and activities allowed in a wilderness setting (Hendee et al., 1968; Stankey, 1973). In order to provide insights for wilderness management, wilderness perception mapping spatially quantified wilderness perceptions by conducting surveys on the basis of this scale and translating survey results into maps using GIS-based models (e.g. Kliskey, 1994; Flanagan & Anderson, 2008). These studies commonly represent the areal extent of wilderness perceptions by identifying all areas that do not include geographic features considered as undesirable in a wilderness setting. However, as these studies only considered geographic features representing conditions in correspondence to existing legal wilderness definitions such as the US Wilderness Act, more fundamental differences in people's representation of wilderness were not captured.

On the basis of this brief overview of existing research, we can conclude that neither the plurality in people's wilderness representations has been explored so far on the basis of quantitative methods, nor has the spatial distribution of the different representations of wilderness been captured without relying on pre-selected sets of wilderness attributes (i.e. participatory GIS studies) or geographic features representing pre-defined scale items (i.e. wilderness perception mapping).

## 3. Methodology

The approach presented in this study involves several steps (Fig. 1).

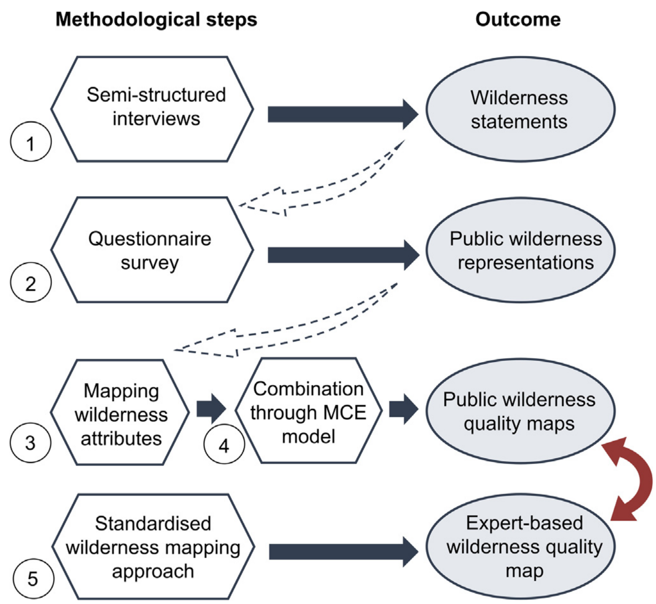


**Fig. 1.** Schematic overview of methodological approach used in this study.

The first part of our study entailed a mixed method approach, combining qualitative with quantitative methods, to explore public wilderness representations. Following a sequential exploratory design (Creswell & Clark, 2011), we first conducted qualitative semi-structured interviews to identify key attributes of individuals' personal representation of wilderness (step 1). Based on these attributes, a large-scale questionnaire survey was conducted to identify shared wilderness representations (step 2). This was followed by the estimation of the geographic coverage of areas of differing wilderness quality as derived from the identified wilderness representations. To this end, different spatial indicators were developed for mapping geographic variation in each of the attributes characterising the identified representations (step 3). These attribute maps were then combined and weighted using a multi-criteria evaluation (MCE) model to map variations in wilderness representations (step 4). In the final step, we compared the generated maps with a standardised wilderness mapping approach reflecting experts' representation of wilderness quality (Radford et al., 2019).

### *3.1. Study area*

The approach developed in this study is applied to the mountain region of South Tyrol, an autonomous region in the north of Italy (Fig. 2). As part of the Central Alps, the study area encompasses a varied topography with deep valleys and steep mountain peaks up to 4000 m a.s.l. as well as a diverse landscape of high mountains, forests, alpine grassland and agricultural land. The region covers a total area of 7400 $km^2$ and stretches over two major geological units, i.e. the Eastern Alpine unit in the north and west and the Southern Alpine unit in the southeast of the study site. South Tyrol is a multilingual region in which German (69%), Italian (26%) or Ladin (4%) is spoken by inhabitants as their first language (ASTAT, 2012). Tourism intensity is very high in the area; while 504,643 inhabitants live in the region (ASTAT, 2012), about 7.5 million tourists, mainly coming from Germany and other regions of Italy, are recorded every year (ASTAT, 2019). Overnight stays are particularly high close to larger cities as well as in the villages located within and surrounding the UNESCO World Heritage site of the Dolomites. Today, pressure on land is most pronounced on the valley floors of the study site, where the majority of inhabitants live, and the most intensive forms of agricultural production are found. Parallel to this intensification on the valley floor, however, less intensive livestock farming systems are increasingly being abandoned on the less accessible, steep, and highly elevated mountain slopes, including many alpine pastures, due to their high labour intensity and low profitability (Tasser, Ruffini, & Tappeiner, 2009). Despite this abandonment, the same areas are increasingly under pressure due to increasing visitor numbers and new infrastructural and tourism developments. The extensive hiking network, large number of skiing resorts and mountain huts offering shelter and food, enable an increasing number of recreationists and tourists to easily reach these areas both in summer and winter.

### *3.2. Identifying public wilderness representations*

#### *3.2.1. Qualitative interviews*

Semi-structured face-to-face interviews (n = 21) were conducted in the study region between May and June 2016. Using both individual as well as group interviews, interviewees were asked about their personal wilderness representations. Due to the explorative nature of the study, potential participants were approached in public spaces using a convenience sampling approach. The resulting sample includes participants with a diverse socio-demographic background and members from three stakeholder groups (i.e. local farmers, local residents, and visitors), but is limited to German-speaking interviewees. The number of interviews reflects the level of saturation in the diversity of expressions interviewees used to describe their personal wilderness representation (i.e. code saturation, Saunders et al., 2018). All interviews lasted between 10 and 90 min and were recorded on tape and then transcribed.

The thematic analysis of interview materials followed multiple steps (Braun & Clarke, 2006), starting by condensing the body of expressions interviewees used to describe their personal wilderness representation. Since we are interested in identifying the descriptive attributes people associate with wilderness, we removed all collected expressions reflecting wilderness attitudes or values (e.g. place of fear, place of thrill, attractiveness of scenery) and categorised the remaining expressions according to the main wilderness attributes (i.e. remoteness, naturalness, lack of human impact) reported in the European literature (e.g. Carver et al., 2012; Orsi et al., 2013; Radford et al., 2019). Some expressions could not be assigned to existing attributes (e.g. wildlife habitat, impassable area, abandonment of cultivation), however, in which case we expanded the list of attributes through inductive analysis of the material. Through the use of *in vivo* coding attention was paid to make use of participants' words to identify emerging attributes that have not previously been reported in literature. Based on the resulting categorisation of participants' expressions, we compiled a list of items to be included in the questionnaire. The final selection of these items includes all wilderness attributes identified in the previous steps, except for attributes describing wilderness as a vicious character trait of animals and humans that cannot be translated into quantitative spatial indicators. For each wilderness attribute, we included at least one item, selecting more than one in more ambiguous cases that cannot be represented in a single item (naturalness, lack of human impact). Overall, a total number of 14 items were included in the questionnaire survey.

