



# What do we know about open spaces and their ecosystem services in the European Alps? Results of a scoping literature review

Kerstin Ströbel<sup>1,2</sup>, Hubert Job<sup>3,2</sup>, and Ludger Brenner<sup>4,2</sup>

<sup>1</sup>Chair for Geography and Regional Science, University of Würzburg, 97074 Würzburg, Germany

<sup>2</sup>AlpPlan Network, Academy for Territorial Development in the Leibniz Association,  
30179 Hannover, Germany

<sup>3</sup>Academy for Territorial Development in the Leibniz Association, 30179 Hannover, Germany

<sup>4</sup>Department of Sociology, Universidad Autónoma Metropolitana, Mexico City, 14387, Mexico

**Correspondence:** Kerstin Ströbel (kerstin.stroebel1@uni-wuerzburg.de)

Received: 22 January 2025 – Revised: 8 May 2025 – Accepted: 22 May 2025 – Published: 12 August 2025

**Abstract.** This review article addresses open spaces in the European Alps by systematically analysing research published in international databases of Scopus, Web of Science, and Georef/Geobase. Additional publications from institutions, such as Alpine Convention and AlpPlan, are also evaluated to support our review of open spaces in research. This approach allowed us to gain further insight into how open spaces are assessed from a spatial planning perspective and how they are valued regarding the Alps and their fringe area. The scoping literature review identified 98 publications that address open spaces in the European Alps framed by the European Union Strategy for the Alpine Region (EUSALP) perimeter. The value of open spaces is highlighted unanimously, though it is evident that a common detailed definition of open spaces, as well as solutions for how to best safeguard them, is yet to be given. This review aims to gain an understanding of open spaces and the role of land use and planning in maintaining ecosystem services. In this respect, spatial planning is identified as the most important tool for safeguarding open spaces, yet it requires transitioning into more proactive and coordinative instruments to strengthen its value in decision-making processes.

## 1 Introduction

Spatial interrelations between high-mountain and peri-mountainous fringe areas are crucial for the provision of ecosystem services (ESs) that mountain areas supply to surrounding lowlands. Covering about one-quarter of the Earth's terrestrial surface, mountains present fragile ecosystems with tremendous importance in the global ecosystem (Scott, 2017). The European Alps provide critical ESs to major urban agglomerations in Central Europe, including cities like Geneva, Milan, Munich, and Vienna. These services range from drinking-water and groundwater supply to biodiversity preservation, as well as aesthetic and recreational landscape value (Meyer and Job, 2024; Job et al., 2017; Chilla et al., 2019). Due to their role as a “water tower” for Europe, the Alps are indispensable for life both within and

beyond their boundaries, providing essential resources such as drinking water (Schirpke et al., 2019).

However, long-term provision of these ESs within mountain regions is under increasing pressure, demanding adaptive governance and effective management strategies at different geographical scales. Significant threats derive from their attraction for leisure and tourism development (Scott, 2017; Mayer et al., 2011), intensified agriculture (Gulinck et al., 2018), industrial infrastructure projects (Cammerer et al., 2013), renewable energy installations, and soil sealing due to expanding settlements. Fringe areas and central valleys are affected due to a rising population, and the slopes of side valleys are affected due to amenity migration and transport infrastructure (Mayer, 2022; Hiess et al., 2022). Therefore, the land-use potential in the context of these threats is highly limited (Salata, 2014). Above all, Alpine valleys face envi-

ronmental stressors such as fragmentation, soil sealing, and loss of biodiversity and landscape diversity, as well as cultural identity – which are all essential to preserving a healthy inner Alpine ecosystem supply chain for long-term provision of the aforementioned ESs (Bätzing, 2002). Soil protection has specifically been a global focus since the 20th century and is recognized under the United Nations Sustainable Development Goal 15.3, which promotes land degradation neutrality (Badura et al., 2017). Despite extensive discussion and frameworks, land take – defined as the loss of natural or semi-natural land for settlement development – continues at a high rate; e.g. Austria loses 20–30 ha of valuable land daily (EU, 2023; Meyer et al., 2021). Since the 1970s, pressures on so-called open and functional spaces have been well documented, yet current rates of land take are alarming, exacerbated by climate change and rising energy demands. However, a widely accepted definition of “open spaces” has so far been missing, making it difficult to harmonize international regulations. A frequently cited working definition is a negative one, arguing for a focus on the situation outside of settlements, including all non-sealed and uncovered areas and thus allowing usage in an extensive manner (Job et al., 2017), e.g. alpine farming, and not being equated to wild or wilderness areas (Alparc, 2023). Another understanding of “open spaces” merely relates to their state of being mostly unsealed, permeable “soft” surfaces in Europe in general (Wandl et al., 2017) and to their importance for conservation and non-fragmentation (Walz et al., 2021).

Political efforts to address transnational land management in the Alps are ruled in the Alpine Convention, which was established in 1991 to manage land-use pressures across member countries. This convention includes protocols with binding commitments for member states, such as the Soil Protection Protocol, defining its goal to balance land-use conflicts with economic and ecological interests in favour of soil protection (CIPRA, 2015). Yet, despite the framework’s importance, implementation at the national level is hampered by a lack of awareness and of local willingness to engage with and implement successful integration into national law (Rudaz, 2009; Badura et al., 2017). To date, no working group has effectively addressed land-use conflicts or landscape protection within the Alpine Convention’s framework (Haßlacher, 2017).

Moreover, regulatory instruments to protect Alpine soils remain underdeveloped (Job et al., 2017). Approaches on a European level for a specific soil directive as a binding measure for member states were started but blocked due to disputes surrounding subsidiarity and administrative burdens (Salata, 2014). So far, the European level has mostly provided strategic and documents that are not legally binding to deliver targets and objectives for land use and development; these require national implementation according to the responsibilities of each respective country and are therefore lacking in regulatory strength (EU, 2025; Heuser, 2022). Some examples of the aforementioned documents are the

Soil Deal for Europe, the EU Biodiversity Strategy for 2030, and “Guidelines on best practices to limit or compensate soil sealing” (CIPRA International, 2022). As soils are a limited resource of high necessity to maintain essential ESs, their protection is non-negotiable and indirectly issued in the new EU Nature Restoration Law (Meyer et al., 2022; CIPRA International, 2022; EU, 2024).

Spatial planning emerges as a primary tool for reconciling economic, social, and ecological land-use interests (Eichhorn et al., 2023; Haßlacher, 2017). Through mechanisms such as the Bavarian Alpenplan (DE) and Tyrolean Landscape Plan (AT), spatial planning offers a means to safeguard soils and open spaces, although scholars discuss open spaces in a heterogeneous manner (Job et al., 2020). Additionally, the Slovenian “Strategija razvoja slovenije” (Ministry of Natural Resources and Spatial Planning, 2023) and the Climate and Resilience Act of 22 August 2021 (France) (Jousseau, 2022) contain objectives for land take limitations as well. Thereby, the main objectives that Alpine spatial planning pursues are cross-border preservation of recreational areas from infrastructural development and safeguarding near-natural spaces in permanent settlement areas. This is achieved by defining protocols and declarations within the Alpine Convention that are to be integrated into national spatial planning without a specific focus on sectoral plans (Tischler, 2022). However, spatial planning lacks robust frameworks and tools to explicitly protect these spaces, which underscores the need for focused research on open spaces, specifically outside of protected areas. Research on the relevance of protected areas excludes the importance of spaces outside protection, which are momentarily threatened, as possible future protected areas and their role as stepping stones that foster connectivity (ARL, 2022; Bender et al., 2017; Ament et al., 2023). Hence, our focus is specifically on research dealing with open spaces outside of protected areas.

This scoping review seeks to identify common characteristics of Alpine open spaces. Today a holistic, region-wide synthesis of available knowledge is missing. A review on the threats posed to open spaces in the European Alps has not been conducted so far. Accordingly, this review systematically assesses the literature to clarify the state of knowledge on a supra-national level on rural Alpine open spaces and efforts to conserve them, highlighting well-covered topics and analysing under-researched issues to assess overlaps. This method enables a systematic review process, unlike policy or narrative reviews that rely on subjective expertise. Additionally, this method allows us to compress all existing knowledge into one paper, allowing easy and quick access to its entirety whilst systematically identifying tendencies. This inductive approach does not try to fill an a priori knowledge gap, but rather it analyses missing knowledge according to the overall existing literature. This approach is framed in our research questions.

Our spatial focus on the Alpine Convention perimeter reflects the region's significance to adjacent areas. However, the study also includes the European Union Strategy for the Alpine Region (EUSALP) due to its interconnected relationship with the Alpine Convention perimeter and the relevance of the Alps to surrounding fringe areas.

In this context, we defined the following five research questions:

- How is the research distributed in spatial and temporal terms?
- What are the main threats to open spaces in the Alps identified in the literature?
- What are the major problems related to the governance of open spaces?
- How does our sample define open spaces?
- How is planning of open spaces confronted by supra-national institutions?

The following sections outline the methodology used for conducting this scoping review, including our structured screening process. Subsequently, we present a quantitative overview of the findings, followed by a qualitative analysis using inductive and iterative coding. The discussion section highlights research foci and identifies gaps in current knowledge.

