

Systematic Review

Mapping Wilderness 1985–2025: A Systematic Review of Concepts, Methods, and Gaps in Global Literature

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Abstract

To date, no systematic review has examined wilderness mapping approaches in relation to stakeholder involvement. This study systematically reviews 55 published articles, identified through Scopus and Web of Science, from the past four decades to evaluate how wilderness has been conceptualized, operationalized, and spatially represented. The analysis identifies nine mapping approaches along with 27 elements used to operationalize wilderness, with an emphasis on perceptions of naturalness and remoteness. Notably, only one study engaged stakeholders to identify specific elements representing wilderness, highlighting the lack of public participation in these processes. This study demonstrates persistent reliance on expert-driven wilderness mapping. Integrating stakeholders into the identification of wilderness elements, appropriate indicators, and their spatial extent supports a more holistic representation of wilderness and better informs sustainable land-use planning by integrating socio-cultural values.

Keywords: wilderness; mapping; stakeholder involvement; methods; review; sustainability; socio-cultural values

1. Introduction

Identifying remaining wilderness is important [1,2]; however, mapping it poses unique challenges [3]. Mapping relies on symbols to geospatially represent entities and constructs, necessitating a clear operational definition to determine what to incorporate and how. However, no universal definition of wilderness exists [2,4–8], leading to a lack of objective criteria, qualities, elements, or characteristics [9,10] which can unequivocally be tied to wilderness.

Wilderness, a conceptually fuzzy, multi-dimensional construct, comprises both natural and socio-cultural elements [11]. However, due to the ambiguity of the wilderness concept, indirect indicators, or proxies, are selected to map wilderness [12], such as land cover as a proxy for naturalness, distance from roads as a proxy for remoteness, or human population data as a proxy for human influence. The choice of proxies is largely based on the authors' conceptualization of the term, the individuals consulted in the data collection, or the available data, all of which influence the elements selected to represent wilderness in each mapping initiative. Without a standardized definition of wilderness to operationalize, how one defines wilderness depends on how one chooses to conceptualize the term [6,13], and this has been shown to vary considerably [14].

Wilderness can be perceived as both an ecological and a psychological concept [13,15,16]. Ecologically, wilderness is reportedly important to combat biodiversity loss [17] and maintain



Academic Editor: Colin Michael Hall

Received: 26 June 2026

Revised: 16 July 2026

Accepted: 21 July 2026

Published: 27 July 2026

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important ecosystem services [18]. Psychologically, one may perceive an area as wilderness based on elements such as aesthetics, the absence of previous human influence or managerial actions, or self-reliance [16,19]. The values associated with the psychological aspect are influenced by the individual's culture, experiences, preferences [16,20,21], and socio-spatial contexts [7,22]. In the mapping context, wilderness is often aligned with social and cultural conceptualizations, and the symbols selected are often representative of wilderness perceptions.

The spatial extent of perceived wilderness can differ from the boundaries of legislative or administratively designated wilderness protection areas (WPAs). WPAs are rarely identified in the academic wilderness mapping literature, appearing as bounding areas for wilderness perception or comparison studies [14,23,24]. Although WPAs may differ in spatial extent from areas identified in wilderness perception mapping, they are not mutually exclusive. The perceptions mapped often highlight the potential values ascribed to wilderness by the data sources and can inform decisions on where, or whether, WPAs are socially acceptable [25]. However, several questions arise: who decides which elements are incorporated into the mapping of wilderness for the area of interest? Whose values are represented and whose are repressed; which environmental values are recognized and which are omitted [26]. And how do these choices affect the outcome of the mapping effort? As Williams and Watson wrote, "As we look around we must ask ourselves: who is not present to participate in this reasoning about wilderness values?" [27] (p. 132).

Social valuation of wilderness is important to incorporate in mapping efforts [14,28], given the plurality of stakeholder values for an area and their relationships with it [9,27,29–31]. At the international level, the International Union for Conservation of Nature (IUCN) calls for stakeholder inclusion in its Wilderness Management Guidelines [32]. A recent article [21] compared stakeholder perspectives of wilderness against expert-knowledge-based identification of wilderness for the same National Park in China. Their results demonstrate the importance of stakeholder engagement: expert-derived wilderness maps did not accurately reflect stakeholder-identified wilderness, and the authors noted that stakeholder maps were more accurate [21]. Similarly, Zoderer et al. (2020) found that spatially identified areas of wilderness in northern Italy were dependent on whether the data were based on public or expert perspectives [31].

Given the complexity of mapping wilderness and the potential disparity between stakeholder and expert-knowledge-based wilderness representation, this study systematically reviewed published wilderness mapping initiatives from the past four decades (1985–2025) to evaluate how wilderness has been conceptualized, operationalized, and spatially represented in existing studies, to identify research gaps and directions for future studies, and to explore the use of participatory methods. In the context of this study, participatory methods are approaches in which stakeholders contribute directly to one or more stages of the wilderness mapping process, including identifying wilderness, spatially delineating wilderness areas, or contributing data for map production. The date range was selected based on Lesslie & Taylor's wilderness continuum framework development in 1985, which facilitated the quantification of wilderness qualities [33].

This work is based on four research questions:

1. What methodological approaches have been employed to map wilderness since 1985?
2. Which biophysical and socio-cultural attributes have been used to operationalize wilderness, and on what basis are they selected?
3. To what extent has wilderness mapping incorporated participatory methods?
4. What conceptual, methodological, and geographical gaps remain in the wilderness mapping literature?

2. Materials and Methods

This research followed the method proposed by Pickering et al. [34] to conduct a systematic literature review. A quantitative systematic approach, the method follows a 10-step knowledge creation process to define the research topic, formulate research questions, identify keywords, identify relevant literature through database queries, assess articles, develop a review database, and develop summary data [34]. Additionally, this systematic literature review complied with the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Supplementary Materials) [35]. Once the topic was defined and the aims refined, four research questions were created. To facilitate the bibliographic database queries, five keywords were identified based on key publications: wilderness, map, model, attribute, and element. A wildcard was applied to all keywords except wilderness to ensure other variants of the terms, including plural forms or differences in spelling, were included in the search.

Two bibliographic databases were selected for the query to ensure a robust selection of relevant literature, focusing on the two leading databases [36]: Scopus and Web of Science (WOS). Within WOS, all databases and all editions were selected. The search was constrained to articles from 1985 through 2025 available in English due to the primary researcher's language proficiency and concerns about the accuracy of translation software. Keyword effectiveness was evaluated based on whether each search included key publications. These two databases ensured broad coverage of peer-reviewed international literature; however, the restriction to English-language articles may exclude relevant articles published in other languages or as grey literature.

The following queries were performed on 17 February 2026, incorporating refinements from the selection criteria: date range, language, and publication type (Appendix A). The queries were deliberately designed to recall a broad range of records related to the term wilderness.

- WOS: ((TS = (wilderness map*)) OR (TS = (wilderness NEAR/15 (model* OR attribute* OR element*))))
- Scopus: (TITLE-ABS-KEY = ((wilderness AND map*) OR (wilderness W/15 (model* OR attribute* OR element*))))

The acronym TS, within WOS, indicates a search within the following fields: title, abstract, and keywords. The terms Near/15 and W/15 represent proximity limits. They limit the search to instances where the two words are within the selected value of one another, in this case, if the two words are within 15 words of one another. The proximity limits were applied to filter out non-relevant search results. A brief description of these queries is then: find all peer-reviewed journal articles, published between 1985 and 2025, that include the keywords wilderness and map/maps/mapping in the abstract, keywords, or title. Or all the articles following those same constraints where the terms wilderness model/models/modelling, wilderness attribute/attributes, or wilderness element/elements are found within 15 words of each other within the title, abstract, or keywords.

Once the queries were complete, a citation management software program (EndNote 20) was used to remove duplicate articles. This was a manual process where EndNote 20 identified the duplicate pairs, and the researcher systematically deleted one of the duplicate files from the EndNote library.

Article screening, coding, and data analysis was conducted by the first author. Abstracts for each article were read and analyzed against the selection criteria for inclusion (Appendix A). Once all potentially relevant articles were identified through abstract screening, a full-text review of the relevant articles was undertaken to ensure they fully met the selection criteria (Appendix A). After screening, the cited references for each selected

article were reviewed to determine whether additional articles fell within the project's scope. Articles were systematically excluded if they did not explicitly concern the mapping of wilderness or explicate the elements or attributes selected to represent wilderness (Appendix A).

A review database was developed to reduce data, generate analytical categories, and produce final interpretation criteria. Ten categories were developed through an iterative process; prespecified criteria, such as the elements incorporated and the spatial resolution employed in the mapping efforts, were expounded upon and revised as themes emerged (Appendix B). The categories used to analyze the articles were based on the methods used, the location where the research was conducted, the scale at which the research was conducted, whether the process included public participation, and which elements were selected to identify wilderness spatial extent.

Data analysis involved thematic coding and the creation of dummy variables to compute instances across the articles. The recorded elements used to operationalize wilderness largely reflect the terms identified in the articles, unless they clearly fit an existing category. The list of elements was reclassified from 41 to 27 (Appendix C), based on the definitions provided in the articles. Reclassification only combined similar elements, such as various types of naturalness (aesthetic, biophysical); no conceptually distinct elements were merged. Once all articles were analyzed, thematic categorization of the included elements was based on similarities in concepts and definitions, or their indicators, across the papers.

3. Results

A total of 893 articles were screened after duplicates were removed (Figure 1). Of those, 844 articles were removed for failure to meet the selection criteria (Appendix A). All citations from the remaining 49 articles were screened for potential inclusion; six articles met the selection criteria, resulting in a total of 55 articles for final analysis.