#### *3.2.2. Questionnaire survey*

Based on the 14 selected items, a paper-based questionnaire survey was conducted inquiring into people's wilderness representations across a larger sample. Survey participants were asked to rate the individual items according to how they correspond with their personal wilderness representation. For each of the 14 items respondents had to indicate on a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree), how strongly they agree or disagree with the presented item. During August and October 2016, we surveyed a total number of 858 respondents either at home or at different public spaces and recreational sites throughout the study region. Following a stratified sampling strategy, survey locations were carefully selected to reach a representative distribution of participants across the main districts of the study region as well as a diverse sample in terms of age, gender, mother tongue, place of residence, and stakeholder group (i.e. local

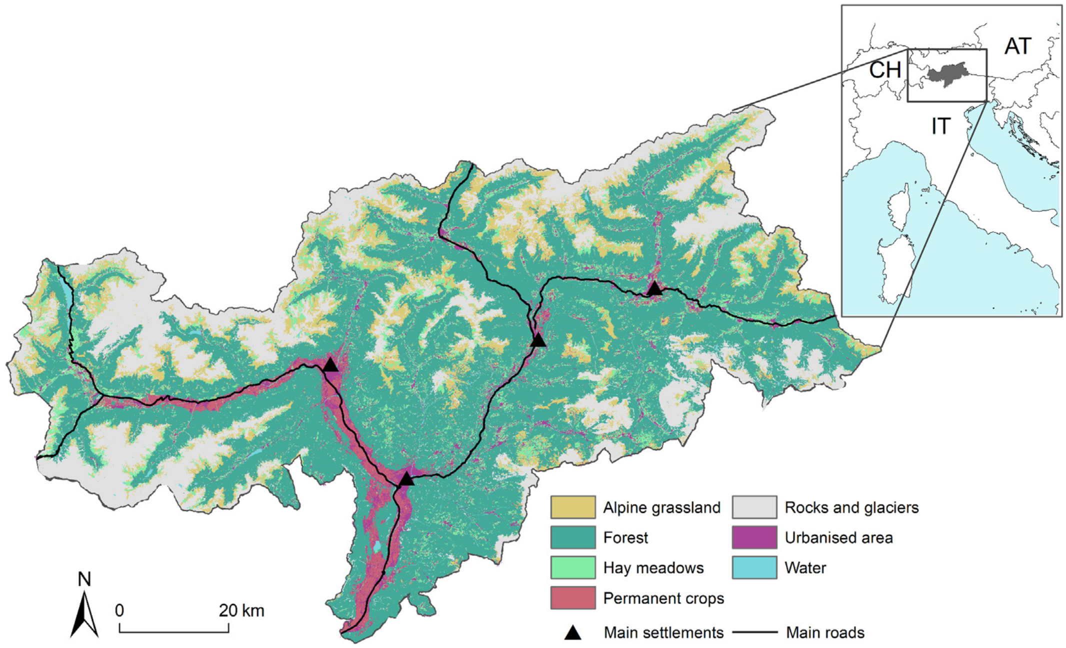


**Fig. 2.** Location of the study area and distribution of the main land use/land cover types.

**Table 1**
Socio-demographic characteristics of survey sample (in %).

| | Local farmers N = 95 | Local residents (excluding farmers) N = 413 | Visitors N = 350 |
|---|---|---|---|
| *Gender* | | | |
| Male | 58.9 | 40.5 | 55.6 |
| Female | 41.1 | 59 | 44.2 |
| Other | 0 | 0.5 | 0.3 |
| *Age* | | | |
| ≤25 | 7.4 | 16.4 | 6.5 |
| 26–35 | 12.8 | 15.7 | 11.5 |
| 36–45 | 17 | 13.5 | 12.1 |
| 46–55 | 24.5 | 25.2 | 25.7 |
| 56–65 | 25.5 | 18.9 | 23.7 |
| > 65 | 12.8 | 10.3 | 20.4 |
| *Mother tongue* | | | |
| German | 93.7 | 74.9 | 71.3 |
| Italian | 6.3 | 23.4 | 25.7 |
| Ladin | 0 | 1.7 | 0 |
| Other | 0 | 0 | 2.9 |
| *Place of residence* | | | |
| Village | 94.7 | 54.1 | 43.5 |
| Small town (≤50,000 inhabitants) | 4.2 | 18.3 | 26.2 |
| City (> 50,000 inhabitants) | 1.1 | 27.6 | 30.3 |

farmers, residents, and visitors) (Table 1). At each location, potential respondents over the age of 18 were approached at random and invited to complete the paper-based questionnaire. The questionnaire was completed either in German or Italian, depending on the mother tongue of the survey participant.

To identify shared wilderness representations, a Principal Component Analysis (PCA) was performed based on respondents' rating of the items. Considering the assumptions of PCA, namely that measurement scales need to be continuous and the observed variables normally distributed, the PCA was conducted based on polychoric correlations between the single items. In this way, the observed ordinal but theorised normal distribution of the continuous Likert-type ratings was considered (Olsson, 1979). To identify a reduced number of uncorrelated variables which account for most of the variance of the observed input variables, we ran the PCA using Kaiser normalisation criterion > 1 and Varimax rotation with 999 permutations. All statistical analyses were performed in R, version 3.4.3.

### 3.3. Mapping wilderness: public perspectives

The quantification of geographical variation in wilderness quality according to the identified public wilderness representations requires the translation of these relative abstract concepts into more concrete spatial terms. To achieve this, geographic coverage of the different wilderness representations was quantified and mapped based on a unique set of spatially explicit indicators. Spatial indicators were first derived to map geographic variations in each of the attributes constituting one wilderness representation. Secondly, these attribute maps were combined and weighted according to their evaluation by participants within a MCE model. As a result, a set of unique public wilderness quality maps were created, each visualising the places of wilderness on a continuum from the least wild to the most wild. The mapping of the different representations of wilderness was done for the entire study region and a spatial resolution of 25 m using ArcMap (version 10.6.1) and bespoke viewshed analysis software.

#### 3.3.1. Mapping wilderness attributes

Based on available spatial datasets from regional authorities, crowdsourcing platforms, historic and European sources, 14 spatial indicators (one for each attribute) were derived (Table 2). Following a hierarchical approach (Fig. 3), these indicators were composed of several quantifiable measures which in turn were linked to different existing data sources. The spatial indicators can be grouped into four major indicator sets, referring to (1) past and present land use, (2) the impact of man-made infrastructure, (3) the probability to encounter wildlife and other humans, and (4) the size of an area and its accessibility considering terrain and vegetation cover. Table 2 provides an overview of all spatial indicators used in this study, their associated wilderness attributes and data sources. Whereas some indicators such as *'Remoteness from mechanised access'* or *'Lack of visual impact from human artefacts'* were calculated following previously published protocols (see Carver et al., 2012), the computation of other indicators required the development and combination of novel methods. In the following

**Table 2**
Overview of spatial indicators and their data sources used to map spatial variation in wilderness attributes of public wilderness representations with a spatial resolution of 25 m.