## 2 Methodology

We employed a scoping review approach to analyse and critically reflect on current research findings, aiming to identify research gaps (Pham et al., 2014). A keyword search using the following databases was conducted (see below and Fig. 1): Web of Science Core Collection (Social Science Citation Index, Science Citation Index Expanded, Art & Humanities Citation Index, Book Citation Index) and Scopus. In addition, we used Geobase and Georef to include relevant geographical studies.

We adopted the PRISMA2020 flow process, using the online tool as a template (Haddaway et al., 2022) (see Fig. 1).

To capture a comprehensive range of discussions and perspectives on Alpine management, we also reviewed publications from the Alpine Convention and other governance and governmental organizations involved in Alpine governance: EUSALP, Alparc, Arge Alp, CIPRA, and AlpPlan (see Supplement S1, S1.1, and S1.2).

The initial search was conducted in May 2024, with updates in July and October 2024. Using English and German keywords with Boolean operators, we searched all electronic databases (see Fig. 1) and the websites of the institutions. After trying a variety of combinations and keywords, we sought the best options to get the most results for our study purpose. The final database search examined the presence of keywords

and Boolean operators by title, abstract, and author keywords (see Supplement S1, S1.1): (open space\* AND “spatial planning”), (“open space\*” AND alp\*), (“open space\*” AND rural), (alp\* AND spatial planning), (alp\* AND “spatial planning”), (Freiraum AND Raumplanung), (Freiraum AND Raumordnung), (Freiraum AND alp\*), (Freiraum AND rural), (alp\* AND Raumplanung), and (alp\* AND Raumordnung).

Subsequently, all results were integrated into several Excel spreadsheets and duplicates were removed. Publications in French, Italian, and Slovenian were excluded to limit the review's scope and to avoid false interpretation due to the authors' lack of fluency. During the exclusion step, there were only a small number of those publications (around 120 publications out of 2521 publications after the removal of duplicates).

Before the search was conducted, we defined the following eligibility criteria: (a) publication dates between 1991 (establishment of the Alpine Convention) and 2024, (b) abstracts and full texts that refer directly to spatial planning or management of rural open spaces with a focus on the geographical scope of the European Alpine Convention perimeter, and (c) research published in peer-reviewed journals, books, and book chapters. We also included reports, protocols, and declarations (normative and policy briefs) issued by the Alpine Convention, EUSALP, Alparc, Arge Alp, CIPRA, and AlpPlan that were checked by a review committee. In the full-text analysis, we only considered publications that were available online. Offline paper publications or irretrievable publications were excluded. Bachelor's, master's, and doctoral theses; annual or monthly subscription newsletters or flyer publications; congress papers; and preprints or conference proceedings were also not considered.

The screening process was carried out by applying the eligibility criteria and first reviewing titles, abstract, and keywords and then reviewing the full text. This was mainly conducted by the corresponding author, but insecurities regarding the eligibility of a paper and the methodological process were regularly discussed and resolved during several meetings within the research team. All results were collected in one single Excel spreadsheet according to the categories of authors, title, abstract, journal or publishing institution, publication data, institutional affiliation of the corresponding author, methodological and theoretical approach, and study area. A qualitative summary of the content and problems was individually synthesized if applicable.

To include relevant publications in all countries that were not available from the electronic databases, we checked the screening results for references according to our eligibility criteria and integrated them into the synthesis.

Following the PRISMA methodology, we developed an inductive and iterative coding process to synthesize qualitative data. The content of each publication was reviewed individually, identifying similarities and redundancies that were then categorized into thematic codes. Where interdependencies

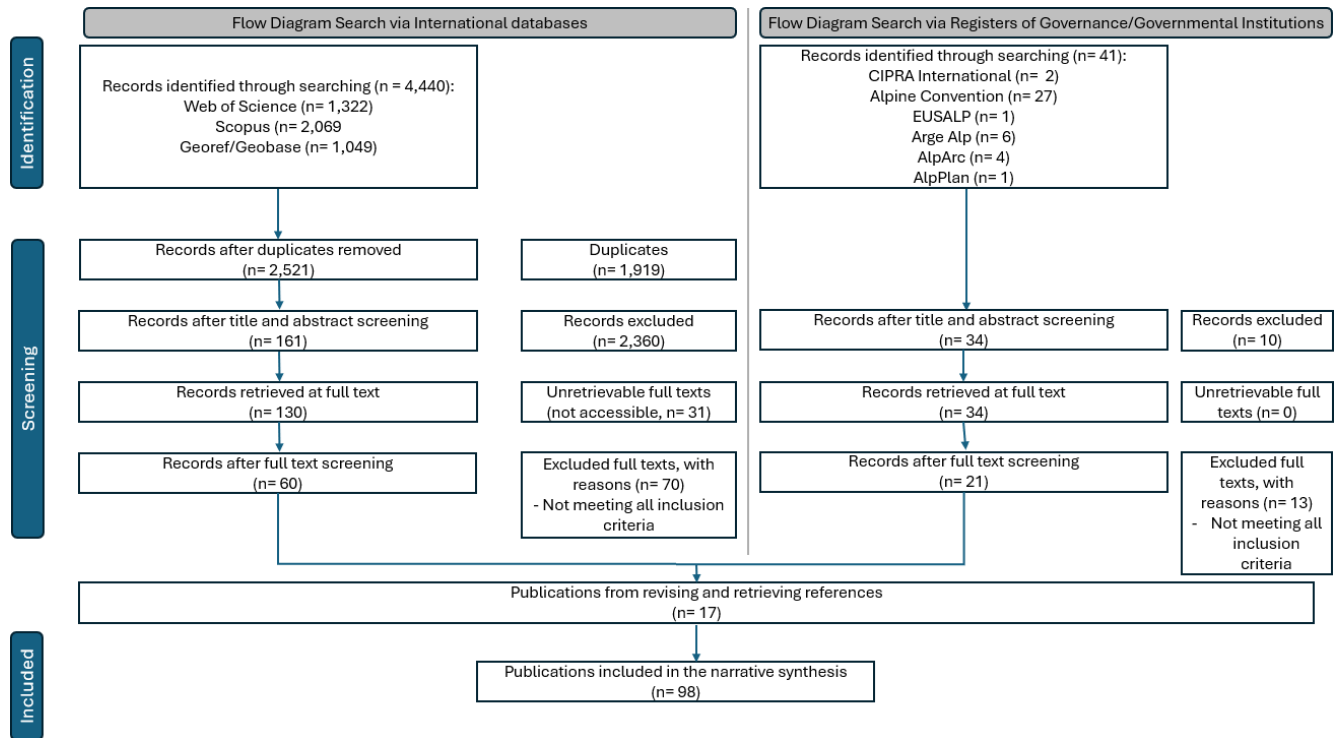


Figure 1. PRISMA flow process of the literature research conducted.

between codes were recognizable, they were grouped into broader categories. This resulted in four main categories that encapsulated nine codes (see Supplement S2). We tested our codes for consistency using ChatGPT. We did this inserting our four main categories, as well as our nine codes; investigating whether the AI could estimate any thematic doubling; and asking for clearer and more concise wording of the categories and codes. The results only offered minor possibilities for change.

Our analysis starts with a descriptive quantitative overview of the research included in our sample, followed by a qualitative evaluation of its content.

### 3 Descriptive analysis

After the screening process, our sample included 98 publications (see Supplement S1, S1.3), of which 77 were scientifically peer-reviewed and published in internationally indexed journals (Web of Science Core Collection, Scopus, Georef/Geobase). A total of 21 were found in outlets of Alpine governance and governmental institutions (see Supplement S1, S1.1 and S1.3), including strategic reports and declarations (not included in Web of Science Core Collection, Scopus, Georef/Geobase) (see Fig. 1).

Regarding language distribution, 69 publications were in English, 22 were in German, and 7 were classified as “multilingual”, indicating availability for download in all languages commonly spoken in the European Alps.

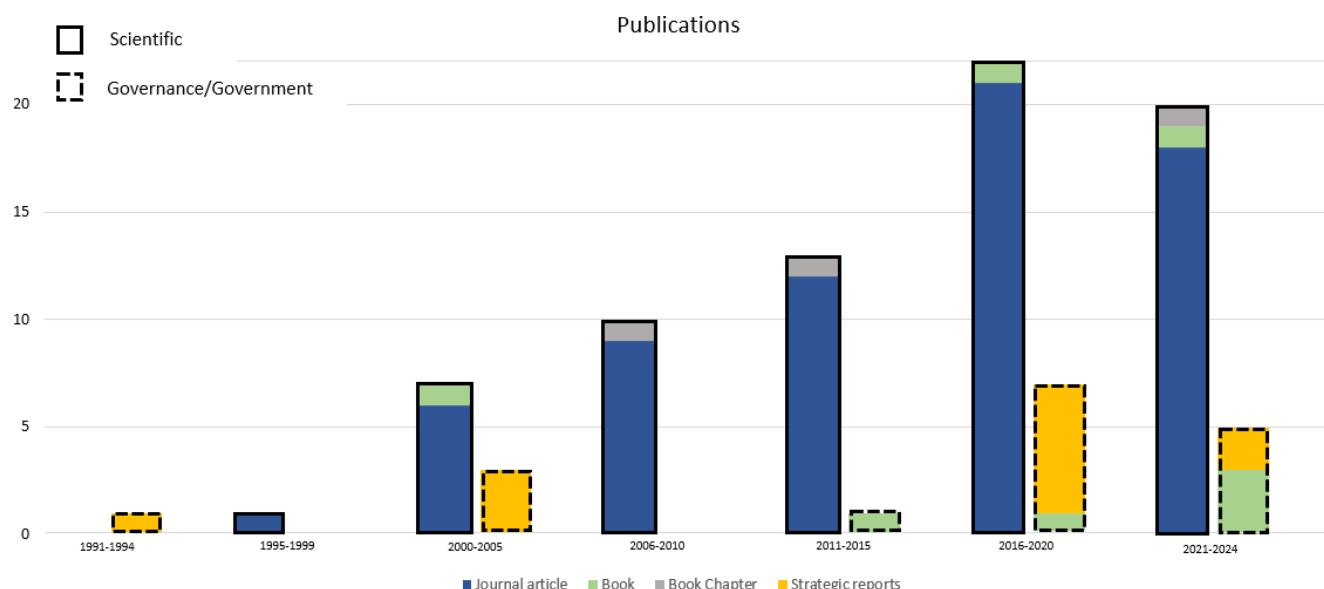
Publications addressing open spaces and spatial planning within the Alps were scarce between 1991 and 2000. The first notable peak in publication volume occurred between 2016 and 2020, followed by a second peak from 2021 to 2024 (see Fig. 2).