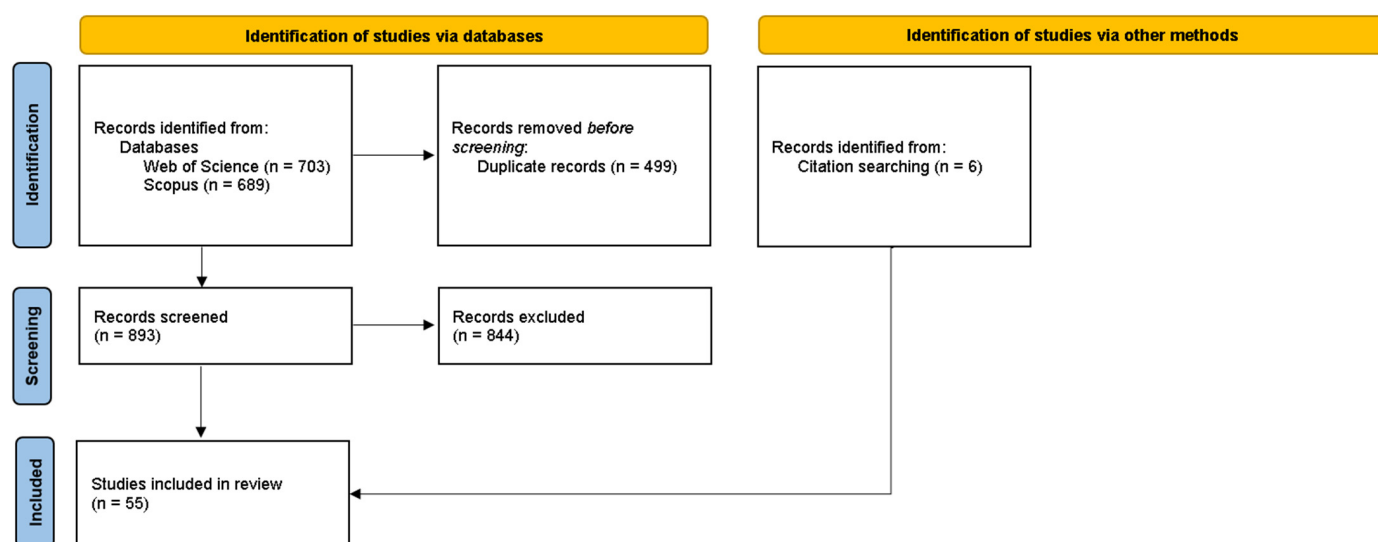


Figure 1. PRISMA 2020 flow diagram depicting screening and selection process [35].

3.1. Timeframe of Articles

A review of publication dates reveals several temporal gaps in the publishing of wilderness mapping literature between 1985 and 2025. The largest occurred between 2003 and 2007, while two separate 3-year gaps occurred from 1990 to 1992 and from 1999 to 2001. Wilderness mapping efforts became more consistent after 2013, with at least one article published each year thereafter. A marked increase in publications is evident between 2018 and 2024, accounting for 62% of the total articles published across those 7 years (Figure 2).

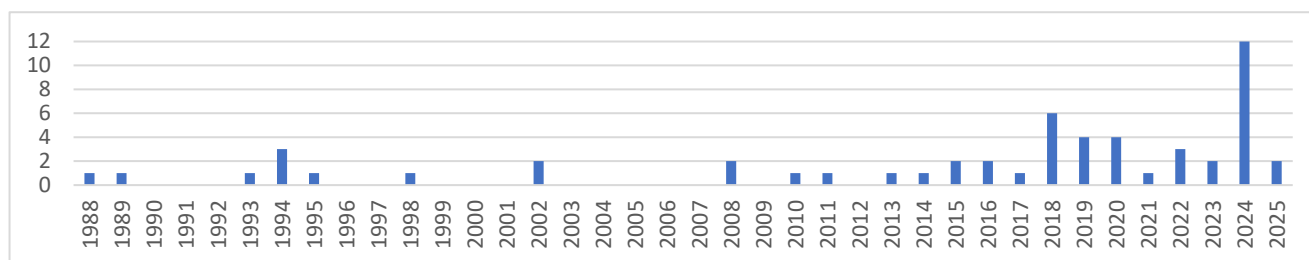


Figure 2. Count of selected articles published by year.

3.2. Area and Scale of Mapping

Wilderness mapping is represented at the global scale ($n = 9$) and in select areas across five of the seven continents (Table 1). Asia accounts for the largest number of studies ($n = 17$), with China ($n = 15$) accounting for 27% of all selected articles in the final analysis. The scale of wilderness identification in China varies: an equal number of studies examine wilderness at the national ($n = 6$) and local ($n = 6$) scales, while three studies focus on the regional scale. The most expansive study of wilderness in Asia examined wilderness across 11 countries, spanning from Russia to Pakistan. Wilderness in Sri Lanka was also mapped at the national scale.

Table 1. Area and scale of wilderness mapping.

Continent	Area	Scale	Count	Percent of Articles (%)
*	Terrestrial	global	8	16.4
	Marine	global	1	
Asia	China	national	6	27.3
		regional	3	
		local	6	
	Sri Lanka	national	1	1.8
	Pan-Asia (Russia to Pakistan)	regional	1	1.8
Europe	Continental Europe	continental	1	1.8
	pre2013 EU (27 countries)	regional	1	1.8
	European Alps	regional	1	1.8
	Denmark	national	1	1.8
	Germany	national	1	1.8
	Switzerland	national	1	1.8
	United Kingdom	national	1	1.8
	Iceland	national	2	5.5
		regional	1	
	Italy	local	1	1.8
	France	local	1	1.8
North America	US	regional	2	9.1
		local	3	
	Canada	local	1	1.8
Oceania	Australia	regional	3	7.3
		local	1	
	New Zealand	local	6	10.9
South America	Argentina	local	1	1.8

* = Global scale.

The second most common continent chosen for wilderness mapping is Europe ($n = 12$). Multiple scales are included in the literature, including the only effort to map wilderness across the entire continent. Three regional-scale wilderness mapping efforts were also undertaken: the European Alps, the 23 EU member nations before 2013, and Iceland's Central Highland. Wilderness was mapped at the national scale across six European countries and at the local scale in two studies.

Oceania is the third most represented area for wilderness mapping in the literature ($n = 10$). At a local scale, New Zealand was examined in six articles. Australia was studied in three articles focused on regional mapping and in one local mapping effort.

North America follows, with a total of six articles. The United States of America is represented in five of those; two at regional scales and three at local scales. Wilderness mapping in Canada is represented by a single article at the local scale.

South America is represented by one study examining wilderness at a local scale in Argentina.

3.3. Area Mapped by Year

A review of articles based on their scope of wilderness mapping and publication year identified several trends (Figure 3). Between 1985 and 2001, the majority of mapping efforts included in this analysis occurred in Australia ($n = 4$) and New Zealand ($n = 6$), with only one effort focused on identifying wilderness at a global scale. Published articles regarding wilderness mapping in the United States first appeared in 2008 and continued until 2021. Efforts to map wilderness in non-Western regions were first published in 2016. Efforts to map wilderness in China account for the largest proportion of articles; these are all written within the last ten years. 2024 saw seven articles alone.

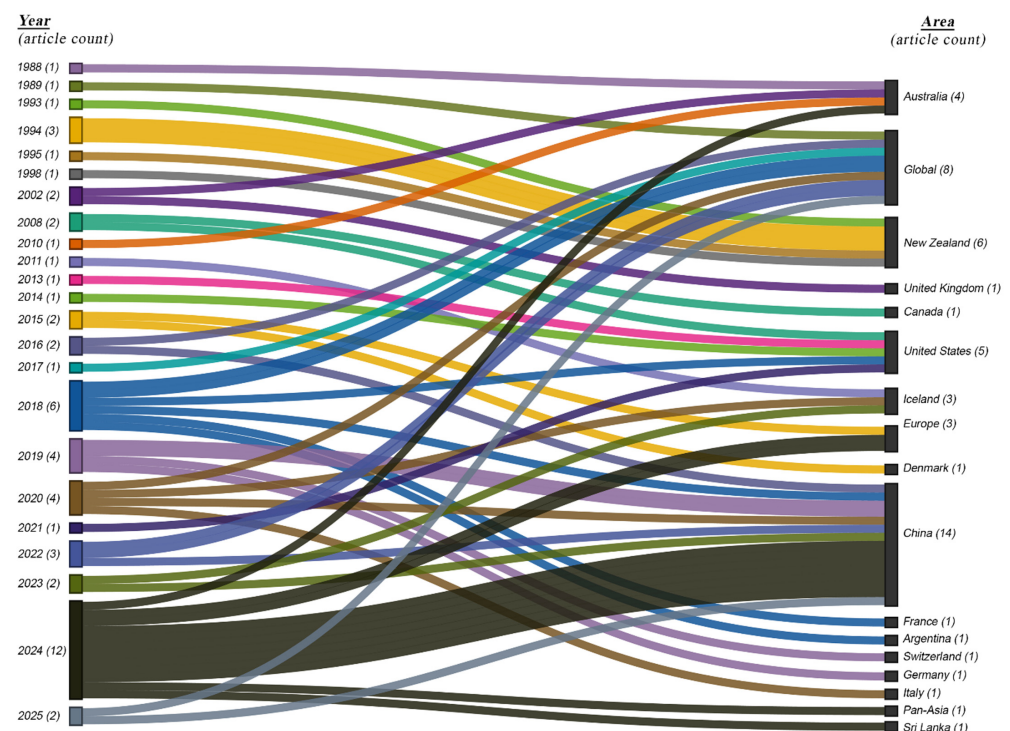


Figure 3. Diagram depicting temporal and spatial patterns of wilderness mapping efforts. The left column represents the year of publication and the number of reviewed articles for each year. The right column shows the area covered in the reviewed articles and the total number of articles addressing that area.

