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Authors: Bertram, Dominik, Lambracht, Markus, and Chilla, Tobias

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Settlement Systems in Mountain Regions: A Research Gap?

Dominik Bertram*, *Markus Lambracht**, and *Tobias Chilla

** Corresponding author: markus.lambracht@fau.de*

Friedrich-Alexander-Universität Erlangen-Nürnberg, Institut für Geographie, Wetterkreuz 15, 91058 Erlangen, Germany

Cities and their networks play a significant role in spatial development. This holds true for settlement systems in general, and there is no reason that this should differ in mountain contexts. However, research on this subject is scarce, and it remains a relatively niche topic. Against this background, our article presents a scoping review of settlement systems in mountain regions, reflecting on thematic foci, temporal developments, and regional differences in the global scientific debate. The results show that the scientific discourse has been a rather Eurocentric debate of modest intensity for several decades. The discussion has become more intense in the past decade because of a substantial number of contributions on Asia. Our findings suggest that the current academic debate does not fully address the potential of settlement systems for sustainable spatial development in mountain areas. Recent articles have been predominantly based on improved data availability and methodological innovation, often in the form of case studies. We conclude that a significant research gap exists in terms of comparative perspectives on settlement systems in mountain regions.

Keywords: *mountain research; scoping review; urbanization; montology; research agenda; mountain geographies.*

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Introduction

Mountains are a specific geographical context for spatial development. Topography strongly influences spatial structures, and the limited accessibility and availability of settlement areas can challenge socioeconomic development in mountain regions (Dematteis 2018; Lambracht 2024). Additionally, environmental vulnerability and the likelihood of disasters tend to be higher in these regions than in lowland areas (Price et al 2022). In particular, cities in mountain areas face increasing pressure to adapt to the accelerating impacts of climate change (Adler et al 2022). Thus, mountain areas demonstrate a growing need for sustainable spatial development from both environmental and socioeconomic perspectives, requiring integrated approaches to ensure equitable access to services of general interest and ecological corridors (Price et al 2022; Bertram, Chilla, and Hippe 2023). Building on these potentials, spatial development in mountain areas has to balance various sectoral settings with the demands of sustainable development (Kohler et al 2015).

In this context, settlement systems are crucial, particularly in terms of socioeconomic dynamics and providing essential services (Dodman et al 2022). At the same time, research on settlement systems, such as those in the European Alps, is limited (Chilla et al 2022). This observation is in line with the main findings of an Intergovernmental Panel on Climate Change (IPCC) study, which highlighted that knowledge on climate change adaptation in mountain settlement systems worldwide remains sparse (Adler et al 2022). Indeed, Scopus searches show a much higher volume of works with keyword combinations containing disaster, climate change, biodiversity, and mountains compared to those featuring settlement systems and urbanization.

In this article, we systematically reflect on this issue by examining the extent to which settlement systems are discussed in the scientific debates of global mountain studies. We hypothesized that settlement systems are underrepresented in the academic discourse. To verify and qualify the research gap, we conducted a scoping review that distinguished between geographical and thematic foci to identify thematic priorities, temporal developments, and geographical patterns. We reflect our results with regard to a research gap and unused potential for sustainable spatial development in mountain regions.

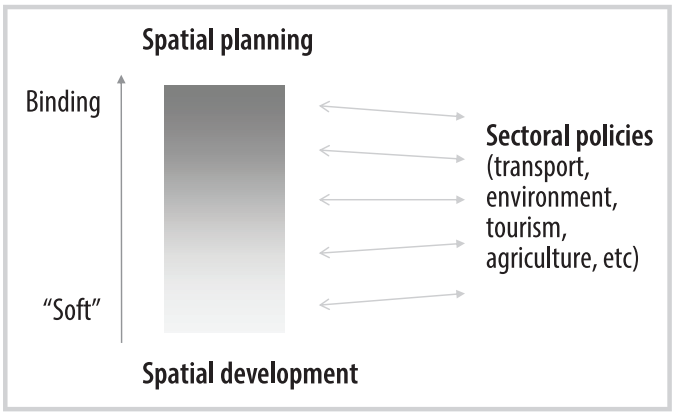
State of the art

The link between spatial development and settlement systems

Spatial development and spatial planning coordinate sectoral policies and dynamics from a territorial perspective and, conversely, are strongly influenced by sectoral dynamics (Figure 1). Although *spatial planning* is primarily the domain of local and regional governments and contains a significant amount of formal and legally binding elements, *spatial development* tends to be less binding and "softer." Funding programs, strategic plans, and governance processes are relevant. Spatial planning—in a formal, juridical, and technical sense—is mostly organized through national mandates.