| No. | Wilderness attribute | Items used in questionnaire | Spatial indicator | Data property | Data source |
|---|---|---|---|---|---|
| 1 | No cultivation | Wilderness is where nothing is cultivated by humans. | No land use today | Binary | Regional LULC map [1], Corine land cover 2012 [2], agroforestry database [3], European river network [4], OpenStreetMap (roads) [5], OpenStreetMap (waterway) [6], and potential treeline [7] |
| 2 | Not changed by humans yet | Wilderness is what hasn't been changed by humans yet. | No land use in 1860 & today | Binary | Francisco Josephinian Cartographical Register (third cartographical register of the Austrian crownlands; 1:25,000), drawn up from 1869 to 1887 [8] plus data sources used for indicator no. 1 |
| 3 | Cultivation is abandoned | Wilderness is where cultivation is abandoned by humans. | Abandonment of land use between 1860 & today | Binary | Same data sources as used for indicator no. 1 and 2 |
| 4 | Nature can self-develop | Wilderness is where nature can self-develop. | Visual perception of naturalness | Ordinal | Regional LULC map [1], Corine land cover 2012 [2], and survey data [9] |
| 5 | No settlements & man-made infrastructure present | Wilderness is where no settlements or man-made infrastructure such as roads, alpine huts, or ski lifts can be found. | Distance from settlements & man-made infrastructure (excluding hiking paths) | Continuous | Regional LULC map [1], Corine land cover 2012 [2], OpenStreetMap (roads) [5], OpenStreetMap (waterway) [6], OpenStreetMap (power) [10], Geobrowser-Infrastructure [11], OpenStreetMap (aerialway) [12], OpenStreetMap (buildings) [13], and Geobrowser-Protection structure [14] |
| 6 | No hiking paths & waymarks | Wilderness is where no hiking paths and waymarks exist. | Distance from man-made infrastructure and path network | Continuous | Same data sources as used for indicator no. 5 |
| 7 | No signs of civilisation visible | Wilderness is where no signs of civilisation are visible. | Lack of visibility of human artefacts | Continuous | European digital terrain model [15] plus same data sources as used for indicator no. 5 |
| 8 | Habitat for red deer, foxes, hares, or chamois | Wilderness is where animals such as red deer, foxes, hares or chamois live. | Probability to encounter wildlife (small game, hoofed game, and winged game) | Continuous | Hunting shots 2016–2017 [16], habitat suitability [17] |
| 9 | Habitat for wolf, bear, or lynx | Wilderness is where native animals such as wolf, bear, or lynx live. | Probability to encounter large predators (wolf and bear) | Continuous | Sightings of bear and wolf 2002–2017 [18] |
| 10 | No other people | Wilderness is where no other people are. | Visitor use density | Continuous | Flickr photos (2004 until the end of December 2016) |
| 11 | Large area | Wilderness is a large area, which stretches for kilometres. | Size of non-fragmented area | Continuous | Corine land cover 2012 [2], OpenStreetMap (roads) [5] |
| 12 | Impassable area | Wilderness is where it is impassable, because it is too overgrown. | Degree of impassibility of vegetation cover | Continuous | Regional LULC map [1], Corine land cover 2012 [2], agroforestry database [3], European river network [4], OpenStreetMap (roads) [5], and European digital terrain model [15] |
| 13 | Inaccessible area (too steep & rugged) | Wilderness is an inaccessible area because it is too steep or rugged. | Degree of inaccessibility of terrain | Continuous | European digital terrain model [15] |
| 14 | Remote area | Wilderness is a remote area. | Remoteness from mechanised access | Continuous | Regional LULC map [1], Corine land cover 2012 [2], agroforestry database [3], European river network [4], OpenStreetMap (roads) [5], OpenStreetMap (aerialway) [12], and European digital terrain model [15] |

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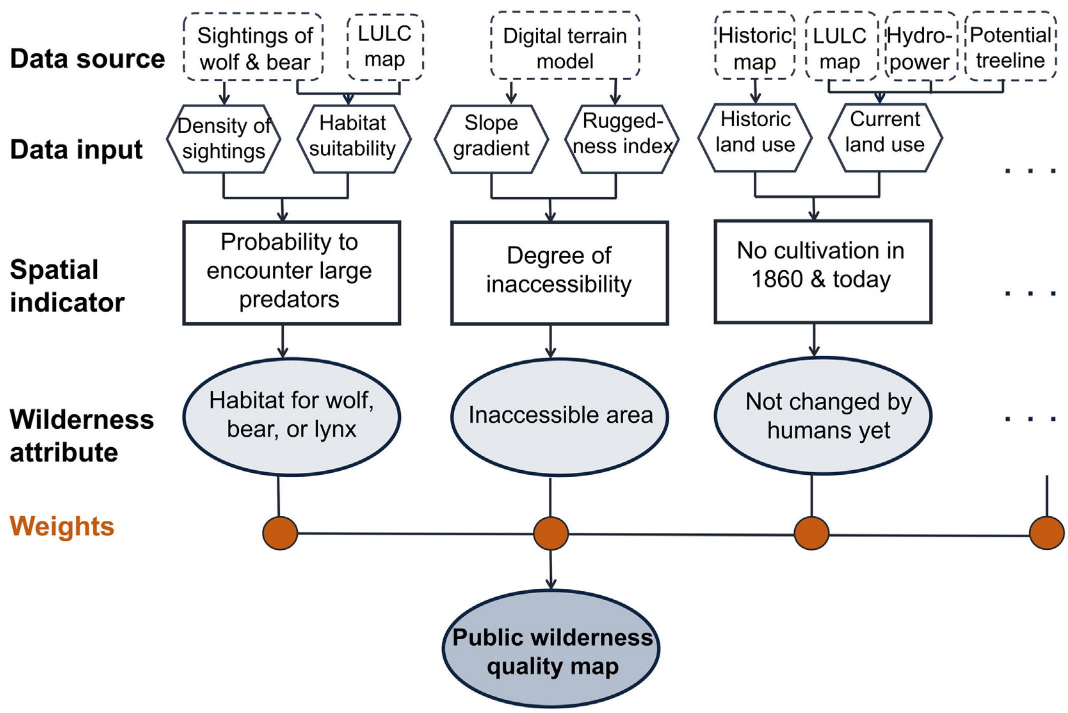


**Fig. 3.** Overview of hierarchical GIS approach to derive spatial indicators for stated wilderness attributes. Wilderness attributes characteristic for one wilderness representation are then combined and weighted within an MCE model to derive public wilderness quality maps. The mapping procedure is illustrated based on three attributes (i.e. 'Habitat for wolf, bear, or lynx', 'Inaccessible area', and 'Not changed by humans yet').

paragraphs, we provide a brief overview of the main characteristics of each indicator and the major steps taken for its calculation. For a more detailed documentation of the methods see supplementary material A.

(1) *Indicators related to past and present land use:* Different binary indicators were developed for wilderness attributes associated with the past and present use of land for agricultural or forestry purposes. Whereas the lack of cultivation was indicated based on a classification of current land use and land cover (LULC) information (*'No land use today'*), areas that haven't been changed by humans yet were identified based on a composite indicator considering both present and past agricultural and forestry activities (*'No land use in 1860 & today'*). Considering that in 1860 the maximum spatial extent of land use was reached in the study region (Tasser et al., 2009), historic spatial data about these activities were derived from the Francisco-Josephinian Cartographical Register, drawn up from 1869 to 1887, and combined with the classification of current LULC information described above. Areas characterised by the abandonment of cultivation, in turn, were mapped by identifying all areas on which agricultural and forestry activities have been abandoned between 1860 and today (*'Abandonment of land use between 1860 & today'*). In contrast to these indicators, we calculated a fourth indicator related to the naturalness of land (*'Visual perception of naturalness'*) based on results from a perception survey (Zoderer, Tasser, Carver, & Tappeiner, 2019). In this survey, respondents' visual perception of the naturalness of a landscape was revealed based on 147 landscape photographs covering the main landscape types of the region.
(2) *Indicators related to the impact of man-made infrastructure:* We developed various spatial indicators to map variations in wilderness attributes related to impacts of settlements and artificial infrastructure. Depending on the attribute, either the *absence* of settlements and man-made infrastructure was quantified or the *lack of visibility* of the same artificial structures. In the former case, we calculated the Euclidean distance from man-made features including pylons, ski lifts, roads, and buildings (see Table A.3 for the full list) (*'Distance from settlements & man-made infrastructure'*). To additionally consider the presence of hiking paths, the Euclidean distance was calculated considering these features plus all paths running through the study region (*'Distance from man-made infrastructure and path network'*). By contrast, the *'Lack of visibility of human artefacts'* was estimated by performing a voxel viewshed analysis using the Viewshed Explorer software (Carver et al., 2012). In this analysis, the cumulative visibility surface of all human artefacts was measured in a full 360° arc around any target location considering the effect of terrain and land cover on the visibility of the features. Viewsheds were calculated considering the effect of distance decay on the relative size of the visible features, and a maximum view distance of 10 km (Schirpke et al., 2013).
(3) *Indicators related to wildlife and visitor use density:* Two indicators were developed to indicate the probability to encounter wildlife such as red deer, foxes, hares or chamois (*'Probability to encounter wildlife'*) and large predators such as wolf and bear in the study region (*'Probability to encounter large predators'*). For each pixel cell, we estimated the probability to encounter wildlife, including small game, hoofed game and winged game, through a composite indicator that combines measures on the suitability of the single LULC classes for 30 indicator species with georeferenced data about the size of hunt bags of the same species. By contrast, we estimated the probability to encounter large predators by running a Kernel density function based on all digitised sightings of bear and wolf and combining this information with a habitat suitability index calculated from intersecting point data about the reported sightings with LULC classes. Spatial variations in *'Visitor use density'* were mapped based on geo-tagged photographs uploaded on the social media platform Flickr. Previous studies (e.g. Wood, Guerry, Silver, & Lacayo, 2013) have reported that this crowdsourced data can be used as reliable proxy for visiting frequencies. The probability of encountering other people was estimated for each raster cell by running a Kernel density based on all 'user days' (Wood et al., 2013), i.e. the number of users who took at least one picture per day within a certain area.