3.4. Type of Wilderness

The wilderness mapping articles analyzed in this study encompassed both terrestrial and marine wilderness areas. Articles, however, were heavily skewed toward terrestrial areas ($n = 53$), with only one focusing solely on mapping marine wilderness at a global scale. Additionally, one article looked at both terrestrial and marine wilderness at the local scale.

3.5. Spatial Resolution Selected by the Authors

Sixty-seven percent of articles reported the resolution chosen for their map(s) (Figure 4). The most common resolution used was 1 km ($n = 18$). Of the 18 articles mapped at a 1 km resolution, 8 addressed wildernesses globally, 6 at the national scale, and 4 at the regional scale. The second most common spatial resolution reported is 100 m ($n = 7$), followed by 30 m ($n = 4$). A complete list of reported spatial resolutions, including the less frequently used ones, is visible in Figure 4.

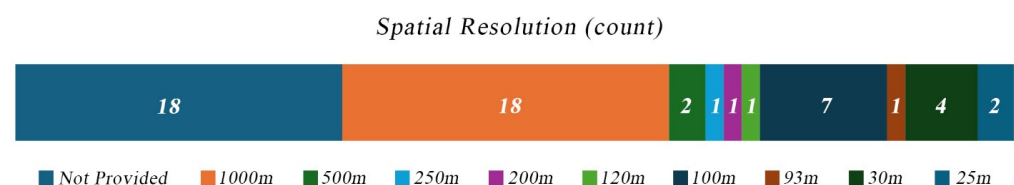


Figure 4. Counts of spatial resolution selected by authors.

3.6. Mapping Approaches

The spatial extent of wilderness was mapped using nine different approaches (Table 2). The most frequently referenced is the Weighted Linear Combination (WLC) method ($n = 17$), also known as the Wilderness Quality Indicator or Wilderness Continuum. The WLC method involves standardizing all data collected for each element selected to represent wilderness into a common value range scale, applying weights to the values if deemed necessary, and then summing the values for each element, resulting in a continuum of values across the selected study area [33]. This method represents the largest span of use, from the first wilderness mapping article included in this review (1988) to the most recent (2025) (Figure 5). The WLC method is used across five scales in the reviewed literature: global ($n = 1$), continental ($n = 1$), national ($n = 7$), regional ($n = 6$), and local ($n = 2$).

Table 2. Approaches to map wilderness and count of their instances.

Approach	Count
Weighted linear combination (WLC)	17
Multi-criteria evaluation (MCE)	11
Purism scale (WPS)	9
Boolean	9
Human pressure (HP)	7
Hotspot analysis (HA)	4
Machine learning (ML)	3
Macrodata (MD)	1
Human Appropriation of Net Primary Production (HANPP)	1
Total	62 *

* Note: seven papers used multiple approaches (Table A3 in Appendix C).

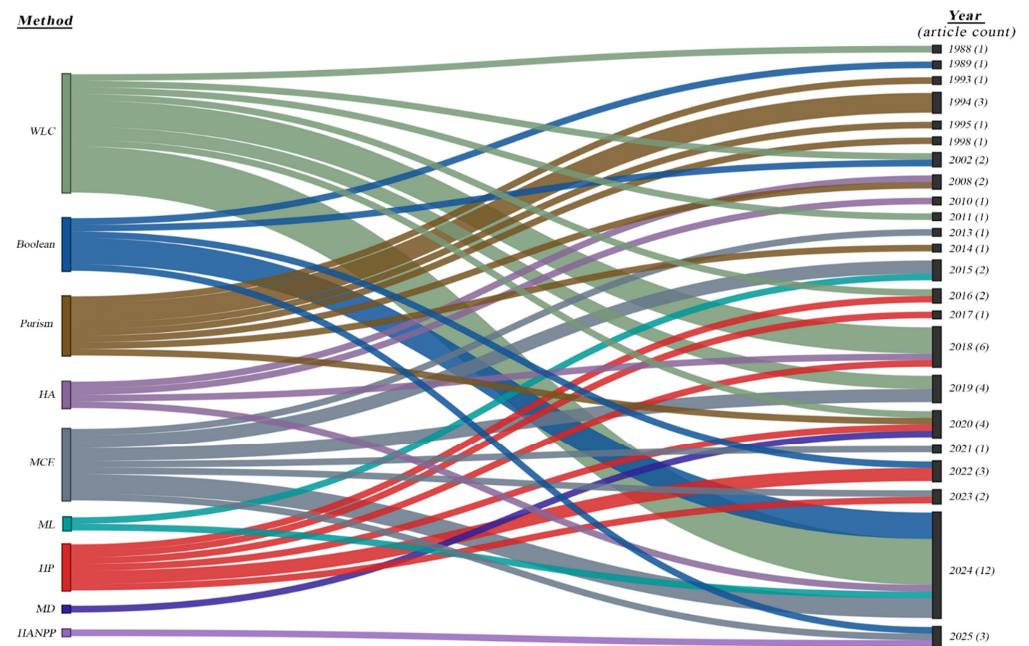


Figure 5. Wilderness mapping approaches and year(s) employed. A count of articles by year is provided in parentheses.

The Multi-Criteria Evaluation (MCE) is the second most commonly used method ($n = 11$). The MCE does not standardize the data for each selected element across a common scale. Instead, an index is formulated based on the value classes chosen to represent each selected element [37]. Its use is more limited, spanning 2013 to 2025. The method is used on national ($n = 3$), regional ($n = 4$), and local ($n = 4$) scales.

The Wilderness Purism Scale (WPS) is the third most used approach ($n = 9$) and was most often employed in the 1990s. The WPS categorizes participants based on the aggregated responses to a set of Likert-scale questions regarding the perceived appropriateness of specified activities or infrastructure in the wilderness [14]. Three articles employed the WPS after 2000; two in the United States (2008, 2014) and one in Iceland (2020). The WPS is most often associated with local ($n = 3$) and regional ($n = 5$) wilderness mapping, except for its use in Iceland to identify wilderness at the national scale.

The Boolean method also has a wide range of use ($n = 9$), ranging from 1989 to the most recent publication reviewed (2025). The Boolean method applies buffers of prespecified distances around entities that are reportedly incompatible with the operationalized definition of wilderness [38]. Its initial use was on a global scale, but since then it has been used at regional ($n = 4$), local ($n = 2$), and national ($n = 2$) scales. The method has been increasingly used in conjunction with the WLC or MCE methods to map wilderness in China, where the Boolean approach defines wilderness boundaries, and the WLC and MCE provide wilderness values within those boundaries.

The Human Pressure (HP), also referenced as the Human Footprint Index, was used in seven articles. The HP is a composite index that measures the cumulative threat on the environment by assessing multiple indicators of anthropogenic disturbances [39]. The HP index follows the MCE methodology but stands apart as it often uses a standardized set of eight elements to operationalize wilderness: "...built environments, crop lands, pasture lands, population density, night-time lights, railways, major roadways, and navigable waterways [40]. Its use in the published literature is more contracted, beginning in 2016 and continuing through 2023. The HP is most commonly associated with efforts to map wilderness at the global scale ($n = 6$); however, it was also employed at a local scale in China ($n = 1$).

The Hotspot Analysis (HA) method was applied in four of the reviewed articles. The HA method largely operationalizes wilderness as a landscape value, asking participants to spatially identify it on a provided map [41], often using points or drawn polygons. Spatial analysis is then applied to identify significant clusters of the identified locations. The method was first published in a Canadian study in 2008 and has since been used in other studies through 2024 to map wilderness at the local scale ($n = 4$).

Three approaches were employed far less frequently: Machine Learning ($n = 3$), Macrodata ($n = 1$), and the Human Appropriation of Net Primary Production ($n = 1$). Machine Learning (ML) is a data-driven approach that relies on algorithms to evaluate data distributions [42]. ML approaches included MaxEnt modeling at the national scale in China (2024) and unsupervised clustering analyses at the local scale in China (2016) and the national scale in Denmark (2015). Macrodata (MD), as defined in this study, uses large-scale aggregate spatial datasets that represent human and environmental characteristics for pattern analysis [43]. MD was used to map wilderness in China at the national scale in 2020 by analyzing location-based service data. The Human Appropriation of Net Primary Production (HANPP) approach in 2025 developed a novel global dataset incorporating land cover data from the European Space Agency, agricultural and forestry production information from the Food and Agriculture Organization of the UN, agricultural production maps, the Human Footprint database, and intact forest landscape data, which facilitated analysis of the intensity of land-use change and patterns [44].

3.7. Elements Used to Operationalize Wilderness

An analysis was conducted to examine how wilderness was operationalized in the articles. After reclassification, 27 elements were used to operationalize wilderness across the studies (Appendix C). Naturalness ($n = 40$) and remoteness ($n = 34$) were the most commonly used elements, followed by undeveloped ($n = 29$), population ($n = 18$), and motorized travel ($n = 16$). Elements focused on ecological concepts were less frequently specified; wildlife was used in four articles, biodiversity was applied in two articles, and fishing was used in one article.

3.8. Public Involvement

An analysis was conducted to determine whether the articles incorporated public involvement across three aspects of wilderness mapping: the identification of which elements to use as proxies for wilderness, the creation of the map, and the collection of the data (Table 3). This study found that almost exclusively (96%), experts selected which elements represented wilderness for mapping purposes. Only one study invited participants to specify which elements they believed represented wilderness in research conducted at the local scale using the WLC method in Italy. In all remaining studies, except one study where the element identification did not take place, these decisions were made by researchers or experts prior to data collection.