Most publications were authored by researchers affiliated with institutions in Germany ( $n = 26$ ), followed by Italy ( $n = 15$ ) and Alpine institutions ( $n = 16$ ). Additional contributions originated from Switzerland ( $n = 15$ ), Austria ( $n = 10$ ), France ( $n = 6$ ), Slovenia ( $n = 5$ ), and other countries, including the Netherlands ( $n = 2$ ), Scotland ( $n = 1$ ), Spain ( $n = 1$ ), and the USA ( $n = 1$ ).

The six most important affiliated institutions of the first author (excluding governance and governmental publications,  $n = 14$ ) were composed by scholars from the University of Erlangen, Germany ( $n = 6$ ), followed by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Switzerland ( $n = 5$ ); the Swiss Federal Institute of Technology in Zurich, Switzerland ( $n = 5$ ); the University of Innsbruck, Austria ( $n = 4$ ); the University of Würzburg, Germany ( $n = 4$ ); and the University of Milan, Italy ( $n = 4$ ).

Publications issued by governance and governmental organizations are from the Alpine Convention ( $n = 16$ ), Alparc ( $n = 2$ ), CIPRA ( $n = 1$ ), and EUSALP ( $n = 1$ ).

Concerning the geographical focus, most publications addressed the entire perimeter of the Alpine Convention ( $n = 31$ ).



**Figure 2.** Development of publications about the European Alps.

Figure 3 illustrates the distribution of case studies at the regional level (NUTS 3; for further information, see <https://ec.europa.eu/eurostat/web/nuts>, last access: 28 April 2025) within the EUSALP macro-region. Additionally, two separate inset maps on the left and the right corner of the main map frame present the distribution of case studies at the national level and within the perimeters of both the Alpine Convention and EUSALP (see Fig. 3). The highest concentration of case studies is observed to be covering the Alpine Convention perimeter ( $n = 31$ ), followed by the EUSALP region ( $n = 17$ ). A differentiation between publicized location was made to include “international” (all journals) and “governance/governmental” (published by international institutions). On a national level, case studies can only be observed in Germany ( $n = 9$ ), Switzerland ( $n = 4$ ), and Slovenia ( $n = 2$ ). On a more localized scale, case studies are predominantly clustered in eastern Austria, Switzerland, and cross-border areas along the fringe of the Alpine Convention, particularly in parts of France, Germany, and Italy – all closely linked to the Alpine Convention area. Notably, no case studies were identified in the southern French Alps (Sea Alps), the western Swiss Alps, or the central Alps of northern Italy and eastern Austria (see Fig. 3).

Most of the publications found are literature and document reviews, as well as quantitatively conducted research articles (see Table 1). Concerning data usage, 55 publications adopted a discursive approach, formulating guidelines or action plans while simultaneously engaging in theoretical discussions. Meanwhile, 26 publications were based on secondary and already existing data, and 17 publications collected primary data (see Table 1).

#### 4 Analysis of addressed topics and research foci

The publications in our sample focus on the role of open spaces in the European Alps, with four key themes/issues emerging: (a) land-use conflicts, (b) role and relevance of ESs of open spaces, (c) governance and management of open spaces, and (d) land-use and open-space planning (see Supplement S2).

##### (a) Land-use conflicts

According to frequency, 43 publications address key risks for open spaces, such as land use arising from expansion of urban settlement, e.g. such as tourism infrastructure, second homes, and permanent housing (e.g. Drobnik et al., 2017; Eichhorn et al., 2023; Meyer et al., 2022); intensification of agricultural use (e.g. Drobnik et al., 2017); traffic infrastructure (e.g. Job et al., 2014; Mose, 2003); effects of climate change (e.g. Schirpke et al., 2020; Vincent et al., 2019), and renewable energies (e.g. Svadlenak-Gomez and Walzer, 2017; Chilla et al., 2019). The different kinds of land use are causing a decline in natural and semi-natural areas and ecological habitats, as shown in the study by Drobnik et al. (2017), conducted in the Canton of Valais in Switzerland.

Land-use conflicts regarding conflicts around natural and semi-natural areas are expressly mentioned within 38 publications. Specifically, the EUSALP (e.g. Bätzing, 2017) and Alpine Convention (e.g. Hill, 2013) general perimeters are studied. A focus of case studies on land-use conflicts in the Swiss Alps can be found in studies by Riva et al. (2024) on a national level, by Drobnik et al. (2017) on the Swiss Canton of Valais, and by Meyer et al. (2022) on the Bavarian Alps. Our sample suggests that land-use types in terms of



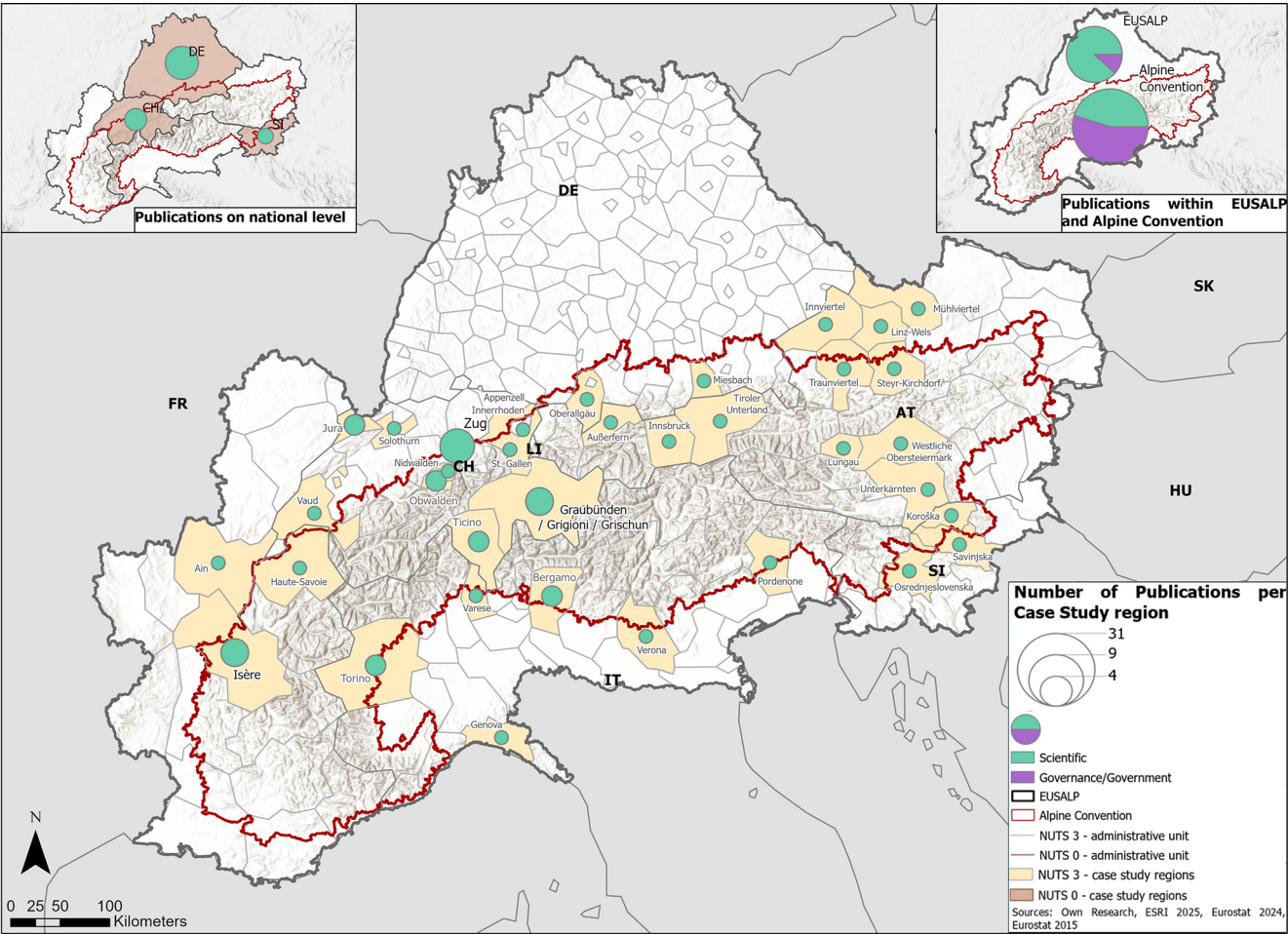


Figure 3. Distribution of case studies. (This map makes no claim to being exhaustive, and we are aware that further case studies might exist.)