(4) *Indicators related to size and accessibility:* To indicate the largeness of an area as perceived by people, a composite indicator (*'Size of non-fragmented area'*) was calculated considering the effect of area size and area shape of all homogenous patches of land cover classes that were not fragmented by linear infrastructure such as roads, railway lines and cycle lanes (Table A.5). Various indicators for wilderness attributes related to the accessibility of an area were further developed. Whereas the *'Degree of inaccessibility of terrain'* was calculated considering effects of both steep and rugged terrain, the *'Degree of impassability of vegetation cover'* was estimated accounting for the vegetation cover of each raster cell. In the latter case, a friction value (see Table A.6) was estimated for each LULC class indicating the extra travel time needed for traversing the area. The *'Remoteness from mechanised access'*, in turn, was calculated by estimating the walking time required to reach each raster cell from the nearest road, railway or cable car station, taking the effects of terrain, ground cover, and barrier features such as open water bodies and very steep slopes into account (Carver et al., 2012).

#### *3.3.2. Combining wilderness attribute maps within MCE model*

In the final stage of our mapping approach, we employed an MCE model (Carver et al., 2012) to combine and weight all attribute layers characteristic for each wilderness representation according to their relative importance given by survey respondents. For each wilderness representation, only the attributes with a factor loading greater than 0.4 were considered (Stevens, 1992), and weighted according to their strength of correlation with the PCA components as indicated by the factor loadings. Before spatially overlaying the respective attribute layers, the attribute maps were checked for outliers (i.e. data points below 1st and above 99th percentile). These were set to values of either the 1st or 99th percentile to retain comparability between data layers with binary, ordinal or continuous distribution of data. All attribute maps were normalised onto a common relative 1–256 scale, where 1 indicates the lowest and 256 the highest attribute values. Normalisation was achieved in ArcGIS using equal interval classes. For each wilderness representation, we overlaid and weighted the attribute maps using the following weighted linear summation formula:

$$S_i = \sum_{j=i}^{n} W_{ij} X_{ij} \tag{1}$$

where $n$ is the number of attributes with factor loading above 0.4, $S_i$ is the overall wilderness quality value of the $i$th pixel cell, $W$ is the attribute weights (i.e. factor loadings), and $X$ is the standardised value of each attribute. Based on the generated public wilderness quality maps, the degree of variance in wilderness quality was calculated for each raster cell to identify areas with high conflict potential across public wilderness representations. In addition, we compared areas reaching wilderness quality above selected arbitrary thresholds of top 10%, 25%, and 50% wilderness quality across the identified wilderness representations, respectively.

### *3.4. Mapping wilderness: expert perspective*

In addition to the spatial quantification of wilderness quality according to public wilderness representations, we quantified and mapped wilderness from the perspective of international wilderness experts. Largely following the standardised approach proposed by Radford et al. (2019), we quantified wilderness quality based on four main wilderness attributes: naturalness, remoteness, human impact, and ruggedness. The selection of these attributes reflects the major components of the standardised wilderness definition proposed by Wild Europe (2012) and so differs significantly from the standardised indicators used to map variations in wilderness character in US National Parks (Carver et al., 2013) according to the US Wilderness Act (1964). Table 3 provides an overview of the methods used to calculate the four attribute layers. The generated attribute maps were normalised onto a common relative scale (1–256) and subsequently combined to one overall wilderness quality index using weighted linear summation. Results from a survey with 22 international experts (see Radford et al., 2019) were further considered to assign weights to the four attribute layers as well as the data input layers for the attribute 'human impact'. Finally, we calculated the degree of variance in wilderness quality for each raster cell considering all public and expert-based wilderness quality maps to identify areas with high conflict potential between public and expert wilderness representations.

## 4. Results

This section presents results on the following three themes: 1) public wilderness representations, 2) spatial distribution of the different public-defined wilderness areas, and 3) their comparison to an expert-defined wilderness.

### *4.1. Public wilderness representations*

Despite great variety in respondents' wilderness representations, the principal component analysis (PCA) reveals three dominant wilderness representations (eigenvalue $> 1$) across the whole survey sample (Table 4). For easier interpretation of the results, we named the identified representations based on their main wilderness attributes: *'Area with no human impact'* (WR1), *'Remote and large area'* (WR2), and *'Area where nature can self-develop'* (WR3). The three identified wilderness representations account for 55.7% of the total variance in respondents' rating of wilderness items and considerably differ in terms of selection and weighting of wilderness attributes. WR1 explains 21.9% of the variance and is characterised by the most rigorous definitions of attributes. According to this representation, an area is conceived as wild only if no traces of human activities can be found, meaning no extractive activities have ever been carried out, no settlements and man-made infrastructure such as roads, ski lifts or alpine huts are visible, and no hiking paths exist. In addition to these criteria, this representation describes wilderness as an area too overgrown by vegetation or too rugged to be accessible for humans. WR2 explains 19.5% of the variance and imagines wilderness as a remote and large area, where one can be alone. While the lack of past human activities or artificial infrastructure is regarded as less relevant, this representation highlights the presence of abandoned land and wildlife, including large predators, as requirements for wilderness. WR3 accounts for 14.3% of the variance and again differs from the other two, in that it defines wilderness according to more moderate criteria. According to this representation, wilderness is perceived as an area where nature can self-develop, no settlements and artificial infrastructure exist, and the land is currently uncultivated. In a similar fashion to WR2, wilderness is understood as a habitat for wildlife, but not as a habitat for large predators.

### *4.2. Public wilderness quality maps*

Based on the three identified public wilderness representations and their underlying attributes (Fig. 4), three distinct public wilderness quality maps were generated that differ in their geographic representation of wilderness quality across the study area (Fig. 5). All three wilderness quality maps indicate lowest wilderness quality in the urbanised and most intensively used valley floors but differ regarding their assignment of highest wilderness quality to areas located at higher elevations (Fig. B.2). Depending on the spatial distribution of wilderness attributes characterising each representation, the generated maps show clear differences in spatial distribution, location, and extent of areas with high wilderness quality. From the perspective of WR1, high wilderness qualities are mainly found on small patches of alpine shrub vegetation that have not yet been used by humans, scattered across the area of the Dolomites in the southeast of the study region.