Table 3. Stages of wilderness mapping and counts of data by source type.

Stage	Expert-Knowledge	Public Participation	Not Identified
Element identification	53	1	1
Mapping process	49	6	0
Data source	40	15	0

Public input increased slightly when examining the mapping processes employed in the literature. Six of the studies used participatory methods to identify wilderness areas on the maps. Four studies were conducted at a local scale using the HA method. In these HA studies, wilderness was defined as a landscape value. Survey participants placed points on

digital maps, drew polygons, or placed circular stickers on paper maps to identify areas they felt were wilderness based on the provided definitions. Spatial analysis was then applied to determine where hotspots occurred. Two studies were conducted at the national scale; one used the purism method while the other employed the WLC method. The study following the purism model used an online survey and asked respondents to use a digital spray can to draw where they felt wilderness existed in the country. Lastly, the study following the WLC method developed an online portal where participants could select from a list of predefined wilderness attributes and then apply their own weighting scheme. The one aforementioned study that allowed participants to identify elements representative of wilderness did not use a participatory approach to map those elements.

Lastly, the literature was reviewed to understand the extent to which data were sourced to quantify the wilderness elements. The public was more involved in this aspect, with 27% of the research using participants' data. Still, 40 of the 55 published articles on wilderness mapping relied solely on expert-driven data collection at some level within the process.

4. Discussion

This review enabled a systematic evaluation of wilderness mapping over the past four decades (1985–2025) to understand how wilderness was spatially represented and operationalized, the level of public participation in mapping efforts, and to identify research gaps and directions for future studies of wilderness.

4.1. Approaches to Mapping Wilderness

Nine approaches to mapping wilderness were identified in the literature. However, when analyzed by scale, country, or resolution, no consistent patterns emerged to indicate a systematic approach to their use or a universal preference. The choice of method appears to reflect the author's conceptualization of the term 'wilderness' rather than indicating any objective, systematic approach. Only the HP index demonstrated consistent use in identifying wilderness at the global scale, using the standardized set of elements to operationalize wilderness. All other approaches show use across all scales and areas worldwide.

Data availability is acknowledged as a possible constraint in the reviewed articles, which address wilderness mapping methodologies and the project's selected spatial resolution. Resampling data to a scale greater than its native resolution can lead to accuracy and precision issues [45], which restricts mapmakers in the level of detail they can display. Additionally, appropriate data for large regions may not exist, or substituted data may serve as a surrogate for the selected indicators. Operationalizing elements of wilderness, such as *naturalness*, across various reviewed papers relied on three data types: vegetative cover, land-use type, or the presence of anthropogenic features, the choice of which appeared to align with data availability for the selected map area.

Wilderness mapping methods have incorporated technological advancements. Early methods focused on perceptions of wilderness based on visitor experiences, as well as proxy-based models of anthropogenic disturbances and land-use changes. Recently, however, with the ability to extract data at large scales, there is an emerging tendency for approaches to mapping wilderness to incorporate machine learning and macrodata analysis.

4.2. Elements Selected to Operationalize Wilderness

Mapping complex, multi-dimensional, and fuzzy constructs such as wilderness requires identifying appropriate elements and quantifiable indicators to determine its spatial extent. Following the review of articles in this study, it is evident that what is being mapped is largely a symbolic representation of wilderness grounded in the psychological dimension,

and less on ecological aspects. Only a few maps incorporated biological and geological data to address environmental elements of wilderness [13,46–48], of which two are reflective of institutional efforts within the United States Federal Land Management Agencies to standardize wilderness character monitoring [49].

The operationalization of the term wilderness for its spatial demarcation is further complicated by data availability and the selection of data types to represent the selected wilderness elements. The element naturalness is one of the most applied across the reviewed articles, but finding available datasets to account for the plurality of indicators within that element has often been limited to land-use types [15,45,50] or land cover [12,16,51]. Although proxy naturalness is often described as encapsulating the maintenance of ecological functions and biodiversity protection, data limitations limit the ability to represent these considerations and their spatial requirements. Instead, reliance is placed on substitute data that may or may not account for the multitude of interdependent environmental systems on which they are founded. Watershed analysis, habitat types, hydrologic connectivity, species-dependent ecotypes, or geologic analysis for land suitability in relation to species needs are limited in the wilderness maps reviewed for this study.

4.3. Level of Participation in the Process

The lack of participatory approaches to establish the operational definition of wilderness in the published literature is one of the most notable findings in this study. Given that the term wilderness may not carry the same meaning between nations [52] or cultures [7,53], the omission of stakeholders' values may lead to a misrepresentation of the spatial extent and characteristics of wilderness.

The identification of wilderness may benefit from understanding people's relationships with the environment [54]. The studies reviewed largely rely on expert-knowledge-based approaches, which may perpetuate the 'Western' view of wilderness, as evidenced by the authors' adherence to the same elements established in 1988, which operationalized wilderness as a primitive area [45]. Recent studies have demonstrated that indigenous cultural practices have developed some of the areas labelled wilderness in the articles reviewed in this research [53].

A discussion point for future studies concerns whether localized cultural relationships are accounted for in mapping efforts that operationalize wilderness in this context. From a local to a global scale, the multitude of values associated with an area, and therefore their conceptualization of wilderness, may vary significantly. The concept of "wild" is often associated with wilderness. Still, this term is vague and varies across cultures [54] and interculturally, e.g., depending on whether an individual lives in a rural or urban environment [55]. Viewed in tandem with the omission of stakeholder involvement in selecting which elements and indicators reflect their conceptualization of wilderness, wilderness mapped in non-Western regions may misrepresent the interrelationship between ecosystem services and the cultural/social practices in those areas [53].

The wilderness definition found in the US Wilderness Act, the precedent for many Western nations' wilderness definitions [56], represented the relationship between the Act's authors and the environment [54], which may not represent the relationships between traditional cultural users and their environments [52]. In other parts of the world, this concept may not reflect the stakeholders' values. Mapping the Western conceptualization of wilderness across all nations has led to issues regarding Indigenous rights [57]. In addition, attempts to identify remaining wilderness without local knowledge can overlook the extent to which cultural practices shape ecological processes in an area [53]. Moving forward, it would seem beneficial to conceptualize the term wilderness based on local stakeholders' diverse relationships with the environment to ensure that conservation of

the area is supported in the community, and, more importantly, that their way of life is sustainable.

4.4. Gaps Identified

Several gaps were identified through this analysis. First, the omission of stakeholder involvement in identifying the elements to operationalize wilderness and in selecting relevant indicators appears to reflect the ‘Western’ conceptualization of the term wilderness and could potentially minimize local cultural and social relationships with the environment. The two most frequently used elements for operationalizing wilderness, naturalness and remoteness, are traceable to the earliest wilderness mapping in Australia, where they were used to identify “primitive” areas [45]. This persistence of wilderness conceptualization within a Western framing would seem at odds with the growing recognition of the need to incorporate the cultural dimensions of wilderness [32]. It may underestimate the level of codependence associated with centuries of traditional cultural practices [53].

Several questions arise for future studies when evaluating whether it is appropriate to map wilderness at scales beyond regional or national, using a standardized set of wilderness elements. At present, many of the articles reviewed in this study that focused on mapping wilderness globally followed the standardized list of elements found in the HP. However, where does one draw the necessary data to quantify each of the eight wilderness elements of the HP if those elements are not universal to all cultures? And do all cultures view wilderness the same? Wilderness is largely a cultural construct [7,25], and applying Western cultural values may negate the cultural practices of local peoples [53]. What relevance does remoteness or naturalness hold to cultures that still practice traditional subsistence livelihoods or to those for whom wilderness is their home? [29]. An analysis of these maps would seem to require a reflection of whose values are represented and whose are omitted [26], and how those choices affect the outcome of the mapping effort.

Existing research has shown cultural differences in what constitutes wilderness and how it is used across nations [52]. Coupled with the knowledge that elements identified to operationalize wilderness are dynamic [58], which supports Leopold’s statement that “wilderness is a relative condition” [59] (p. 399), the apparent reliance on expert-based knowledge to define wilderness spatially appears at odds with the international calls to incorporate local stakeholder involvement in environmental conservation efforts. Incorporation of stakeholder values toward the environment may offer a more holistic approach to wilderness identification and identify additional wilderness beyond expert-based knowledge approaches.

And lastly, geographically, large areas of the globe are not represented in the articles reviewed for this study: much of Central and South America, the African continent, and much of Asia. This may be a function of the methodology employed, with the readings filtered to include only those written in English. At least one known study was identified in Russia, but a translated copy was not available [60]. Wilderness mapping studies may have taken place in these countries, but they were beyond the scope of this systematic review.

4.5. Study Limitations

Three potential limitations are identified in this review. First, only articles available in English were selected for the systematic literature review. Non-English studies in environmental conservation are increasing, and future systematic literature reviews of wilderness mapping can benefit from incorporating their methods, results, and discussion points.

Second, only peer-reviewed, published articles were pulled for this analysis. It is acknowledged that a large body of wilderness research is conducted by professionals in universities,

government agencies, non-governmental organizations, and businesses, including wilderness mapping. Subsequent literature reviews may benefit from a thorough review of these agency reports, conference proceedings, consultation deliverables, and books.

Lastly, this study followed a binary approach to distinguish amongst data sources and identification of wilderness elements since the objective was to specifically examine who contributed to the conceptualization of wilderness. Future reviews could evaluate these at a more granular level to distinguish among expert judgement, government datasets, remotely sensed data, citizen science, and other data sources.