Table 1. Distribution of research methods and data acquisition methods.

Research methods					
Qualitative	Quantitative	Mixed methods	Literature and document review	Policy briefs and reports	Total
2	29	11	36	20	98
Data acquisition method					
Discursive commentary	Secondary data analyses	Primary data collection	Total		
55	26	17	98		

forest, agricultural, or settlement use have fundamental consequences for open-space functionality, which is furthermore highlighted across all countries as declared in a broader study by Bovet et al. (2018) throughout Germany and Switzerland. Highly intensive agricultural or settlement use in valley floors influences local ecosystems and fosters loss of

the cultural landscapes and biodiversity migration deficits (e.g. Drobniak et al., 2017). Open spaces are mentioned as areas of high ES and nature conservation value, but the literature addressing areas all over the EUSALP region stresses the fact that these areas are increasingly threatened, espe-

cially concerning rural areas across the Alps, as shown by Job et al. (2017).

Additionally, 5 publications on the EUSALP (e.g. Briquel, 2006) and the Alpine Convention (e.g. Alparc, 2023) perimeters, as well as on Slovenia (e.g. Pirnat and Hladnik, 2018) and Italy (e.g. Gottero et al., 2023), highlight the importance of conserving the (cultural) landscape of the Alps. Sustainable regional development and the implementation of nature-based solutions, especially in relation to climate change adaptation (e.g. Dubo et al., 2023), are mentioned in relation to the management of open spaces and their usage (e.g. Gottero et al., 2023).

#### (b) Definitions and ecosystem services of open spaces

Table 2 shows the difference between a small selection of four prominent definitions and understandings of open spaces within our sample at different geographical and institutional levels. It also embeds them in the general critique that exists on open spaces and their management. A common tendency of these definitions is the highlighting of the role of ESs.

The international and national publications ( $n = 52$ ) in our evidence base deem assessing and quantifying ESs as indispensable for protecting, evaluating, and managing open spaces efficiently (e.g. Bovet et al., 2018; Job et al., 2020). Herein the functions of soil for food provision and buffering, as well as filtration of water for water retention and drinking-water provision, are evidently stressed (e.g. Briner et al., 2013; Schirpke et al., 2019). Furthermore, landslide protection and floodplain zones (e.g. Cammerer et al., 2013), as well as general protection against natural hazards, carbon sequestration, outdoor recreation, and biotic habitat provision (e.g. Schirpke et al., 2019), are studied across the Alps.

Eight publications stress that ESs allow the measurement of the effects of land-use pressures on open spaces and can be seen as an estimation factor for adaptive management and integrative planning (e.g. Huber et al., 2012; Gulinck et al., 2018; Kruse and Pütz, 2014). The publications are found in Switzerland (e.g. Vincent et al., 2019), Austria (e.g. Cammerer et al., 2013), France (e.g. Gonzalez-Gedin et al., 2016), Germany (e.g. Grunewald et al., 2022), Slovenia (e.g. Hladnik and Nastran, 2013), the Alpine Convention perimeter (e.g. Job et al., 2020; Schirpke et al., 2020) and the EUSALP perimeter (e.g. Schirpke et al., 2019).

Furthermore, 26 publications estimate a method for evaluating the value of open spaces as highly useful for safeguarding their functionality (e.g. Bovet et al., 2018). For this, research suggests that spatial planning systems are needed to serve as a backbone of this safeguarding goal (e.g. Job et al., 2020). Specifically, a market-based estimation via the ES approach or the soil function approach, as was studied in Slovenia (e.g. Bovet et al., 2018) and South Tyrol (Schirpke et al., 2020), should be fostered in the planning and discussion systems about open spaces. Seven of these evaluation sugges-

tions are projected onto the Alpine Convention (e.g. Dubo et al., 2023) and the EUSALP (e.g. Plassmann et al., 2016) perimeters, but they can also be found equally in each of the individual countries (e.g. Grunewald et al., 2022; Hladnik and Nastran, 2013; Mayer, 2022; Vanham et al., 2011). As a requirement for successfully understanding ecosystem value, the publications identify the lack of an official definition of open spaces as problematic (e.g. Job et al., 2017).

An additional 18 publications assess the spatial interdependencies within and connected to the Alps and the requirements needed for open-space protection. Within these publications, the paradigms of spaces and the functionality of spaces address three different interrelationships present in the Alps: highland vs. lowland (e.g. Vanham et al., 2011; Job et al., 2017), Alpine vs. fringe (e.g. Schirpke et al., 2019; Egarter-Vigl et al., 2017), and urban vs. rural (e.g. Gulinck et al., 2018). These three categories are primarily analysed in a EUSALP context, and the work is focused on individual case studies in South Tyrol and Switzerland (e.g. Schirpke et al., 2019). The supply–demand flow system in connection to the three categories of spaces in our findings highlights where open spaces are deemed necessary and where they are primarily under pressure (e.g. Schirpke et al., 2014).

#### (c) Governance of open spaces

A total of 45 publications in our evidence base focus on governance structures relating to Alpine-wide institutional and network activities and Alpine-wide planning documents. A total of 22 publications analyse existing governance structures and consider the lack of regulation by effective governance to be concerning for open-space safeguarding. In this context, spatial planning is subject to priorities defined by local authorities and their decisions, which are majorly economically biased, as was studied in Grenoble and Greater Geneva (e.g. Bertrand et al., 2015). Hence, the existence of governance and governmental institutions, such as the Alpine Convention with its framework convention defining necessities for protection of the Alps and responsibilities, is stressed as important (e.g. Alpine Convention, 1991). However, gaps in the knowledge of implementation of regulating Alpine-wide documents and of the ecological value of the local region, on both a local and a decision-making level (e.g. Rudaz, 2009), underline the insufficient care for open spaces and a remaining need for successful governance (e.g. Mertens et al., 2022).

A total of 23 of our total publications consider planning instruments such as the Bavarian Alpenplan (e.g. Job et al., 2014) and cross-border networks existing beyond the Alpine Convention (e.g. Interreg Alpine Space projects or the AlpPlan spatial planning network) (e.g. Meltzian et al., 2022a) that are viable for governing open spaces successfully. The advantage is seen to lie in planning “with” rather than “against” sustainable European development (e.g. Huber et al., 2012).

**Table 2.** Definitions of open spaces within our sample (selected by authors).

	Definition of open spaces	Institutional perimeter	Criticism and need
A	“They are areas free of buildings or infrastructures, and they can occur within and outside protected areas” (Alparc, 2023)	EUSALP	“Urban sprawl and infrastructure pose a major sustainability challenge. It is therefore extremely important for countries
B	“The open space concept refers to areas which are kept free permanently from buildings, technical infrastructures and soil sealing. This approach focuses on open spaces outside continuous settlements” (ARL, 2022)	Alpine Convention	to implement advanced land use planning and steering instruments that are designed to mitigate urban sprawl and to enforce thrift development within a coherent legal framework of sustainable
C	Indicators for ecosystem services provision: “Protection from gravitational hazards”, “Biodiversity”, “Carbon sequestration/release”, “food production” (Briner et al., 2013)	Mountain region: Central Valais (CH)	land use governance” (Bovet et al., 2018).  “Open space planning is not an isolated subject but is rather considered an integrated part of
D	Open spaces are “crucial for the management of green infrastructures and the production of goods and ecosystem services such as food, leisure, recreational, tourist, educational, and social services” (Gottero et al., 2023)	Mountain fringe area region: Turin (IT)	comprehensive spatial planning . . . There is a need for tailored planning strategies for open spaces, which differ to some extent from spatial planning for non-mountain areas” (ARL, 2022).

It is evident that our sample focuses on the role of spatial planning as the most suitable tool for balancing land-use conflicts and safeguarding open spaces, combining both strict and communicative elements (e.g. Domhardt, 2005). The requirement for successful planning is found in the necessity for authorities to realize and fulfil their responsibilities – to plan not only for local or sector-based interests, but also for Alpine-wide interests from a long-term perspective and to effectively and sustainably develop open spaces (e.g. Bertrand et al., 2015).

(d) Land-use and open-space planning

Overall, 72 of our publications deal with planning of open spaces. Because spatial planning is named as the main tool in managing settlement developments and in balancing the use of soil in the required sustainable manner, our sample ( $n = 35$ ) highlights different existing paradigms of spatial planning that have changed over time and influenced land-use decisions that still affect modern land-use planning (e.g. Fabbro, 2010). Historical planning paradigms not only relate to understandings of a “region” from an EU or a regionally centred point of view, but also integrate different planning styles such as the Nordic comprehensive–integrated and the French regional–economic style, which need to be harmonized and added to a base of common trust today to balance European and Alpine development (e.g. Fabbro, 2010).