**Table 3**
Overview of methods (adapted from Radford et al., 2019) to spatially quantify wilderness attributes of experts' representation of wilderness with a spatial resolution of 25 m.

| Wilderness attribute | Description | Overview of method |
|---|---|---|
| Naturalness | Degree of anthropogenic interferences on plants, animals, and the ecosystems as a whole | Reclassification of LULC data along a seven staged hemeroby scale as done by Rüdisser et al. (2012) |
| Human impact | Absence of human activities and artificial structures including infrastructure, settlements, light and noise pollution | Weighted linear summation of data input layers indicating human activities and infrastructure: noise and light pollution, infrastructure-free areas, guesthouses and mountain huts, skiing and hiking trails, degree of landscape fragmentation, and population centres (Radford et al., 2019) |
| Remoteness | Remoteness from mechanised access, i.e. walking time required to access any location on the map from the nearest road, railway and cable car station | Following Carver et al. (2012), calculations were done as described in 3.3.1 and supplementary material (Tables A.7 and A.8). |
| Ruggedness | Physically challenging terrain | Standard deviation of terrain curvature within a 250 m radius of the observer (Carver et al., 2012; Radford et al., 2019). |

Their dense vegetation and rugged terrain mean that they are hard to access and traverse, while also impairing the sight of any signs of civilisation. Apart from these areas, high wilderness quality can also be found on rocks and glaciers mainly located in the northwest of the study site because of their great distance from man-made infrastructure as well as complex topography which reduces the visibility of human artefacts.

Places regarded as wild by WR2, in contrast, are located on higher elevations spread across the main mountain groups of the study region with exception of the most frequently visited mountain peaks of the Dolomites. In particular, the highest wilderness qualities occur on the less frequented, formerly cultivated grasslands where probabilities to encounter wildlife are highest, and on the most remote and vast mountains and glaciers located in the north and west of the study region where visitor densities are low. From the perspective of WR3, high wilderness qualities are associated with larger patches spread across the entire study site, including most natural grassland, rocks and glaciers located above 2200 m. All three landscape types are regarded as wild because of their current lack of cultivation, perceived naturalness and great distance from settlements and human artefacts. Considering these differences in attribution of high wilderness quality across the three representations, potentials for conflict are particularly likely to arise in the area of the Dolomites in the southeast of the study site (Fig. 6 and Fig. B.2).

The three patterns of public-defined wilderness differ in terms of their geographic coverage (Table 5, Fig. 6b). Whilst areas lying within the top 25% wilderness quality cover less than 1% of the study area in case of WR1 and WR2, about 5% of the territory is covered by areas lying within the top 25% wilderness quality according to WR3. Apart from these differences, the three representations of wilderness differ in terms of spatial distribution across elevation classes, landscape types, and protected areas (Fig. 7 and Table 5). Whereas high wilderness values of both WR2 and WR3 are almost entirely found on higher elevations above 2,200 m, most areas with highest wilderness qualities according to WR1 are located between 1,800 and 2200 m a.s.l. where most alpine shrub vegetation occurs. Relatedly, highest wilderness qualities of WR1 are mainly associated with the upper forest belt, whilst those of WR2 and WR3 can predominantly be found on rocks and glaciers (Fig. 7b). Table 5 shows that about 70% of areas lying within the top 25% wilderness quality according to WR1 are currently protected by several conservation programs, whereas only about half of the top 25% wilderness quality areas of WR3 and about a third of those of WR2 are currently protected by the same schemes.

### 4.3. Comparison to expert-based wilderness map

We compared the different generated public wilderness quality maps to a standardised expert-based wilderness quality map (Radford et al., 2019). According to experts' representation of wilderness, areas with high wilderness qualities are predominantly located on higher elevations above 2200 m, distributed across the main mountain groups of the study region (Fig. 5). Areas with very high wilderness quality mainly comprise the mountain peaks and glaciers of the study region as well as few patches of alpine grassland and forests characterised by a

**Table 4**
Results from the PCA showing the three public wilderness representations identified across the survey sample. All wilderness attributes characterising one wilderness representation (factor loading > 0.4) are indicated in bold and translated into spatial indicators for the mapping of wilderness quality.

| | Wilderness representation 1 **'Area with no human impact'** | Wilderness representation 2 **'Remote and large area'** | Wilderness representation 3 **'Area where nature can self-develop'** |
|---|---|---|---|
| | 21.9% | 19.5% | 14.26% |
| No cultivation | **0.593** | 0.114 | **0.488** |
| Not changed by humans yet | **0.804** | −0.052 | 0.149 |
| No signs of civilisation visible | **0.810** | 0.100 | 0.220 |
| No hiking paths & waymarks | **0.604** | 0.289 | 0.238 |
| Impassable area | **0.708** | 0.357 | −0.135 |
| Inaccessible area (too steep & rugged) | **0.460** | 0.375 | −0.125 |
| Large area | 0.195 | **0.732** | 0.000 |
| Remote area | 0.275 | **0.716** | −0.074 |
| No other people | −0.039 | **0.643** | 0.180 |
| Cultivation is abandoned | 0.288 | **0.462** | 0.249 |
| Habitat for wolf, bear, or lynx | 0.182 | **0.613** | 0.339 |
| Habitat for red deer, foxes, hares, or chamois | 0.165 | **0.544** | **0.568** |
| Nature can self-develop | 0.038 | 0.069 | **0.743** |
| No settlements & man-made infrastructure present | 0.326 | 0.081 | **0.713** |