5. Conclusions

Mapping wilderness, a complex, multi-dimensional construct, poses unique challenges as no universal definition exists to specify the objective criteria, qualities, elements, or characteristics to incorporate. How one defines wilderness depends on how one conceptualizes the term, and this has been shown to vary considerably between expert knowledge and public participation approaches. Values associated with wilderness depend on an individual's culture, experiences, and preferences; wilderness mapping, then, is reliant on the operational definition selected and the proxy data chosen to represent wilderness.

Recent studies highlight the potential for large disparities in wilderness identification depending on whether the process was based on expert-driven or public knowledge. This systematic literature review examined all journal articles published in English within Scopus and Web of Science over the past 40 years to identify the methods used, the elements selected to represent wilderness, and the level of public participation in the process. Nine mapping approaches and methods were identified, including efforts to map wilderness globally and at varied scales across five continents. Across the articles, twenty-seven elements were identified as symbols of wilderness. No clear pattern emerged regarding which method was applied to map wilderness at global, national, regional, or local scales, nor was there a consistent approach to selecting which elements were representative of wilderness.

The greatest finding is the apparent lack of public involvement across the three stages of wilderness mapping examined in this review: 1. identification of wilderness elements, 2. spatial delineation of wilderness, and 3. data collection. No wilderness mapping effort has engaged the public at all three stages. Given the disparity between expert- and public-based identification of wilderness, there is a potential for misrepresentation of important wilderness areas when the public is not involved in selecting the elements that symbolize wilderness, spatially demarcating them on a map, and assigning relative importance to each element. Future efforts to map wilderness can benefit from involving the public across these three stages to provide a more holistic representation of wilderness and to strengthen public buy-in for conservation policies and protected area designation. The results of this study highlight the need for stakeholder identification, collaborative conceptualization, indicator and measure selection, weighting, participatory mapping approaches, and validation to facilitate sustainable land use and planning when it concerns mapping wilderness values and potential perceived threats.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18157627/s1>, PRISMA 2020 checklist.

Author Contributions: Conceptualization, C.C., B.D.H. and P.Á.; methodology, C.C. and B.D.H.; software, C.C.; validation, C.C.; formal analysis, C.C.; investigation, C.C.; resources, C.C.; data curation, C.C.; writing—original draft preparation, C.C.; writing—review and editing, B.D.H. and P.Á.; visualization, C.C.; supervision, B.D.H. and P.Á.; project administration, C.C.; funding acquisition, C.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by Landsvirkjun Research Fund under Grant number nýr-10-2025.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

WPA	Wilderness protected area
IUCN	International Union for Conservation of Nature
EU	European Union
WLC	Weighted linear combination
MCE	Multi-criteria evaluation
WPS	Wilderness purism scale
HP	Human pressure
HA	Hotspot analysis
ML	Machine learning
MD	Macrodata
HANPP	Human appropriation of net primary production

Appendix A

Table A1. Selection criteria established to search, screen, and select articles.

No.	Criterion
1.	Peer reviewed, journal article
2.	Published between 1 January 1985 and 31 December 2025
3.	Article is available in English
4.	Article explicates the wilderness mapping method(s) used
5.	Article states the elements/attributes used to map wilderness and who selected them for inclusion
6.	Article identifies source of data used, whether participatory or expert-based

Appendix B

Table A2. Coded reading list for all selected articles.

Author(s)	Year	Area	Scale	Type of Wilderness	Spatial Resolution (m)	Elements of Wilderness Employed *		Method(s) Employed	Element Identification	Mapping Process	Data Source
Lesslie et al. [45]	1988	Australia	regional	terrestrial	1000	1, 2		WLC	Expert	Expert	Expert
McCloskey, & Spalding [61]	1989	Global	global	terrestrial	not provided	3		Boolean	Expert	Expert	Expert
Kliskey & Kearsley [20]	1993	New Zealand	regional	terrestrial	not provided	1, 2, 3, 4		Purism	Expert	Expert	Participatory
Kliskey [62]	1994	New Zealand	regional	terrestrial	not provided	1, 2, 3, 4		Purism	Expert	Expert	Participatory
Kliskey [63]	1994	New Zealand	regional	terrestrial	not provided	1, 3, 4, 12		Purism	Expert	Expert	Participatory
Kliskey et al. [64]	1994	New Zealand	regional	terrestrial	not provided	1, 2, 3, 4		Purism	Expert	Expert	Participatory
Kliskey [65]	1995	New Zealand	local	terrestrial	not provided	1, 2, 3, 4		Purism	Expert	Expert	Expert
Kliskey [66]	1998	New Zealand	regional	terrestrial	not provided	1, 2, 3, 4		Purism	Expert	Expert	Participatory
Mendel [3]	2002	Tasmania	regional	terrestrial	not provided	1, 2, 8, 14		Boolean	Expert	Expert	Expert
Carver et al. [12]	2002	United Kingdom	national	terrestrial	1000	1, 2, 9		WLC	Expert	Participatory	Participatory
Beverly et al. [67]	2008	Canada	local	terrestrial	120	No elements-landscape value		HA	Expert	Participatory	Participatory
Flanagan & Anderson [14]	2008	Colorado, USA	local	terrestrial	not provided	1, 2, 3, 4		Purism	Expert	Expert	Participatory
Zhu et al. [41]	2010	Australia	local	terrestrial	500	No elements-landscape value		HA	Expert	Participatory	Participatory
Ólafsdóttir & Runnström [68]	2011	Iceland	national	terrestrial	93	1, 2, 3		WLC	Expert	Expert	Expert
Carver et al. [23]	2013	US—Death Valley	regional	terrestrial	100	2, 3, 4, 10		MCE	Expert	Expert	Expert
Larkin et al. [24]	2014	Adirondacks, US	local	terrestrial	not provided	1, 2, 3, 4, 8, 10, 12, 14, 17		Purism	Expert	Expert	Participatory
Ceaușu et al. [51]	2015	Continental Europe	regional	terrestrial	1000	1, 2, 15, 18		MCE	Expert	Expert	Expert
Müller et al. [16]	2015	Denmark	national	terrestrial	100	ML 2, 9, 1, 6	MCE 2, 9, 1, 6	ML MCE	Expert	Expert	Expert
Watson et al. [69]	2016	Global	global	terrestrial	1000	not provided		HP	Expert	Expert	Expert
Lin et al. [17]	2016	Three Parallel Rivers Region, southwest China	local	terrestrial	30	1, 2, 6, 7, 8, 9		ML	Expert	Expert	Expert
Allan et al. [40]	2017	Global	global	terrestrial	1000	3, 6, 7, 8, 15, 19		HP	Expert	Expert	Expert
Allan et al. [70]	2018	Global	global	terrestrial	1000	3, 6, 7, 8, 15, 19		HP	Expert	Expert	Expert
Ernoult et al. [71]	2018	Southern France	local	terrestrial and marine	500	not provided		HA	Expert	Participatory	Participatory
Jones et al. [46]	2018	global marine areas	global	marine	1000	2, 3, 15, 20, 21, 22		WLC	Expert	Expert	Expert

Table A2. Cont.

Author(s)	Year	Area	Scale	Type of Wilderness	Spatial Resolution (m)	Elements of Wilderness Employed *		Method(s) Employed	Element Identification	Mapping Process	Data Source
Martinuzzi et al. [72]	2018	Argentina, South Yungas	local	terrestrial	100	2, 3, 6, 8, 19		WLC	Expert	Expert	Expert
Tricker & Landres [47]	2018	US Wilderness (select areas)	regional	terrestrial	not provided	10, 2, 3, 4, 23		WLC	Expert	Expert	Expert
Cao et al. [73]	2018	China	national	terrestrial	1000	1, 2		WLC	Expert	Expert	Expert
Cao et al. [15]	2019	China	national	terrestrial	1000	Boolean 1, 2	WLC 1, 2, 6, 7	Boolean WLC	Expert	Expert	Expert
Hou et al. [37]	2019	Beijing, China	local	terrestrial	100	2, 6, 7, 8		MCE	Expert	Expert	Expert
Radford et al. [74]	2019	Switzerland	national	terrestrial	100	1, 2, 3, 9		WLC	Expert	Expert	Expert
Brackhane et al. [75]	2019	Germany	national	terrestrial	not provided	7, 12		MCE	Expert	Expert	Expert
Ma & Long. [43]	2020	China	national	terrestrial	1000	24		Macrodata	Expert	Expert	Expert
Ólafsdóttir & Sæþórsdóttir [76]	2020	Iceland	national	terrestrial	not provided	1, 2, 3, 9		Purism	No elements identified	Participatory	Participatory
Williams et al. [27]	2020	Global	global	terrestrial	1000	3, 6, 7, 8, 15, 19		HP	Expert	Expert	Expert
Zoderer et al. [31]	2020	South Tyrol, Italy	local	terrestrial	25	2, 3, 11, 12,		WLC	Participatory	Expert	Participatory
Dawson et al. [77]	2021	Kobuk Preserve and Gates of the Arctic National Park, US	local	terrestrial	100	2, 3, 4, 10, 23		MCE	Expert	Expert	Expert
Mu et al. [78]	2022	Global	global	terrestrial	1000	3, 6, 7, 8, 15, 19		HP	Expert	Expert	Expert
Perez-Hammerle et al. [13]	2022	Global	global	terrestrial	1000	1, 3, 6, 7, 8, 15, 16, 19, 25		HP	Expert	Expert	Expert
Xu, B et al. [50]	2022	Nujian Prefecture, China	local	terrestrial	30	1, 2		Boolean	Expert	Expert	Expert
Carver et al. [79]	2023	Central Highland, Iceland	regional	terrestrial	not provided	1, 2, 3		MCE	Expert	Expert	Expert
Wang et al. [80]	2023	Lhasa River Basin in the Qinghai- Tibet Plateau of China	local	terrestrial	100	3, 6, 8, 15, 19, 26		HP	Expert	Expert	Expert
Hu et al. [81]	2024	Asiatic ibex range (11 countries): Russia to Pakistan)	regional	terrestrial	200	Boolean 1, 2 8	WLC 1, 2, 3, 6, 7	Boolean WLC	Expert	Expert	Expert
Johnson et al. [26]	2024	Huon Valley, Tasmania, Australia	local	terrestrial	not provided	2		HA	Expert	Participatory	Participatory
Ma & Pan [82]	2024	China	national	terrestrial	not provided	1, 2, 5, 6, 9, 15, 27		ML	Expert	Expert	Expert

Table A2. Cont.