Historically, the literature, especially in Germany (e.g. Eichhorn et al., 2023), has reflected on the reduction of the responsibility of spatial plans that minimized the regulatory intensity and fostered requests for new forms of governance and planning processes in the 1970s and 1980s (e.g. Eichhorn et al., 2023). Planning competencies in Germany were shifted from a federal to local level or to larger scaling in France, and created a heterogeneous

landscape of planning units within the Alpine countries while also creating problems for coordinating thematic priorities (e.g. Fabbro and Haselsberger, 2009). Planning of open spaces needs better coordination, vertically as much as cross-sectorally, as this is a question of transnationality (e.g. Fabbro, 2010; Peterlin, 2010). Different hypotheses for land-use planning can be found: from the worthless-land hypothesis, where spaces with low levels of conflict, such as high-mountain bedrock areas with no economic importance for humans were chosen for protection, to the current sustainable development paradigm that takes into account all needs of the environment and population. Objectives for spatial use have shifted tremendously and have been influenced by political and societal discussions (e.g. Mayer, 2022). Therefore, protection of open spaces needs to be more integrative and coordinative in order to achieve the overall goal of Alpine planning: to guarantee economic competitiveness within the Alps (e.g. Permanent Secretariat of the Alpine Convention, 2021).

The majority of literature addressing spatial planning needs in our sample can be located within the Alpine Convention (e.g. ARL, 2022; Ballerin-Denti et al., 2014) as well as Italy (e.g. Pristeri et al., 2023).

A total of 37 publications include specific targets and requirements addressed at spatial planning such as the need to better coordinate sector-specific and cross-border aspects (e.g. Fabbro, 2010) and to be more proactive than reactive (e.g. Farinós-Dasí et al., 2024) while also highlighting the need for action and change within spatial planning in all Alpine member states to protect open spaces more strongly (e.g. ARL, 2022). A study conducted by Briner et al. (2013) highlights the potential for spatial planning in cross-sectoral coordination with agriculture, renewable energy construction, settlement development, and providing sources for financial support. As stated by Bätzing (1999), lack of coor-



dination of the different sectors counts as a major threat to planning.

## 5 Discussion

Our scoping review aimed to map the existing literature on open spaces in the European Alps and addressed the five research questions outlined in the introduction. It highlights the notion that threats to open spaces in the Alps are a major concern within EUSALP and the Alpine Convention, with publications that emphasize land-use conflicts (e.g. Job et al., 2022), governance (e.g. Gottero et al., 2023), and spatial planning (e.g. Eichhorn et al., 2023). Settlement development and climate change are identified as key threats, alongside increasing debates over the suitability of the Alps for renewable energy projects, which could impact the ecosystem services (ESs) of open spaces (e.g. Svadlenak-Gomez and Walzer, 2017). The loss of permanent meadows in the Alpine lowlands is also highlighted as a significant, yet often underestimated, ecological threat to habitats and ESs (e.g. Monteiro et al., 2011).

A major threat to open spaces is the inadequate governance system, marked by a lack of knowledge and inefficient spatial planning for climate adaptation (e.g. Kruse and Pütz, 2014). Addressing these issues is crucial to the entire EUSALP area and beyond. Our findings show that effective governance regulations are lacking, especially for managing land-use conflicts. Local decision-making is particularly inefficient in preserving open spaces amidst settlement development, due to inconsistent data availability (e.g. Mann, 2009; Meltzian et al., 2022a).

ESs are named the most valuable elements for enabling the evaluation of the use of open spaces for balanced Alpine development. The main ESs of open spaces found are habitat provision (e.g. Monteiro et al., 2011), biodiversity conservation (e.g. Ramel et al., 2020), water supply, and soil stability in terms of climate resilience (e.g. Schirpke et al., 2014). Nonetheless, individual evaluation of local ESs for spatial planning is seen as important in accordance with the availability of spatial data (e.g. Schirpke et al., 2014). Through the integration of green infrastructure elements into spatial planning, ESs have become further established in spatial planning, but they are still at a low level of recognition and integration into spatial dialogues (e.g. Pristeri et al., 2023). The ES approach to evaluating open spaces is of high value for making political decision-makers aware that open spaces need proactive protection and planning (e.g. Gottero et al., 2023).

Spatial planning in the Alps is shaped by the Alpine Convention, its protocols, and related regional plans, positioning the convention as a key policy tool for addressing land-use conflicts (e.g. Kruse and Pütz, 2014; Haßlacher, 2004). However, the main challenge remains the lack of effective coordination between authorities and sectoral planning institutions,

compounded by historical shifts that have made regulatory capacities more heterogeneous across the Alps (e.g. Fabbro, 2010; Peterlin, 2010).

Spatial planning itself is seen as not being strong enough to influence local decision-makers aiming to avoid a broader economic focus in spatial developments. Nevertheless, spatial balance between ecological and economic needs for the local population should be considered when discussion on open-space potential arises. Avoiding “lock-in” effects for settlement and infrastructure whilst ensuring economic strength evidently continues to enable a multifunctional use of space (e.g. Permanent Secretariat of the Alpine Convention, 2021).

Measures to protect Alpine open spaces remain insufficient, as they are not fully integrated into spatial planning on an Alpine-wide scale. In Slovenia and Italy, open spaces are uncommon and mostly limited to inner urban areas, leading to their neglect in regional and rural plans (e.g. Job et al., 2022). Research calls for more proactive spatial planning to strengthen regulatory capacity, particularly in regulating privately owned land and sectoral plans (e.g. Permanent Secretariat of the Alpine Convention, 2019). Additionally, planning and open-space management should adopt a more integrative, network-oriented, and capacity-building approach to reduce vulnerability to political decisions (e.g. Huber et al., 2013).

Research on open spaces in the Alps so far has failed to present sufficient hands-on solutions and has focused mostly on problem statements while analysing planning documents and policies rather than evaluating new scenarios and solutions on how planning could efficiently, and in a locally specified manner, protect differentiated open spaces with use for specific ESs. Additionally, it was evident that certain topics have not been discussed at all. In particular, futuristic prognoses are largely missing – e.g. in relation to new spatial availabilities with the melt of glacial ice and the formation of new lake landscapes (e.g. Haeberli and Hohmann, 2008), as well as their consequences for spatial discussions and for open-space management. Open spaces in the Alps and beyond are broadly evaluated for both ecosystems and human impact (e.g. Chilla et al., 2019). However, large-scale analyses dominate, while detailed, small-scale studies on specific ecosystem services (ESs) and land-use planning remain under-researched and yet are essential for addressing local environmental needs.

A key research priority is establishing a clearer definition of open spaces, as the current negative definition – contrasting them with settlement areas – is insufficient for effective protection (e.g. Job et al., 2017). The lack of a common and official understanding also prevents policies from working sufficiently and coordinating planning for open spaces. Most publications align with the definition of Alpine open spaces as non-sealed, uncovered areas. Critical areas in need of protection include natural and near-natural landscapes (e.g. Drobnik et al., 2017) and those providing key ESs, such

as food and water supply, natural hazard mitigation, carbon sequestration, and recreational spaces (e.g. Schirpke et al., 2019). Threatened open spaces and their ESs are found not primarily in high-mountain areas but mostly in Alpine valleys. Here, the biggest need is to proactively plan for the safeguarding and restoration of open spaces in riverine landscapes.

The above-mentioned criteria can be taken as a minimum consensus for evaluating planning and land use in open spaces and to attempt to establish a common and thorough definition of open spaces. Agreement on the relevance of intensively used agricultural areas as open spaces was not found and depends on which ES is at stake (e.g. Schirpke et al., 2019). In general, this analysis highlights the need for coordination and cross-border and cross-sectoral planning, but it also takes into account the lack of methods to assess how open spaces can multifunctionally preserve ecosystems and their services at relevant scales (e.g. Cortinovis and Geneletti, 2018).

Our sample reveals a research imbalance, with most studies focused on large-scale Alpine areas and the eastern Swiss Alps, while the French and Slovenian Alps seem to be under-researched according to our review. The Sea Alps and central Alpine valleys also receive less attention. In contrast, eastern Austria, Tyrol, and cross-border regions – especially Bavaria and northern Italy – are well represented, with early discussions on the Bavarian Alpenplan being a key example of spatial planning for landscape-scale conservation (e.g. Ströbel et al., 2025; Job et al., 2017).

However, this imbalance could also be related to some research limitations, as we were not able to analyse all Alpine languages due to our focus on publications in English and German. We tried to incorporate national publications via the references as best as possible. Also, our number of keywords (titles, abstracts) was relatively small during the search. Our focus on the supra-national level and search for publications by supra-national institutions omitted searching within local and regional published documents. Therefore, we might have missed some publications that employed other terms and spatial levels.

## 6 Conclusion

This scoping review analysed the major threats to, the role of ESs in, and the governance of open spaces, as well as planning of open spaces and land use in the European Alps. A pressing need exists for targeted research and actionable solutions, aligning with current decisions on a global and EU-wide level. Actions must be taken on by future studies that move beyond problem identification to offer concrete strategies for implementing sustainable land-use practices in general. Current research seems to underscore the critical role of open spaces within the European Alps as essential providers of ESs, particularly for climate change adaptation,

biodiversity, and landscape sustainability. Despite the recognized value of these spaces, their management and safeguarding remain fragmented and inconsistent, with significant gaps in governance and spatial planning.