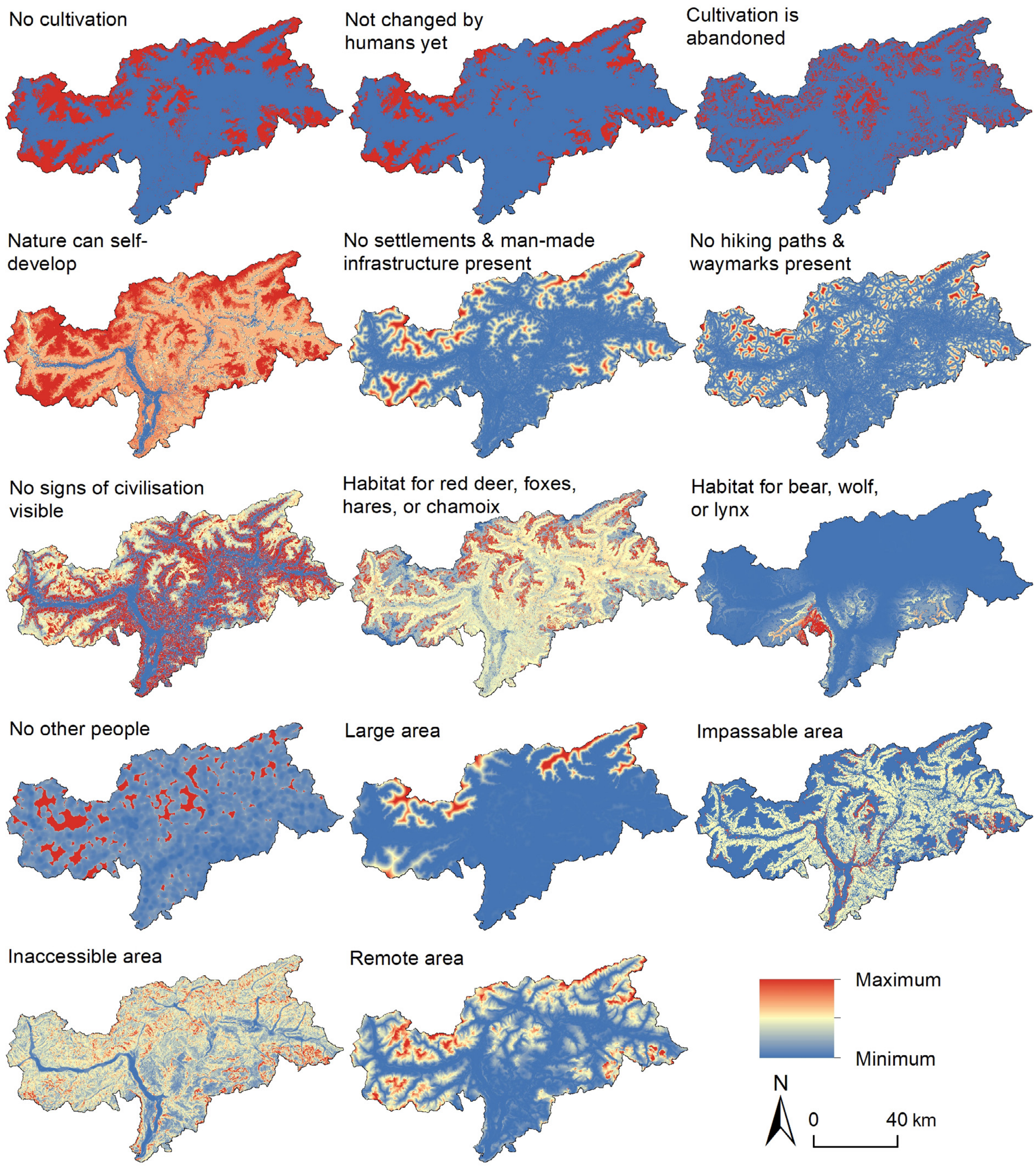


**Fig. 4.** Wilderness attribute maps showing spatial variation in attributes across the study site.

combination of high values of naturalness, remoteness, and lack of human impact (Fig. 7). A considerable share of the study area (12.8%) lie within the top 25% wilderness quality and about 1.5% of the mapped territory within the top 10% wilderness quality (Table 5).

Visual comparisons between all four maps show that the expert-based approach tends to localise larger areas of high wilderness quality as compared to public wilderness representations WR1 and WR2 (Fig. 6b). Patches with highest wilderness quality are larger in extent, more numerous, and more equally distributed across the study area when mapped according to experts' representation of wilderness. Fig. 6a reveals distinct differences between the expert-based wilderness quality map and public wilderness quality maps at different levels of the wilderness quality spectrum. Whilst the potential for conflicts across public wilderness representations is predominantly concentrated on areas of high wilderness quality (Fig. B.2), potential for conflict between expert and public wilderness representations are associated with a larger area including areas of moderate and high wilderness quality.

## 5. Discussion

### 5.1. Different representations of wilderness and their spatial distributions

Despite increasing societal demand for wilderness, little knowledge exists about public wilderness representations and the places regarded as wild. Although much previous work has been carried out in North America on wilderness meanings and values (e.g. Cole, 2005; Gunderson, 2006), research on fundamental differences in public's wilderness representations remains limited. Based on a mixed-method

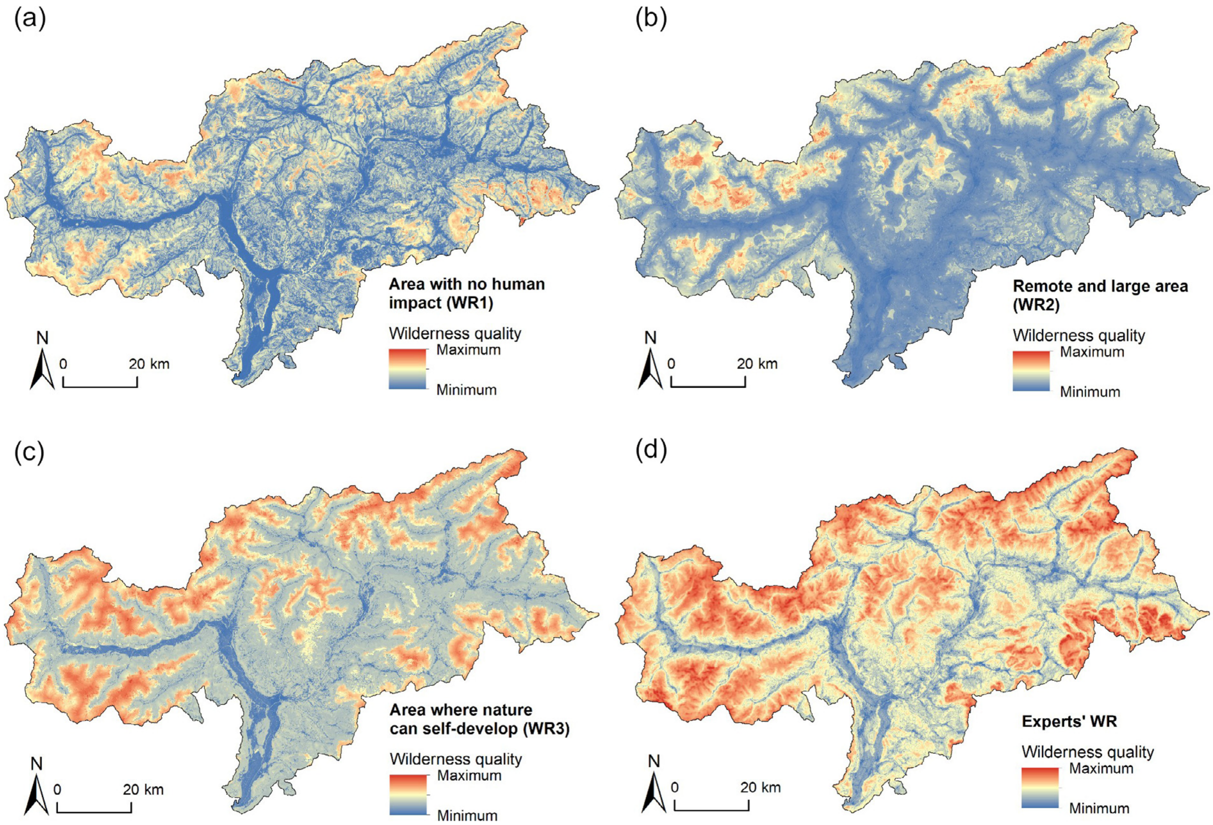


**Fig. 5.** Spatial distribution of wilderness quality according to the three identified public wilderness representations, i.e. a) *'Area with no human impact'* (WR1), b) *'Remote and large area'* (WR2), c) *'Area where nature can self-develop'* (WR3), and d) experts' wilderness representation (WR).

approach, this study explored variations in public's wilderness representation and provided means to estimate their geographic coverage. Overall, a total number of three public wilderness representations were identified. Each of these intersubjective representations is characterised by an intricate mix of distinct wilderness attributes identified by study participants. The identified attributes cover attributes considered in previous work on expert-informed wilderness mapping (e.g. Radford et al., 2019), participatory wilderness mapping (e.g. Carver et al., 2002) and wilderness perception mapping (e.g. Larkin & Beier, 2014), but also include additional attributes such as the presence of wildlife habitats, impassability of vegetation cover, lack of past human use or the abandonment of cultivation.