Author(s)	Year	Area	Scale	Type of Wilderness	Spatial Resolution (m)	Elements of Wilderness Employed *		Method(s) Employed	Element Identification	Mapping Process	Data Source
Mudalige & Carver [1]	2024	Sri Lanka	national	terrestrial	250	1, 2, 3		MCE	Expert	Expert	Expert
Strus & Carver [83]	2024	Continental Europe	continental	terrestrial	not provided	1, 2		WLC	Expert	Expert	Expert
Tang et al. [84]	2024	China	national	terrestrial	1000	1, 2, 15, 16		WLC	Expert	Expert	Expert
Wang et al. [2]	2024	Daxing'anling, China	local	terrestrial	1000	Boolean 3	MCE 1, 2, 6, 9	Boolean MCE	Expert	Expert	Expert
Weng et al. [21]	2024	Wuyishan National Park, China	local	terrestrial	not provided	Stakeholder-Based 3, 4, 8, 9, 10, 11, 12, 13, 14	Expert-Based 1, 2, 6, 7	MCE	Expert	Expert	Participatory
Xu, T et al. [85]	2024	China	national	terrestrial	1000	Boolean 2, 6, 8	WLC 1, 2, 6, 7	Boolean WLC	Expert	Expert	Expert
Xu, Z. et al. [38]	2024	Fujian Province, China	regional	terrestrial	30	WLC 1, 2, 6	Boolean 1, 2, 8	Boolean WLC	Expert	Expert	Expert
Zhu et al. [86]	2024	Shandong province, China	regional	terrestrial	1000	1, 2, 6, 7		WLC	Expert	Expert	Expert
Zoderer et al. [87]	2024	European Alps	regional	terrestrial	25	1, 2, 3, 9		WLC	Expert	Expert	Expert
Matej et al. [44]	2025	Global	global	terrestrial	1000	18		HANPP	Expert	Expert	Expert
Ren et al. [88]	2025	Henan Province, China	regional	terrestrial	1000	Boolean 1, 2, 19	MCE 1, 2, 7, 16, 25	Boolean MCE	Expert	Expert	Expert

* Elements by code: 1—Remoteness, 2—Naturalness, 3—Undeveloped, 4—Solitude, 5—Climate suitability, 6—Population/settlement density, 7—Fragmentation, 8—Motorized travel, 9—Terrain, 10—Untrammelled, 11—Wildlife, 12—Size of area, 13—Unexplored, 14—Developed recreation, 15—Artificial light, 16—Biodiversity, 17—Commercial recreation, 18—Primary production, 19—Agricultural, 20—Pollution, 21—Climate change impacts, 22—Fishing/bycatch, 23—Other features of value, 24—Visitation numbers, 25—Ecosystem Services, 26—Grazing density, 27—Land suitability.

Appendix C

Table A3. Elements of wilderness used to define wilderness.

Reclassified Element	Elements Contained (If Multiple)	Total Instances *	Element by Article **
Naturalness	aesthetic naturalness, biophysical naturalness, land use, land type, naturalness	53	40
Remoteness	remoteness from access, remoteness from settlement, travel time, remoteness	52	34
Undeveloped	artificialism, undeveloped	29	29
Population/settlement density	population density, settlement density, population data	21	18
Motorized travel	motorized travel, road/railway presence	16	16
Fragmentation	navigable waterway, road/railway density, fragmentation	14	14
Solitude	solitude, unconfined recreation	12	12
Artificial light		11	11
Terrain	ruggedness, altitude, terrain, impassable	10	9
Agricultural land	pasture lands, agricultural lands, farm	9	9
Size of area	large area, size of area	5	5
Untrammelled	untrammelled, nature can self develop	5	5
Wildlife	wildlife, probability to encounter wildlife, wild animals live, large carnivores live	4	2
Developed recreation	walking trails, huts, maintained campgrounds	3	3
Biodiversity	species richness, biodiversity	3	3
Other features of value		2	2
Primary production		2	2
Commercial recreation		1	1
Ecosystem Services		1	1
Pollution		1	1
Climate change impacts		1	1
Fishing	fishing, bycatch	1	1
Grazing density		1	1
Climate suitability		1	1
Visitation numbers		1	1
Land suitability		1	1
Unexplored		1	1

* Many articles contained multiples of the elements contained within the reclassified elements. Each instance of their usage within papers is identified. ** Condensed to only one instance of the reclassified element. Instances where articles used multiple individual elements contained within the reclassified elements are only counted once.

References

1. Mudalige, U.; Carver, S. Unveiling Sri Lanka's Wilderness: GIS-Based Modelling of Wilderness Attributes. *Land* **2024**, *13*, 402. [\[CrossRef\]](#)
2. Wang, Q.; Fu, A.; Yan, C.; Hou, P.; Luan, X. Spatial Identification and Conservation Gaps of Wilderness Areas in the State-Owned Forest Region of Daxing'anling. *Diversity* **2024**, *16*, 594. [\[CrossRef\]](#)
3. Mendel, L. The consequences for wilderness conservation in the development of the National Park system in Tasmania, Australia. *Aust. Geogr. Stud.* **2002**, *40*, 71–83. [\[CrossRef\]](#)
4. Hawes, M.; Dixon, G. A remoteness-oriented approach to defining, protecting and restoring wilderness. *Parks* **2020**, *26*, 23–36. [\[CrossRef\]](#)
5. Hawes, M.; Dixon, G.; Bell, C. *Refining the Definition of Wilderness—Safeguarding the Experiential and Ecological Values of Remote Natural Land*; Bob Brown Foundation: Hobart, Australia, 2018.
6. Saarinen, J. Wilderness use, conservation and tourism: What do we protect and for and from whom? *Tour. Geogr.* **2016**, *18*, 1–8. [\[CrossRef\]](#)
7. Watson, A.; Matt, R.; Knotek, K.; Williams, D.R.; Yung, L. Traditional Wisdom: Protecting Relationships with Wilderness as a Cultural Landscape. *Ecol. Soc.* **2011**, *16*, 36. [\[CrossRef\]](#)
8. Watson, J.E.M.; Venter, O. Wilderness. *Curr. Biol.* **2021**, *31*, R1169–R1172. [\[CrossRef\]](#) [\[PubMed\]](#)