Whilst the Alpine Convention and European strategies provide foundational frameworks, their effectiveness is hindered by a lack of knowledge and robust implementation mechanisms and by insufficiently harmonized definitions of open spaces. This gap complicates regulatory cohesion across national and regional contexts, exacerbating land-use conflicts such as settlement development and rapidly growing renewable energy demands. Spatial planning emerges as the most viable tool to reconcile ecological, social, and economic interests. However, its current limitations, particularly in regulating privately owned land and integrating ecosystem service valuations, restrict its potential to manage open spaces proactively and efficiently. A paradigm shift is needed – one that transitions from reactive, sector-based approaches to proactive, integrative planning that prioritizes long-term ecological health and resilience. Various Alpine developments, such as the influence of mobility choices or the real-estate economy, drive soil sealing as a symptom, underlining the need for harmonization of all sectoral planning with spatial planning. A common base for planning along with a common understanding of what needs to be preserved is necessary. Therefore, we conclude with a proposal for a common positive definition of open spaces based on our insights from this strategic review:

Open spaces are technically unimpaired and uncovered<sup>1</sup> semi-natural or near-natural areas, which, due to their provision of ecosystem services, are proactively safeguarded through incorporation into spatial (or sectoral) planning frameworks and integration into broader, climate-proof land-use strategies to ensure their long-term protection.

This definition of open spaces specifically refers to open spaces without neglecting neighbouring issues such as ecological connectivity, arguing for protection of natural spaces as well. Besides the European Alps, open-space pressures exist in other comparable mountain regions, mostly due to their touristic attraction in morphologically similar environments. As the American Rocky Mountains are equally interesting in terms of outdoor recreation pressures, our findings could be adaptable for comparison, but further research in the frame of a scoping review would be specifically necessary for this mountain region. Open-space or ecosystem service management could benefit from a scientific base for the preservation of open spaces.

In conclusion, safeguarding the Alps' open spaces is not merely a regional issue but a transnational imperative.

<sup>1</sup>This definition preliminarily excludes cave systems (e.g. in Slovenia) as it highlights open spaces. Further research could be interesting and necessary to elaborate on the role of cave systems in open spaces.

Strengthening governance structures, leveraging spatial planning tools, and fostering interdisciplinary research will be critical to ensure that Alpine landscapes continue to support both human and ecological systems for generations to come. Therefore, spatial and sectoral planners need to be addressed explicitly to raise awareness of the importance of balancing the use of open spaces with ecological needs, as this influences social and economic dependencies in the long-term. Communicating our findings to practitioners, as well as political decision-makers, and achieving this vision demand a collective commitment to sustainable development, guided by already-existing informed policy, adaptive management, and innovative planning frameworks.

**Data availability.** No data sets were used in this article.

**Supplement.** The supplement related to this article is available online at <https://doi.org/10.5194/gh-80-207-2025-supplement>.

**Author contributions.** All authors jointly conducted the research design and concept. KS conducted the main review research, but all authors met regularly to discuss the results. KS developed the manuscript and wrote all sections in joint communication with and contributions from LB and HJ.

**Competing interests.** The contact author has declared that none of the authors has any competing interests.

**Disclaimer.** Publisher's note: Copernicus Publications remains neutral with regard to jurisdictional claims made in the text, published maps, institutional affiliations, or any other geographical representation in this paper. While Copernicus Publications makes every effort to include appropriate place names, the final responsibility lies with the authors.

**Acknowledgements.** We thank the two anonymous reviewers. We also thank Carla Brenner for proofreading an earlier version of this article for grammar and syntax.

**Review statement.** This paper was edited by Marco Pütz and reviewed by two anonymous referees.

## References

- Alparc: Alpine Parks 2030: Biodiversity conservation for generations to come, Alpine Convention, Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and consumer Protection, ISBN 979-10-94590-60-7, 2023.
- Alpine Convention: Alpenkonvention. Rahmenkonvention, [https://www.alpconv.org/fileadmin/user\\_upload/Convention/DE/Framework\\_Convention\\_DE.pdf](https://www.alpconv.org/fileadmin/user_upload/Convention/DE/Framework_Convention_DE.pdf) (last access: 20 January 2025), 1991.
- Ament, R., Clevenger, A., and van der Ree, R. (Eds): Addressing ecological connectivity in the development of roads, railways and canals, in: IUCN WCPA Technical Report Series No. 5, IUCN, <https://doi.org/10.53847/IUCN.CH.2023.PATRS.5.en>, 2023.
- ARL – Academy for Territorial Development in the Leibniz Association: Safeguarding Open Spaces in the Alpine Region, Positionspapier aus der ARL, <http://nbn-resolving.org/urn:nbn:de:0156-01339> (last access: 22 January 2025), 2022.
- Badura, M., Kuenzer, N., Sutor, G., Kals, R., and Schmid, S.: Quo vadis Bodenschutz in den Alpen? Bilanzierung des Protokolls, Bodenschutz der Alpenkonvention, in: TEXTE 27, <https://www.umweltbundesamt.de/publikationen/quo-vadis-bodenschutz-in-den-alpen-bilanzierung-des> (last access: 28 April 2025), 2017.
- Ballerin-Denti, A., Cetara, L., and Idone, M. T.: Leitfaden für die lokale Anpassung an den Klimawandel in den Alpen, Alpine Signals, ISBN 9788897500247, 2014.
- Bätzing, W.: The Alps: in the Web of European Spatial Planning Policy. Comments on the ESDP draft against the backdrop of on-going structural changes in the Alp REgion, *Raumforsch. Raumord.*, 57, 3–13, <https://doi.org/10.1007/BF03183772>, 1999.
- Bätzing, W.: Ökologische und Sozioökonomische Anforderungen an das Schwerpunktthema der Alpenkonvention “Bevölkerung” und Kultur, TEXTE, <https://www.umweltbundesamt.de/publikationen/oekologische-soziooekonomische-anforderungen-an> (last access: 28 April 2025), 2002.
- Bätzing, W.: Die Alpen – tiefgreifende Nutzungsveränderungen als Herausforderungen für den Naturschutz, *Natur Landschaft*, 9–10, 398–406, <https://doi.org/10.17433/9.2017.50153497.398-406>, 2017.
- Bender, O., Roth, C. E., and Job, H.: Protected areas and population development in the Alps, *eco.mont*, 9, 5–16, <https://doi.org/10.1553/eco.mont-9-sis5>, 2017.
- Bertrand, N., Cremer-Schulte, D., and Perrin, M.: Strategic Spatial Planning and Territorial Asymmetries. Grenoble and Greater Geneva: Two Alpine City Regions Put to the Challenge of Coherence, *J. Alp. Res.*, 103, 1–15, <https://doi.org/10.4000/rga.3126>, 2015.
- Bovet, J., Reese, M., and Köck, W.: Taming expansive land use dynamics – Sustainable land use regulation and urban sprawl in a comparative perspective, *Land Use Policy*, 77, 837–845, <https://doi.org/10.1016/j.landusepol.2017.03.024>, 2018.
- Briner, S., Huber, R., Bebi, P., Elkin, C., Schmatz, D. R., and Grêt-Regamey, A.: Trade-Offs between Ecosystem Services in a Mountain Region, *Ecol. Soc.*, 18, 3, <https://doi.org/10.5751/ES-05576-180335>, 2013.