Comparisons of the three public wilderness representations reveal that differences mainly occur in terms of selection and relevance of attributes characteristic for each representation. For instance, whilst criteria associated with visitor use density, the remoteness and size of a place are regarded as important by WR2, the same criteria are not considered relevant by the other two representations. Differences between representations also emerge regarding the interpretation of attributes such as 'naturalness' or the 'lack of human impact'. In case of naturalness, for example, our participants considered places as wild either when they appear natural to people (WR3) or when they know that these places originated without human intention (WR1). These empirical differences in understandings of naturalness coincide with Birnbacher's theoretical distinction between qualitative and genetic naturalness (Birnbacher, 2006), where the former focuses on the

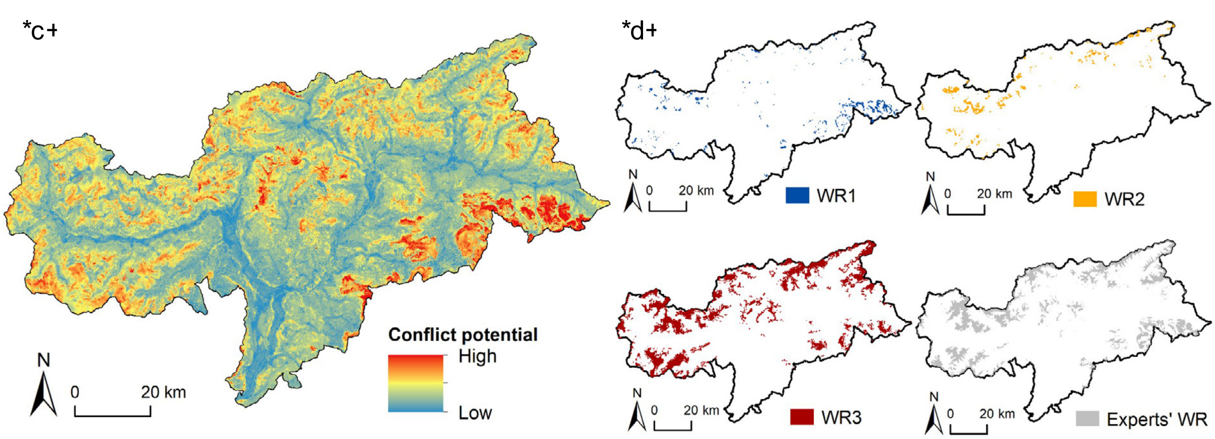


**Fig. 6.** a) Spatial localisation of conflict potential across public and expert wilderness representations, and b) the spatial distribution of the top 25% wilderness quality according to each wilderness representation. Note: WR1 refers to wilderness representation 1 (*'Area with no human impact'*), WR2 to wilderness representation 2 (*'Remote and large area'*), and WR3 to wilderness representation 3 (*'Area where nature can self-develop'*).

**Table 5**
Overview of geographic coverage of highest wilderness quality according to the three identified public wilderness representations and experts' wilderness representation (WR). Note: WR1 refers to wilderness representation 1 (*'Area with no human impact'*), WR2 to wilderness representation 2 (*'Remote and large area'*), and WR3 to wilderness representation 3 (*'Area where nature can self-develop'*).

| Wilderness quality | Area covered (ha) | % of study area | % currently protected |
|---|---|---|---|
| *Top 10%* | | | |
| WR1 | 240 | 0 | 89.5 |
| WR2 | 41 | 0 | 10.6 |
| WR3 | 594 | 0.1 | 64.3 |
| Experts' WR | 11,260 | 1.5 | 66.4 |
| *Top 25%* | | | |
| WR1 | 2294 | 0.3 | 72.1 |
| WR2 | 4123 | 0.6 | 26.6 |
| WR3 | 39,362 | 5.3 | 50.4 |
| Experts' WR | 94,634 | 12.8 | 53.3 |
| *Top 50%* | | | |
| WR1 | 123,252 | 16.7 | 53.2 |
| WR2 | 63,361 | 8.6 | 34.4 |
| WR3 | 247,899 | 33.5 | 43.9 |
| Experts' WR | 417,950 | 56.5 | 36.9 |

present state of an object and the latter on its history. Similarly, the degree of tolerance expressed towards human artefacts differs between the three wilderness representations. While neither the physical presence nor the visibility of man-made infrastructure is tolerated in a wild landscape according to WR1, the same features are accepted by WR3 when only visible from afar.

Differences in selection and interpretation of wilderness attributes lead to significant differences in spatial distribution and localisation of the three wilderness representations. Spatial differences are greatest between WR1 and WR2, with most variation in wilderness quality occurring in the area of the Dolomites in the southeast of the study site. The Dolomites are frequently advertised by travel guides and tourist agencies as a spectacular place offering "a number of stunning wilderness areas" (Lonely Planet, 2019). However, our results indicate that it is likely that the Dolomites' wilderness quality is perceived differently depending on how their unique characteristics are evaluated by different groups of people with a different representation of wilderness. In comparison to most other mountain groups of the study region, the Dolomites are smaller in scale, more rugged in terms of relief, and characterised by a great popularity among recreationists and tourists. The extensive hiking network, high density of facilities including mountain huts and cable cars as well as the existence of several protected areas (e.g. UNESCO World Heritage Site), attracts a high number of visitors in both summer and winter. Whilst such features seem to not impair, at least in part, the area's wilderness quality according to WR1 and WR3, the lack of remoteness and vastness as well as high visitor use densities mean that the occurrence of wilderness tends to be considerably reduced according to WR2.

### *5.2. Comparison to expert-based wilderness quality map*

Different expert-informed approaches have been developed to quantify and map wilderness quality in a robust and repeatable matter across various scales and for different places (Carver and Fritz, 2016). In this study, we compared the generated public wilderness quality maps with an expert-based wilderness quality map produced according to a recently published mapping method (Radford et al., 2019). Our comparison reveals that the expert-based wilderness quality map associates high wilderness quality with larger areas, especially with regard to the alpine and nival zone, as compared to public wilderness representations WR1 and WR2. Differences between our maps and that of the expert-based approach can mainly be related to differences in selected wilderness attributes: On one hand, the expert-based approach did not consider some of the attributes (e.g. presence of wildlife habitat, cultivation is abandoned, lack of past human use) relevant for public wilderness representations; on the other hand, it assumes that certain attributes (e.g. naturalness, lack of human impact) can be generalised without paying attention to differences in interpretation of these attributes across the different representations.

### *5.3. Implications for landscape management and planning*

The results of this study have important implications in three areas. These are related to differences 1) in judgements among the public itself, 2) between experts and the public, and 3) in coverage between identified wilderness areas and existing conservation areas.

Firstly, our results suggest that caution is needed when exclusively formulating policy measures on the basis of a single definition. Whilst we find that an expert-informed perspective on wilderness, such as the one adopted here based on the standardised wilderness definition proposed by Wild Europe (2012), can be useful for capturing public's most valued wilderness areas in a simple and pragmatic way, our results further show that relying on one single, expert-informed wilderness map would overlook important disparities between expert and public representations of wilderness as a potential source of conflict. In order not to marginalise less powerful groups and local communities, our findings thus demonstrate the need for greater public involvement in

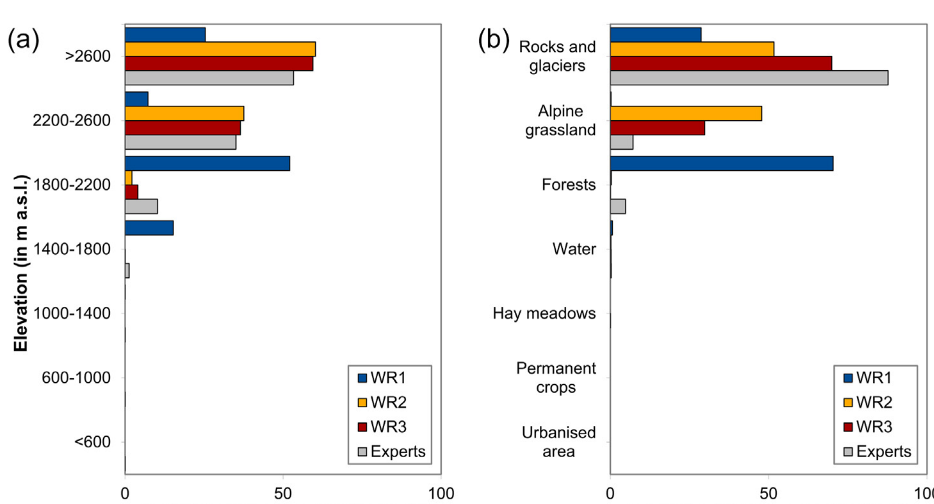


**Fig. 7.** Distribution of top 25% wilderness quality across a) elevation classes and b) landscape types.

identifying potential wilderness areas and their management measures.