9. Klein, D.R.; Watson, A.E.; Alessa, L.; Sproull, J. Perspectives on Wilderness in the Arctic. In *Proceedings of the Wilderness in the Circumpolar North: Searching for Compatibility in Ecological, Traditional, and Ecotourism Values*, Anchorage, AK, USA, 15–16 May 2001, *Proceedings RMRS-P-26*; Watson, A.E., Alessa, L., Sproull, J., Eds.; US Department of Agriculture, Forest Service, Rocky Mountain Research Station: Ogden, UT, USA, 2002; Volume 26, pp. 1–6.
10. Kliskey, A. Wilderness perception mapping: Using GIS in wilderness management. *N. Z. Geogr.* **1995**, *51*, 28–34. [[CrossRef](#)]
11. Watson, A.; Matt, R.; Waters, T.; Gunderson, K.; Carver, S.; Davis, B. Mapping tradeoffs in values at risk at the interface between wilderness and non-wilderness lands. In *Proceedings of the Third International Symposium on Fire Economics, Planning, and Policy: Common Problems and Approaches. Gen. Tech. Rep. PSW-GTR-227 (English)*; Gonzalez-Caban, A., Ed.; US Department of Agriculture, Forest Service, Pacific Southwest Research Station: Albany, CA, USA, 2009; pp. 375–387.
12. Carver, S.; Evans, A.; Fritz, S. Wilderness attribute mapping in the United Kingdom. *Int. J. Wilderness* **2002**, *8*, 24–29.
13. Perez-Hammerle, K.-V.; Moon, K.; Venegas-Li, R.; Maxwell, S.; Simmonds, J.S.; Venter, O.; Garnett, S.T.; Possingham, H.P.; Watson, J.E.M. Wilderness forms and their implications for global environmental policy and conservation. *Conserv. Biol.* **2022**, *36*, e13875. [[CrossRef](#)] [[PubMed](#)]
14. Flanagan, T.S.; Anderson, S. Mapping perceived wilderness to support protected areas management in the San Juan National Forest, Colorado. *For. Ecol. Manag.* **2008**, *256*, 1039–1048. [[CrossRef](#)]
15. Cao, Y.; Carver, S.; Yang, R. Mapping wilderness in China: Comparing and integrating Boolean and WLC approaches. *Landsc. Urban Plan.* **2019**, *192*, 103636. [[CrossRef](#)]
16. Mueller, A.; Bocher, P.K.; Svenning, J.-C. Where are the wilder parts of anthropogenic landscapes? A mapping case study for Denmark. *Landsc. Urban Plan.* **2015**, *144*, 90–102. [[CrossRef](#)]
17. Lin, S.; Wu, R.; Hua, C.; Ma, J.; Wang, W.; Yang, F.; Wang, J. Identifying local-scale wilderness for on-ground conservation actions within a global biodiversity hotspot OPEN. *Sci. Rep.* **2016**, *6*, 25898. [[CrossRef](#)] [[PubMed](#)]
18. Cao, Y.; Wang, F.; Tseng, T.-H.; Carver, S.; Chen, X.; Zhao, J.; Yu, L.; Li, F.; Zhao, Z.; Yang, R. Identifying ecosystem service value and potential loss of wilderness areas in China to support post-2020 global biodiversity conservation. *Sci. Total Environ.* **2022**, *846*, 157348. [[CrossRef](#)] [[PubMed](#)]
19. Aplet, G.; Thomson, J.; Wilbert, M. Indicators of wildness: Using attributes of the land to assess the context of wilderness. In *Wilderness Science in a Time of Change*; USDA Forest Service Rocky Mountain Research Station, RMRS-P-15-VOL-2: Missoula, MT, USA, 2000; pp. 89–98.
20. Kliskey, A.D.; Kearsley, G.W. Mapping multiple perceptions of wilderness in southern New Zealand. *Appl. Geogr.* **1993**, *13*, 203–223. [[CrossRef](#)]
21. Weng, A.; Liao, L.; Cao, Y.; Carver, S.; Lin, L.; Shen, S.; Xu, Z.; Dong, J.; Lan, S.; Yang, R. Different people, different wild: Comparing and mapping wilderness representation in Wuyishan National Park, China. *Geogr. Sustain.* **2024**, *5*, 144–156. [[CrossRef](#)]
22. Lutz, A.R.; Simpson-Housley, P.; Deman, A.F. Wilderness: Rural and Urban Attitudes and Perceptions. *Environ. Behav.* **1999**, *31*, 259–266. [[CrossRef](#)]
23. Carver, S.; Tricker, J.; Landres, P. Keeping it wild: Mapping wilderness character in the United States. *J. Environ. Manag.* **2013**, *131*, 239–255. [[CrossRef](#)] [[PubMed](#)]
24. Larkin, A.M.; Beier, C.M. Wilderness perceptions versus management reality in the Adirondack Park, USA. *Landsc. Urban Plan.* **2014**, *130*, 1–13. [[CrossRef](#)]
25. Mackey, B.; Lesslie, R.G.; Lindenmayer, D.; Nix, H.A. Wilderness and its place in nature conservation in Australia. *Pac. Conserv. Biol.* **1998**, *4*, 182–185. [[CrossRef](#)]
26. Johnson, M.S.; Adams, V.M.; Byrne, J. Enhancing climate adaptation: Integrating place-based risk perceptions and coastalscape values using Q plus PPGIS. *Landsc. Urban Plan.* **2024**, *252*, 105197. [[CrossRef](#)]
27. Williams, D.R.; Watson, A.E. Wilderness values: Perspectives from non-economic social science. In *Science and Stewardship to Protect and Sustain Wilderness Values; Eighth World Wilderness Congress Symposium: Fort Collins, CO, USA, 30 September–6 October 2005*; Watson, A., Sproull, J., Dean, L., Eds.; US Department of Agriculture, Forest Service, Rocky Mountain Research Station: Ogden, UT, USA, 2007; pp. 123–133.
28. Ye, J.; Xiao, C.; Feng, Z.; Qiao, T. A review of global wilderness area identification since the 21st century. *J. Environ. Manag.* **2024**, *358*, 120946. [[CrossRef](#)] [[PubMed](#)]
29. Watson, A.; Alessa, L.; Glaspell, B. The Relationship between Traditional Ecological Knowledge, Evolving Cultures, and Wilderness Protection in the Circumpolar North. *Conserv. Ecol.* **2003**, *8*, 2. [[CrossRef](#)]
30. Williams, D. The social construction of Arctic wilderness: Place meanings, value pluralism, and globalization. In *Proceedings of the Wilderness in the Circumpolar North: Searching for Compatibility in Ecological, Traditional, and Ecotourism Values*, Anchorage, AK, USA, 15–16 May 2001, *Proceedings RMRS-P-26*; Watson, A.E., Alessa, L., Sproull, J., Eds.; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: Ogden, UT, USA, 2002; pp. 120–132.

31. Zoderer, B.M.; Carver, S.; Tappeiner, U.; Tasser, E. Ordering ‘wilderness’: Variations in public representations of wilderness and their spatial distributions. *Landsc. Urban Plan.* **2020**, *202*, 103875. [\[CrossRef\]](#)
32. IUCN. Protected Areas: Management Guidelines. 2016. Available online: <https://www.iucn.org/news/protected-areas/201612/wilderness-protected-areas-management-guidelines> (accessed on 17 February 2026).
33. Lesslie, R.G.; Taylor, S.G. The wilderness continuum concept and its implications for Australian wilderness preservation policy. *Biol. Conserv.* **1985**, *32*, 309–333. [\[CrossRef\]](#)
34. Pickering, C.; Grignon, J.; Steven, R.; Guitart, D.; Byrne, J. Publishing not perishing: How research students transition from novice to knowledgeable using systematic quantitative literature reviews. *Stud. High. Educ.* **2015**, *40*, 1756–1769. [\[CrossRef\]](#)
35. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, 71. [\[CrossRef\]](#)
36. Zhu, J.; Liu, W. A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics* **2020**, *123*, 321–335. [\[CrossRef\]](#)
37. Hou, W.; Zhai, L.; Qiao, Q.; Walz, U. Monitoring the intensity of human impacts on anthropogenic landscape: A mapping case study in Beijing, China. *Ecol. Indic.* **2019**, *102*, 382–393. [\[CrossRef\]](#)
38. Xu, Z.; Liao, L.; Hou, S.; Gan, Q.; Shen, S.; Cao, Y.; Lan, S. Modeling multi-scale relationships between wilderness area changes and potential drivers: Evidence from the southeast coastal area of China. *J. Nat. Conserv.* **2024**, *78*, 126583. [\[CrossRef\]](#)
39. Venter, O.; Sanderson, E.W.; Magrach, A.; Allan, J.R.; Beher, J.; Jones, K.R.; Possingham, H.P.; Lurance, W.F.; Wood, P.; Fekete, B.M.; et al. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nat. Commun.* **2016**, *7*, 12558. [\[CrossRef\]](#) [\[PubMed\]](#)
40. Allan, J.R.; Venter, O.; Watson, J.E.M. Temporally inter-comparable maps of terrestrial wilderness and the Last of the Wild. *Sci. Data* **2017**, *4*, 170187. [\[CrossRef\]](#) [\[PubMed\]](#)
41. Zhu, X.; Pfueller, S.; Whitelaw, P.; Winter, C. Spatial Differentiation of Landscape Values in the Murray River Region of Victoria, Australia. *Environ. Manag.* **2010**, *45*, 896–911. [\[CrossRef\]](#) [\[PubMed\]](#)
42. Maxwell, A.E.; Warner, T.A.; Fang, F. Implementation of machine-learning classification in remote sensing: An applied review. *Int. J. Remote Sens.* **2018**, *39*, 2784–2817. [\[CrossRef\]](#)
43. Ma, S.; Long, Y. Mapping Potential Wilderness in China with Location-based Services Data. *Appl. Spat. Anal. Policy* **2020**, *13*, 69–89. [\[CrossRef\]](#)
44. Matej, S.; Weidinger, F.; Kaufmann, L.; Roux, N.; Gingrich, S.; Haberl, H.; Krausmann, F.; Erb, K.-H. A global land-use data cube 1992–2020 based on the Human Appropriation of Net Primary Production. *Sci. Data* **2025**, *12*, 511. [\[CrossRef\]](#) [\[PubMed\]](#)
45. Lesslie, R.G.; Mackey, B.G.; Preece, K.M. A Computer-based Method of Wilderness Evaluation. *Environ. Conserv.* **1988**, *15*, 225–232. [\[CrossRef\]](#)
46. Jones, K.R.; Klein, C.J.; Halpern, B.S.; Venter, O.; Grantham, H.; Kuempel, C.D.; Shumway, N.; Friedlander, A.M.; Possingham, H.P.; Watson, J.E.M. The Location and Protection Status of Earth’s Diminishing Marine Wilderness. *Curr. Biol.* **2018**, *28*, 2506–2512. [\[CrossRef\]](#) [\[PubMed\]](#)
47. Tricker, J.; Landres, P. Mapping threats to wilderness character in the National Wilderness Preservation System. *Biol. Conserv.* **2018**, *227*, 243–251. [\[CrossRef\]](#)
48. Tricker, J.; Schwaller, A.; Hanson, T.; Mejicano, E.; Landres, P. Mapping wilderness character in the boundary waters canoe area wilderness. *USDA For. Serv.-Gen. Tech. Rep. RMRS-GTR* **2017**, *2017*, 1–81.
49. Landres, P.; Barns, C.; Boutcher, S.; Devine, T.; Dratch, P.; Lindholm, A.; Merigliano, L.; Roeper, N.; Simpson, E.; U.S. Department of Agriculture; et al. *Keeping It Wild 2: An Updated Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System*; U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: Ogden, UT, USA, 2015. [\[CrossRef\]](#)
50. Xu, B.; Zhang, Y.; Lin, W. A connectivity modeling and evaluating methodological framework in biodiversity hotspots based on naturalness and linking wilderness. *Conserv. Sci. Pract.* **2022**, *4*, 12750. [\[CrossRef\]](#)
51. Ceausu, S.; Hofmann, M.; Navarro, L.M.; Carver, S.; Verburg, P.H.; Pereira, H.M. Mapping opportunities and challenges for rewilding in Europe. *Conserv. Biol.* **2015**, *29*, 1017–1027. [\[CrossRef\]](#)
52. Gladden, J.N. Arctic Wilderness Policy in the United States and Finland. *Environ. Manag.* **2001**, *27*, 367–376. [\[CrossRef\]](#) [\[PubMed\]](#)
53. Fletcher, M.S.; Hamilton, R.; Dressler, W.; Palmer, L. Indigenous knowledge and the shackles of wilderness. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2022218118. [\[CrossRef\]](#) [\[PubMed\]](#)
54. Watson, A. Human Relationships with Wilderness The Fundamental Definition of Wilderness Character. *Int. J. Wildern* **2004**, *10*, 4–7.
55. Barr, B.W.; Kliskey, A.D. Perceptions of wilderness and their application to ocean and coastal waters. *Ocean Coast. Manag.* **2014**, *96*, 1–11. [\[CrossRef\]](#)
56. Kormos, C.F. *A Handbook on International Wilderness Law and Policy*; Fulcrum Pub.: Golden, CO, USA, 2008.
57. Dominguez, L.; Luoma, C. Decolonising Conservation Policy: How Colonial Land and Conservation Ideologies Persist and Perpetuate Indigenous Injustices at the Expense of the Environment. *Land* **2020**, *9*, 65. [\[CrossRef\]](#)