- Briquel, M. V.: Development issues for the Alps: survey of convergences and divergences in their meaning, *Revue de géographie alpine*, 94, 71–84, <https://doi.org/10.3406/rga.2006.2397>, 2006.
- Cammerer, H., Theiken, A.-H., and Verbarg, P.-H.: Spatio-temporal dynamics in the flood exposure due to land use changes in the Alpine Lech Valley in Tyrol (Austria), *Nat. Hazards*, 68, 1243–1270, <https://doi.org/10.1007/s11069-012-0280-8>, 2013.
- Chilla, T., Heugel, A., Streifeneder, T., Ravazzoli, E., Laner, P., Teston, F., Tappeiner, U., Egarter, L., Dax, T., Machold, I., Pütz, M., Marot, N., and Ruault, J. F.: The Alps 2050 Atlas, ESPON by the European Union, Luxembourg, ISBN 978-99959-55-66-3, 2019.
- CIPRA: Das Bodenschutzprotokoll der Alpenkonvention – Bedeutung und Anwendung, <https://www.cipra.org/de/news/das-bodenschutzprotokoll-der-alpenkonvention-bedeutung> (last access: 21 January 2025), 2015.
- CIPRA International: Save land, save soil, CIPRA International, <https://www.cipra.org/en/publications/save-land-save-soil> (last access: 20 January 2025), 2022.
- Cortinovis, C. and Geneletti, D.: Ecosystem services in urban plans: What is there, and what is still needed for better decisions, *Land Use Policy*, 70, 298–312, <https://doi.org/10.1016/j.landusepol.2017.10.017>, 2018.
- Domhardt, H.-J.: Steuerung des Siedlungsflächenwachstums durch raumordnerische Instrumente des Freiraumschutzes in Regionalplänen, *Informationen zur Raumentwicklung*, 4, 231–239, 2005.
- Drobnik, T., Huber, R., and Grêt-Regamey, A.: Coupling a settlement growth model with agro-economic land allocation model for securing ecosystem services provision, *J. Environ. Plan. Manage.*, 60, 1127–1152, <https://doi.org/10.1080/09640568.2016.1197828>, 2017.
- Dubo, T., Palomo, I., Camacho, L. L., Locatelli, B., Cugniet, A., Racinais, N., and Lavorel, S.: Nature-based solutions for climate change adaptation are not located where they are most needed across the Alps, *Reg. Environ. Change*, 23, 12, <https://doi.org/10.1007/s10113-022-01998-w>, 2023.
- Eichhorn, S., Diller, C., and Pehlke, D.: Die Entwicklung der Regulierungsintensität der deutschen Regionalpläne von 1985 bis 2017. Ein empirischer Beitrag zur Diskussion um den Bedeutungsverlust der Raumordnung, *Raumforsch. Raumord.*, 81, 207–224, <https://doi.org/10.14512/rur.941>, 2023.
- Egarter-Vigl, L., Depellegrin, D., Pereira, P., de Groot, R., and Tappeiner, U.: Mapping the ecosystem service delivery chain: Capacity, flow, and demand pertaining to aesthetic experiences in mountain landscapes, *Sci. Total Environ.*, 574, 422–436, <https://doi.org/10.1016/j.scitotenv.2016.08.209>, 2017.
- EU – European Union: Rescue4Soil – Nature-based solutions to combat soil degradation and climate change, <https://www.interregeurope.eu/project-ideas/rescue4soil-nature-based-solutions-to-combat-soil-degradation> (last access: 20 January 2025), 2023.
- EU – European Union: Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32024R1991&qid=1722240349976> (last access: 21 January 2025), 2024.
- EU – European Union: Types of legislation, [https://european-union.europa.eu/institutions-law-budget/law/types-legislation\\_en](https://european-union.europa.eu/institutions-law-budget/law/types-legislation_en) (last access: 20 January 2025), 2025.
- Fabbro, S.: The Euroregional Planning Approach as a Possible Variant of Regional Planning in Complex Multi-Regional Spaces, *disP – The Planning Review*, 46, 30–40, <https://doi.org/10.1080/02513625.2010.10557109>, 2010.
- Fabbro, S. and Haselsberger, B.: Spatial Planning Harmonisation as a Condition for Trans-National Cooperation, *Eur. Plan. Stud.*, 17, 1335–1356, <https://doi.org/10.1080/09654310903053521>, 2009.
- Farinós-Dasí, J., Pinazo-Dallenbach, P., Sánchez-Manjavacas, E. P., and Rodríguez-Bernal, D. C.: Disaster risk management, climate change adaptation and the role of spatial and urban planning: evidence from European case studies, *Nat. Hazards*, <https://doi.org/10.1007/s11069-024-06448-w>, in press, 2024.
- Gonzalez-Gedin, J., Luque, S., Poggio, L., Smitz, R., and Gimona, A.: Spatial Bayesian belief networks as a planning decision tool for mapping ecosystem services trade-offs on forested landscapes, *Environ. Res.*, 144, 15–26, <https://doi.org/10.1016/j.envres.2015.11.009>, 2016.
- Gottero, E., Larcher, F., and Cassatella, C.: Defining and Regulating Peri-Urban Areas through a Landscape Planning Approach: The Case Study of Turin Metropolitan Area (Italy), *Land*, 12, 2017, <https://doi.org/10.3390/land12010217>, 2023.
- Grunewald, K., Syrbe, R.-U., Walz, U., Wende, W., Bastian, O., Meier, S., and Zieschank, R.: Nationale Indikatoren zur Bewertung von Ökosystemen und deren Leistungen, *Naturschutz Landschaftsplan.*, 54, 2, <https://doi.org/10.1399/NuL.2022.02.01>, 2022.
- Gulinc, H., Marcheggiani, E., Verhoeve, A., Bomans, K., Dewaelheyns, V., Lerouge, F., and Galli, A.: The Fourth Regime of Open Spaces, *Sustainability*, 10, 2143, <https://doi.org/10.3390/su10072143>, 2018.
- Haddaway, N. R., Page, M. J., Pritchard, C. C., and McGuinness, L. A.: PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis, *Campbell Syst. Rev.*, 18, e1230, <https://doi.org/10.1002/cl2.1230>, 2022.
- Haerberli, W. and Hohmann, R.: Climate, glaciers and permafrost in the Swiss Alps 2050: scenarios, consequences and recommendations, in: 9th International Conference on Permafrost, 29 June–3 July 2008, Fairbanks, Alaska, <https://doi.org/10.5167/uzh-6025>, 2008.
- Haßlacher, P.: Die Alpenkonvention – Markierungen für ihre Umsetzung, *Alpine Raumordnung* Nr. 24, ÖAV, Innsbruck, 5–8, [https://www.alpenverein.at/portal/natur-umwelt/publikationen/liste\\_AROs\\_PDF/24\\_alpenkonvention.php](https://www.alpenverein.at/portal/natur-umwelt/publikationen/liste_AROs_PDF/24_alpenkonvention.php) (last access: 28 April 2025), 2004.
- Haßlacher, P.: The protection of Alpine open spaces and the Alpine Convention – a timeline, *eco.mont*, 9, 98–99, <https://doi.org/10.1553/eco.mont-9-sis98>, 2017.
- Heuser, I.: Soil Governance in Current European Union Law and in the European Green Deal, *Soil Secur.*, 6, 100053, <https://doi.org/10.1016/j.soisec.2022.100053>, 2022.
- Hiess, H., Job, H., Kuncio, P., Meyer, C., Salzmann, G., and Tischler, S.: Handbuch Alpine Raumordnung. Ein Raumentwicklungskonzept für den Alpenen Raum, *Umweltdachverband gGmbH*, Vienna, <https://www.umweltdachverband.at/assets/Umweltdachverband/>



- Publikationen/Eigene-Publikationen/2022/CIPRA\_Handbuch\_AlpineRaumordnung\_2022.pdf (last access: 28 April 2025), 2022.
- Hill, M.: Adaptive Capacity of Water Governance: Cases from the Alps and the Andes, *Mt. Res. Dev.*, 33, 248–259, <https://doi.org/10.1659/MRD-JOURNAL-D-12-00106.1>, 2013.
- Hladnik, D. and Nastran, M.: Landscape Structure and Fragmentation: Key Factors in the Characterisation of Urban and Peri-Urban Forests in Slovenia, *Land*, 12, 1968, <https://doi.org/10.3390/land12111968>, 2013.
- Huber, R., Bebi, P., Briner, S., Bugmann, H., Buttler, A., Grêt-Regamey, A., Hirschi, C., Zimmermann, W., and Rigling, A.: Waldausdehnung in zwei Regionen des Schweizer Berggebiets: eine integrative Analyse, *Schweiz Z. Forstwes.*, 163, 502–511, <https://doi.org/10.3188/szf.2012.0502>, 2012.
- Huber, R., Rigling, A., Bebi, P., Brand F. S., Briner, S., Buttler, A., Elkin, C., Gillet, F., Grêt-Regamey, A., Hirschi, C., Lischke, H., Scholz, R. W., Seidl, R., Spiegelberger, T., Walz, A., Zimmermann, W., and Bugmann, H.: Sustainable Land Use in Mountain Regions Under Global Change: Synthesis Across Scales and Disciplines, *Ecol. Soc.*, 18, 3, <https://doi.org/10.5751/ES-05499-180336>, 2013.
- Job, H., Mayer, M., and Kraus, F.: Die beste Idee, die Bayern je hatte: der Alpenplan, oekom verlag, <https://doi.org/10.14512/gaia.23.4.9>, 2014.
- Job, H.; Mayer, M., Haßbacher, P., Nischik, G., Knauf, C., Pütz, M., Essl, J., Marlin, A., Kopf, M., and Obkircher, S.: Analyse, Bewertung und Sicherung Alpiner Freiräume durch Raumordnung und räumliche Planung, *Forschungsberichte der ARL*, Hannover, ISBN 978-3-88838-084-6, 2017.
- Job, H., Willi, G., Mayer, M., and Pütz, M.: Open Spaces in Alpine Countries: Analytical Concepts and Preservation Strategies in Spatial Planning, *Mt. Res. Dev.*, 40, 3, <https://doi.org/10.1659/MRD-JOURNAL-D-20-00016.1>, 2020.
- Job, H., Meyer, C., Coronado, O., Koblar, S., Laner, P., Omizzolo, A., Plassmann, G., Riedler, W., Vesely, P., and Schindelegger, A.: Open Spaces in the European Alps – GIS-Based Analysis and Implications for Spatial Planning from a Transnational Perspective, *Land*, 11, 1605, <https://doi.org/10.3390/land11091605>, 2022.
- Jousseume, M.: The French Climate and Resilience Law, [https://www.cep.eu/fileadmin/user\\_upload/cep.eu/Studien/cepInput\\_Franzoesisches\\_Klima-\\_und\\_Resilienzgesetz/cepInput\\_The\\_French\\_Climate\\_and\\_Resilience\\_Law.pdf](https://www.cep.eu/fileadmin/user_upload/cep.eu/Studien/cepInput_Franzoesisches_Klima-_und_Resilienzgesetz/cepInput_The_French_Climate_and_Resilience_Law.pdf) (last access: 25 April 2025), 2022.
- Kruse, S. and Pütz, M.: Adaptive Capacities of Spatial Planning in the Context of Climate Change in the European Alps, *Eur. Plan. Stud.*, 22, 2620–2638, <https://doi.org/10.1080/09654313.2013.860516>, 2014.
- Mann, S.: Institutional causes of urban and rural sprawl in Switzerland, *Land Use Policy*, 26, 919–924, <https://doi.org/10.1016/j.landusepol.2008.11.004>, 2009.
- Mayer, M.: Schutzgebiete in den Alpen – zwischen Bewahrung und Dynamik, *Geographische Rundschau*, 28–33, <https://www.westermann.de/anlage/4643930/Schutzgebiete-in-den-Alpen-zwischen-Bewahrung-und-Dynamik> (last access: 28 April 2025), 2022.
- Mayer, M., Kraus, F., and Job, H.: Tourismus – Treiber des Wandels oder Bewahrer alpiner Kultur und Landschaft?, *Mitt. D. Österr. Geogr. Gesellschaft*, 153, 31–74, <https://doi.org/10.1553/moegg153s31>, 2011.
- Meltzian, D., Marzelli, S., Lintzmeyer, F., and Chilla, T.: Cross-border spatial development in the Alpine Convention area. Assessment study, [https://www.alpconv.org/fileadmin/user\\_upload/Organisation/TWB/SPSD/Assessment\\_study\\_Cross-border\\_Cooperation.pdf](https://www.alpconv.org/fileadmin/user_upload/Organisation/TWB/SPSD/Assessment_study_Cross-border_Cooperation.pdf) (last access: 20 January 2025), 2022a.
- Mertens, E., Stiles, R., and Karadeniz, N.: Green May Be Nice, but Infrastructure Is Necessary, *Land*, 11, 89, <https://doi.org/10.3390/land11010089>, 2022.
- Meyer, C. and Job, H.: Developing a data-driven approach to climate-proof a regional spatial planning instrument: the Bavarian Alpenplan, *eco.mont*, 16, 16–29, <https://doi.org/10.1553/eco.mont-16-2s16>, 2024.
- Meyer, C., Peters, J. C., Thiel, M., Rathmann, J., and Job, H.: Monitoring von Freiflächeninanspruchnahme und -versiegelung für eine nachhaltige Raumentwicklung in Bayern, *Raumforsch. Raumord.* 79, 172–189, <https://doi.org/10.14512/rur.40>, 2021.
- Meyer, C., Job, H., and Knoll, L.: Längsschnittanalyse Alpiner Siedlungsgeographie: Das Tegernseer Tal, Bayern, *Mitt. D. Österr. Geogr. Gesellschaft*, 164, 283–309, <https://doi.org/10.1553/moegg164s283>, 2022.
- Ministry of Natural Resources and Spatial Planning: Strategija Prostorskega Razvoja Slovenije 2050, <https://faolex.fao.org/docs/pdf/slv222519.pdf> (last access: 25 April 2025), 2023.
- Monteiro, A. T., Fava, F., Hiltbrunner, E., Della Marianna, G., and Bocchi, S.: Assessment of land cover changes and spatial drivers behind loss of permanent meadows in the lowlands of Italian Alps, *Landsc. Urban Plan.*, 100, 287–294, <https://doi.org/10.1016/j.landurbplan.2010.12.015>, 2011.
- Mose, I.: Brennpunkt Alpen – Zur Einleitung, *Ber. z. Dt. Landeskunde*, 77, 2/3, Flensburg, 117–132, <https://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=15243285> (last access: 28 April 2025), 2003.
- Permanent Secretariat of the Alpine Convention: Naturgefahren. Risiko-Governance. Alpenzustandsbericht, *Alpine Signals*, ISBN 9788897500537, 2019.
- Permanent Secretariat of the Alpine Convention: Klima-Aktions-Plan 2.0, <https://www.alpconv.org/de/startseite/news-publikationen/publikationen-multimedia/detail/klimaaktionsplan-20/> (last access: 20 January 2025), 2021.
- Peterlin, M.: Territorial Coordination or Territorial Governance, *disP – Plan. Rev.*, 46, 69–79, <https://doi.org/10.1080/02513625.2010.10557113>, 2010.
- Pham, M. T., Rajic, A., Greig, J. D., Sargeant, J. M., Papadopoulos, A., and McEwen, S. A.: A scoping review of scoping reviews: advancing the approach and enhancing the consistency, *Res. Synth. Meth.*, 5, 371–385, <https://doi.org/10.1002/jrsm.1123>, 2014.
- Pirnat, J. and Hladnik, D.: The Concept of Landscape Structure, Forest Continuum and Connectivity as a Support in Urban Forest Management and Landscape Planning, *Forests*, 9, 584, <https://doi.org/10.3390/f9100584>, 2018.
- Plassmann, G., Kohler, Y., Badura, M., and Walzer, C.: *Alpine Nature 2030*, BMUB, Berlin, ISBN 978-3-00-053702-8, 2016.
- Pristeri, G., di Martino, V., Ronchi, S., Salata, S., Mazza, F., Benedini, A., and Arcidiacono, A.: An Operational Model to Downscale Regional Green Infrastructures in Supra-Local Plans: A