Furthermore, spatial comparisons of the generated wilderness maps reveal areas of agreement and disparity across the different representations of wilderness that can be useful for landscape planning and management. In particular, the generated wilderness maps can serve as a decision-support tool to evaluate the impacts of planned infrastructural developments early in the planning process. For instance, it can be shown that the realisation of a new ski resort can impact the wilderness qualities far beyond their actual site in case of WR1, whilst the same project might impact the site's wild character only when new levels of disturbance and overcrowding are caused (in case of WR2). Furthermore, our results suggest that current trends in land abandonment, especially those in mountainous areas, can differ in their impact across the varying representations of wilderness. Our results indicate that the extension of abandoned land is likely to increase the wilderness described by WR2 but not necessarily that described by WR1.

Finally, our results highlight that a substantial proportion of public-defined wilderness (e.g. 72% of top 25% wilderness quality in case of WR2) as well as expert-defined wilderness (47% of top 25% wilderness quality) is currently not subject to any conservation scheme. This implies greater opportunity for the designation of new protected areas or the extension of existing ones across the study area. Spatial comparisons of the different representations of wilderness reveal greatest potential for protecting wilderness at higher elevations located in the west and north of the study site, where a substantial share of highest wilderness qualities is localised according to both experts and the public. Differences across wilderness representations, however, point to the need for a 'zoning' system as discussed previously (Bauer, Wallner, & Hunziker, 2009). Protected wilderness areas could be divided into zones to accommodate varying representations of wilderness, with a core zone of uncontrolled natural development (i.e. WR1), for instance, and several surrounding buffer zones in which different levels of recreation and low-intensity land uses are allowed (i.e. WR2 and WR3). Our results further indicate that the potential for designating wilderness areas is particularly low on elevations below 1800 m a.s.l. From the perspective of WR2 and WR3, however, the implementation of wilderness areas on lower elevations, where agriculture and forestry are abandoned and infrastructure development is halted, could provide new opportunities to experience wilderness qualities in areas closer to people's homes. At the same time, caution needs to be paid when labelling an area as 'wilderness', as this is likely to impair the notion of wilderness for those excluding any human activities from wilderness (i.e. WR1) or seeking to avoid large numbers of visitors (i.e. WR2). Whilst our wilderness maps can serve as an important information base for the design and management of such protected areas, we recommend using these maps as part of a participatory process, wherein the needs and preferences of all involved stakeholders are considered.

### 5.4. Methodological considerations

The methodological approach used in this study provides evidence about the plurality of wilderness representations as well as their geographic coverage in an Alpine region. The application of a mixed method approach together with the development of GIS models proved to be a valuable tool to deal with the plurality and complexity in people's wilderness representations on one hand, and to allow for a comprehensive spatial integration of this information on the other hand. In particular, the exploratory study design, namely, to use semi-structured interviews at the beginning of our study, allowed to first explore the wide range of differing components characterising individuals' personal wilderness representations without relying on predefined scales or lists of attributes. The subsequent integration of this information into a questionnaire survey provided means to condense the myriad of individual wilderness representations to a limited number of shared representations that can be more meaningfully included in planning and decision-making. In addition, our approach to translating wilderness representations into multiple maps provides a useful adjunct to previous research on wilderness perception mapping (Flanagan & Anderson, 2008; Kliskey, 1994). Instead of mapping the lack of undesired features in a wilderness setting based on simple geographic buffer analyses only as is typically done in wilderness perception mapping, our approach considered specific, more sophisticated spatial models to capture the complex interrelationship between terrain, land cover and/or human-made features for each of the wilderness attributes.

Alongside the steps of our methodological approach we also encountered some limitations. First, our study was designed to capture the plurality of wilderness representations based on a diverse sample. Due to the explorative nature of this research, we have potentially suppressed variations across German and Italian-speaking respondents. Our interview sampling approach was based on convenience criteria, including only German-speaking participants. Furthermore, the questionnaire was available in two languages, i.e. German and Italian, which may have impacted respondents' assessment of the wilderness attributes. In particular, the fact that the word *wilderness* does not exist in Italian and an equivalent word (i.e. *natura selvaggia*) had to be used instead may have led to some bias in data collection. Further research is needed to assess potential cross-cultural variations in wilderness representations.

Second, not all wilderness expressions identified in the phase of conducting qualitative interviews were considered in the questionnaire survey since they could not be meaningful quantified and mapped. For instance, expressions of two interview partners describing wilderness as 'the other' or 'the unknown', thereby thinking of wilderness as a threatening character trait adopted by animals or even humans, were not further considered.

Third, the development of spatial indicators for wilderness attributes was in part an interpretative step, which may have influenced the results of the wilderness quality maps. Each attribute was spatially defined by linking it to one specific spatial indicator, thus suppressing potential other interpretations of the same attribute. For instance, wilderness attribute 'Habitat for red deer, foxes, hares or chamois' was measured as the *probability to encounter* these animals. Similarly, 'No settlements and man-made infrastructure present' was mapped by quantifying the *distance* from these features.

Finally, the development and interpretation of spatial indicators was also dependent on the availability of spatial datasets. Despite the high availability and accuracy of spatial databases on land use, land cover, transportation, infrastructure and terrain for the study region, we had to rely on proxy indicators in case of some attributes. For instance, crowd-sourced pictures from the social media platform Flickr were used as a proxy for actual visitation numbers. Similarly, forestry areas where no management actions are implemented were identified based on expert knowledge since spatial data about the intensity of forest management was missing.

## 6. Conclusion

An ongoing dilemma in wilderness research is the need to reconcile both variation in wilderness definitions and the requirement to develop clear spatial criteria for effectively protecting and managing wilderness areas. At a policy level, responses to this dilemma tend to suppress the plurality of existing wilderness representations in favour of an expert-informed top-down approach on wilderness mapping and conservation. This paper presents an alternative approach as a potential way out of this dilemma. Using an exploratory, mixed method study design, we explored the plurality in public wilderness representations, and combined this with GIS models to translate the identified representations into maps. In contrast to the common assumption that the number of possibly existing wilderness definitions may be endless and thus cannot be considered in planning and decision-making, our study shows that the myriad of individual definitions can be reduced to three intersubjective public wilderness representations. This limited number of identified public representations provides a manageable information base that can be reasonably considered in landscape planning and management. Differences in geographic coverage between these three representations of wilderness, and their comparison to an expert-defined wilderness quality map, underline the need for a bottom-up, participatory approach emphasising public involvement in order to sustainably manage and protect wilderness. Finally, our overview of existing public wilderness representations and their differences in spatial localisation can aid to better resolve wilderness conflicts that are otherwise interpreted as mere expressions of different wilderness attitudes and values.

## 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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