58. Cole, D. Beyond Naturalness Adapting Wilderness Stewardship to an Era of Rapid Global Change. *Int. J. Wilderness* **2012**, *18*, 9–14. [[CrossRef](#)]
59. Leopold, A. Wilderness as a form of land use. *J. Land Pub. Util. Econ.* **1925**, *1*, 398. [[CrossRef](#)]
60. Bocharnikov, V. Spatial thinking, cultural geography and wilderness. *Izv. Ross. Akad. Nauk. Seriya Geogr.* **2018**, *3*, 105–116. [[CrossRef](#)]
61. McCloskey, J.M.; Heather, S. A Reconnaissance-Level Inventory of the Amount of Wilderness Remaining in the World. *Ambio* **1989**, *18*, 221–227.
62. Kliskey, A.D. A Comparative Analysis of Approaches to Wilderness Perception Mapping. *J. Environ. Manag.* **1994**, *41*, 199–236. [[CrossRef](#)]
63. Kliskey, A.D. Mapping multiple perceptions of wilderness in southern New Zealand, II: An alternative multivariate approach. *Appl. Geogr.* **1994**, *14*, 308–326. [[CrossRef](#)]
64. Kliskey, A.D.; Hoogsteden, C.C.; Morgan, R.K. The application of spatial-perceptual wilderness mapping to protected areas management in New Zealand. *J. Environ. Plan. Manag.* **1994**, *37*, 431–445. [[CrossRef](#)]
65. Kliskey, A.D. Wilderness Perception Mapping. *N. Z. Geogr.* **1995**, *51*, 28–34. [[CrossRef](#)]
66. Kliskey, A.D. Linking the Wilderness Perception Mapping Concept to the Recreation Opportunity Spectrum. *Environ. Manag.* **1998**, *22*, 79–88. [[CrossRef](#)] [[PubMed](#)]
67. Beverly, J.L.; Uto, K.; Wilkes, J.; Bothwell, P. Assessing spatial attributes of forest landscape values: An internet-based participatory mapping approach. *Can. J. For. Res.* **2008**, *38*, 289–303. [[CrossRef](#)]
68. Ólafsdóttir, R.; Runnström, M.C. How Wild is Iceland? Wilderness Quality with Respect to Nature-based Tourism. *Tour. Geogr.* **2011**, *13*, 280–298. [[CrossRef](#)]
69. Watson, J.E.M.; Shanahan, D.F.; Di Marco, M.; Allan, J.; Laurance, W.F.; Sanderson, E.W.; Mackey, B.; Venter, O. Catastrophic Declines in Wilderness Areas Undermine Global Environment Targets. *Curr. Biol.* **2016**, *26*, 2929–2934. [[CrossRef](#)] [[PubMed](#)]
70. Allan, J.R.; Kormos, C.; Jaeger, T.; Venter, O.; Bertzky, B.; Shi, Y.; Mackey, B.; van Merm, R.; Osipova, E.; Watson, J.E.M. Gaps and opportunities for the World Heritage Convention to contribute to global wilderness conservation. *Conserv. Biol.* **2018**, *32*, 116–126. [[CrossRef](#)] [[PubMed](#)]
71. Ernoul, L.; Wardell-Johnson, A.; Willm, L.; Béchet, A.; Boutron, O.; Mathevet, R.; Arnassant, S.; Sandoz, A. Participatory mapping: Exploring landscape values associated with an iconic species. *Appl. Geogr.* **2018**, *95*, 71–78. [[CrossRef](#)]
72. Martinuzzi, S.; Rivera, L.; Politi, N.; Bateman, B.L.; De Los Llanos, E.R.; Lizarraga, L.; De Bustos, M.S.; Chalukian, S.; Pidgeon, A.M.; Radeloff, V.C. Enhancing biodiversity conservation in existing land-use plans with widely available datasets and spatial analysis techniques. *Environ. Conserv.* **2018**, *45*, 252–260.
73. Cao, Y.; Yang, R.; Long, Y.; Carver, S. A Preliminary Study on Mapping Wilderness in Mainland China. *Int. J. Wilderness* **2018**, *24*.
74. Radford, S.L.; Senn, J.; Kienast, F. Indicator-based assessment of wilderness quality in mountain landscapes. *Ecol. Indic.* **2019**, *97*, 438–446. [[CrossRef](#)]
75. Brackhane, S.; Schoof, N.; Reif, A.; Schmitt, C.B. A new wilderness for Central Europe?—The potential for large strictly protected forest reserves in Germany. *Biol. Conserv.* **2019**, *237*, 373–382. [[CrossRef](#)]
76. Ólafsdóttir, R.; Sæþórsdóttir, A.D. Public Perception of Wilderness in Iceland. *Land* **2020**, *9*, 99. [[CrossRef](#)]
77. Dawson, N.G.; Tricker, J.; Landres, P. Evaluating Potential Impacts of Proposed Industrial Access Road Routes on Wilderness Character in Gates of the Arctic National Park and Preserve, Alaska. *Arctic* **2021**, *74*, 469–481.
78. Mu, H.; Li, X.; Wen, Y.; Huang, J.; Du, P.; Su, W.; Miao, S.; Geng, M. A global record of annual terrestrial Human Footprint dataset from 2000 to 2018. *Sci. Data* **2022**, *9*, 176. [[CrossRef](#)] [[PubMed](#)]
79. Carver, S.; Konráðsdóttir, S.; Guðmundsson, S.; Carver, B.; Kenyon, O. New Approaches to Modelling Wilderness Quality in Iceland. *Land* **2023**, *12*, 446. [[CrossRef](#)]
80. Wang, L.; Fu, J.; Ji, X.; Tan, P.; Li, Y. Spatio-temporal variation and conservation priorities of wilderness in Lhasa River Basin, Tibetan Plateau. *Front. Ecol. Evol.* **2023**, *11*, 1254540. [[CrossRef](#)]
81. Hu, F.; Wanghe, K.; Guo, X.; Ahmad, S.; Fu, A.; Deng, M.; Lin, S.; Luan, X. Wilderness networks contributed the efforts of existing protected area networks: The cost-effective comparison among multiple conservation scenarios. *Glob. Ecol. Conserv.* **2024**, *54*, e03102. [[CrossRef](#)]
82. Ma, L.; Pan, J. Spatial identification and priority *Conserv.* areas determination of wilderness in China. *J. Clean. Prod.* **2024**, *451*, 142069. [[CrossRef](#)]
83. Strus, I.; Carver, S. Developing a Wilderness Quality Index for Continental Europe. *Land* **2024**, *13*, 428. [[CrossRef](#)]
84. Tang, X.; Chen, J.; Wen, N.; Chen, Y.; Meng, W.; Xu, W.; Li, H. Spatiotemporal evolution and influencing factors analysis of wilderness in China. *Environ. Impact Assess. Rev.* **2024**, *106*, 107513. [[CrossRef](#)]
85. Xu, T.; Chen, R.; Carver, S.; Wu, J. Mapping potential conflicts between wilderness travel and ecological values on a national scale. *Landsc. Urban Plan.* **2024**, *246*, 105029. [[CrossRef](#)]

86. Zhu, R.; Liu, W.; Xue, R.; Teng, S.; Wang, Y.; Pan, Y.; Gao, W. Linking wilderness mapping and ecosystem services: Identifying integrated wilderness and ecological indicators to quantify ecosystem services of wilderness. *Ecol. Indic.* **2024**, *160*, 111915. [[CrossRef](#)]
87. Zoderer, B.M.; Marsoner, T.; Tasser, E. Protecting wilderness or rewilding? An ecoregion-based approach to identifying priority areas for the protection and restoration of natural processes for biodiversity conservation. *J. Nat. Conserv.* **2024**, *81*, 126661. [[CrossRef](#)]
88. Ren, Y.; Wang, S.; Cui, B.; Ding, Y.; Cao, R. Research on wilderness area identification and distribution of spatial characteristics based on Boolean-multi-indicator evaluation approach—A case study of wilderness areas in Henan Province, China. *Front. Environ. Sci.* **2025**, *13*, 1650454. [[CrossRef](#)]

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