- Case Study in an Italian Alpine Sub-Region, *Sustainability*, 15, 11542, <https://doi.org/10.3390/su151511542>, 2023.
- Ramel, C., Rey, P.-L., Fernandes, R., Vincent, C., Cardoso, A. R., Broennimann, O., Pellissier, L., Pradervand, J.-N., Ursenbacher, S., Schmidt, B. R., and Guisan, A.: Integrating ecosystem services within spatial biodiversity conservation prioritization in the Alps, *Ecosyst. Serv.*, 45, 1–16, <https://doi.org/10.1016/j.ecoser.2020.101186>, 2020.
- Riva, M., Kienast, F. and Grêt-Regamey, A.: Mapping open spaces in Swiss mountain regions through consensus-building and machine learning, *Appl. Geogr.*, 165, 103237, <https://doi.org/10.1016/j.apgeog.2024.103237>, 2024.
- Rudaz, G.: Territorial redefinition and the governance of mountain regions, *Rev. Geogr. Alp.*, 97, 27–37, <https://doi.org/10.4000/rga.866>, 2009.
- Salata, S.: Land take in the Italian Alps. Assessment and proposals for further development, *Manage. Environ. Qual.*, 25, 407–420, <https://doi.org/10.1108/MEQ-12-2012-0079>, 2014.
- Schirpke, U., Tasser, E., and Tappeiner, U.: Mapping ecosystem services supply in mountain regions: A case study from South Tyrol (Italy), *Ann. Bot.*, 4, 35–42, <https://doi.org/10.4462/annbotrm-11599>, 2014.
- Schirpke, U., Candiago, S., Egarter-Vigl, L., Jäger, H., Labadini, A., Mersoner, T., Meisch, C., Tasser, E., and Tappeiner, U.: Integrating supply, flow and demand to enhance the understanding of interactions among multiple ecosystem services, *Sci. Total Environ.*, 651, 928–941, 2019.
- Schirpke, U., Leitinger, G., Tasser, E., Rüdissler, J., Fontana, V., and Tappeiner, U.: Functional spatial units are fundamental for modelling ecosystem services in mountain regions, *Appl. Geogr.*, 118, 102200, <https://doi.org/10.1016/j.apgeog.2020.102200>, 2020.
- Scott, D.: Global environmental change and mountain tourism, in: *Tourism and Global Environmental Change. Ecological, social, economic and political interrelationships*, edited by: Gössling, S. and Hall, M., Routledge, Abingdon, USA, 54–76, <https://doi.org/10.4324/9780203011911-4>, 2017.
- Ströbel, K., Job, H., and von Ruschkowski, E.: Regional governance as success factor in protected area management. Network analysis of the Lüneburg Heath Nature Park (Germany), *Spat. Res. Plan.*, 83, 1–14, <https://doi.org/10.14512/rur.2925>, 2025.
- Svadlenak-Gomez, K. and Walzer, C.: Bäume, Wasser, Wind und Sonne – Natur pur?, *Natur Landschaft*, 9, 458–463, <https://doi.org/10.17433/9.2017.50153515.458-463>, 2017.
- Tischler, S.: Alpine Raumordnung, in: *Handbuch Alpine Raumordnung. Ein Raumentwicklungskonzept für den Alpenraum*, Umweltdachverband gGmbH, Vienna, 7–15, [https://www.umweltdachverband.at/assets/Umweltdachverband/Publikationen/Eigene-Publikationen/2022/CIPRA\\_Handbuch\\_AlpineRaumordnung\\_2022.pdf](https://www.umweltdachverband.at/assets/Umweltdachverband/Publikationen/Eigene-Publikationen/2022/CIPRA_Handbuch_AlpineRaumordnung_2022.pdf) (last access: 28 April 2025), 2022.
- Vanham, D., Millinger, S., Pliessnig, H., and Rauch, W.: Rasterised Water Demands: Methodology for Their Assessment and Possible Applications, *Water Resour. Manage.*, 25, 3301–3320, <https://doi.org/10.1007/s11269-011-9857-3>, 2011.
- Vincent, C., Fernandes, R. F., Cardoso, A. R., Broennimann, O., Di Cola, V., D’Amen, M., Ursenbacher, S., Schmidt, B. R., Pradervand, J.-N., Pellissier, L., and Guisan, A.: Climate and land-use changes reshuffle politically-weighted priority areas of mountain biodiversity, *Global Ecol. Conserv.*, 17, 1–12, <https://doi.org/10.1016/j.gecco.2019.e00589>, 2019.
- Walz, U., Schumacher, U., and Krüger, T.: Landschaftszerschneidung und Waldfragmentierung in Deutschland - Ergebnisse aus einem Monitoring im Kontext von Schutzgebieten und Hemerobie, *Natur Landschaft*, 97, 85–95, <https://doi.org/10.19217/NuL2022-02-04>, 2021.
- Wandl, A., Rooij, R., and Rocco, R.: Towards Sustainable Territories-in-Between: A Multidimensional Typology of Open Spaces in Europe, *Plan. Pract. Res.*, 32, 55–84, <https://doi.org/10.1080/02697459.2016.1187978>, 2017.