In this context, settlement systems are defined by interactions between a set of local units (villages, towns, or cities; Bura et al 1996). They play a significant role in shaping socioeconomic and environmental dynamics, as well as in structuring space. Cities and towns are densely

FIGURE 1 The links between spatial planning, spatial development, and sectoral policies.



populated areas where residents, businesses, transportation, and services are concentrated. In mountain studies, the debate on urban dynamics dates back to the 1970s, with case studies focusing on individual cities and their urbanization processes (Borsdorf 1978).

Urban networks present both challenges and opportunities for spatial development (Harbiankova and Scherbina 2021). For instance, specific challenges arise when urban structures are organized in ways that threaten environmental quality (McDonnell and Hahs 2008). Moreover, high social inequalities and polarized economies further threaten sustainable spatial development. Effective organization of urban functions holds the potential to ensure efficiency, for example, via spatial concentration of socioeconomic activities. The links between local units can lead to improved overall functioning in economic, social, and environmental terms. Such potential is particularly high when polycentric spatial patterns come into play. Research on so-called morphological (focusing on nodal characteristics) and functional (focusing on the relationships between centers) urban networks reveals opportunities for polycentric spatial structures (Meijers 2008; Burger et al 2014). Conceptual arguments and frameworks, such as the concept of "borrowing size" (Meijers and Burger 2017), the method of calculating "population catchment intensities" (Bertram and Chilla 2023), and multiagent and evolutionary analysis (Bura et al 1996; Pumain 2000), are strands of research that have been used to investigate and discuss the roles of local units within settlement systems. Prominent arguments have flourished regarding the prospects of efficient transport systems, the balanced integration of regional and global economies, and equitable access to services of general interest (Chilla and Streifeneder 2018; Möck and Küpper 2020). In this regard, the theory of central places remains the most relevant conceptual framework for research on settlement systems (Christaller 1933). Existing work on the European Alps underlines the relevance of polycentric spatial development and a mountain-specific scale for settlement systems (Dematteis 2009; Vaz and Matos 2015; Liu et al 2019; Bertram, Chilla, and Lambracht 2023). Studies in this vein have illustrated that settlement systems capture mountain specificities such as the functional relevance of small settlements, efficient spatial organization along valley axes, and cross-border dimensions.

Sustainable spatial development in mountain settlement systems

The concept of sustainability emphasizes the need for a long-term perspective that prioritizes the wellbeing and concerns of future generations. Moreover, it often highlights the need to balance environmental considerations with socioeconomic concerns (Bibri et al 2020). Accordingly, sustainable development is of paradigmatic importance in mountain contexts (Hock et al 2019).

Spatial development aims to balance different and often conflicting needs and interests. It has to manage various sectoral concerns in mountain areas, such as tourism, biodiversity, and transport infrastructure (Tischler and Mailer 2014: 149). Topographic challenges, low population density, and (in most cases) multiple national borders further complicate spatial development in such contexts. Thus, policy frameworks have to support spatial development processes throughout the multilevel system from the global to the local level. Examples include sustainable mountain development as an objective of the Sustainable Development Goals, transnational policy frameworks like the Alpine Convention in the European Alps or the International Centre for Integrated Mountain Development in the Hindu Kush Himalaya (HKH) region, and thematic working groups such as the Working Group on Spatial Planning and Sustainable Development of the Alpine Convention.

From a scientific perspective, research on mountain settlement systems has primarily focused on 4 particular fields. First, many studies have dealt with ecological issues. In terms of spatial development, research on green infrastructure and biodiversity has been especially widespread. Topics such as environmental impact assessments in settlement systems (Peng et al 2016), ecological connectivity and resilience (Job et al 2022; Wang et al 2023), and disaster risk reduction (Poudel et al 2023) are highly relevant.

Second, research on settlement systems in mountain regions has paid close attention to socioeconomic development. In this vein, topics have ranged from demographic development and migration to transportation and mobility patterns (Bätzing et al 1996; Perlik and Messerli 2004; Chilla and Heugel 2022; Öncü et al 2023).

The third area encompasses urbanization dynamics in general and includes studies on urban sprawl in valleys (eg Romero and Ordenes 2004), rural–urban linkages (Haller and Branca 2023), and peri-urbanization and suburbanization processes in mountain regions (Brighenti 2013).

Finally, several publications have foregrounded spatial development and planning, particularly the topics of centrality and functions (Perlik et al 2001; Torricelli 2001; Dematteis 2009; Bole et al 2016; Ortman et al 2016; Bertram and Chilla 2023). A certain dominance is also seen within this domain of addressing spatial monitoring and methods illustrating urbanization processes and environmental challenges—mostly by remote sensing analysis in case studies (Li et al 2022; Wang et al 2022; Ziwei et al 2022). In

TABLE 1 Search terms used for the IPCC mountain groups. (The asterisk, *, is attached to the stem of a word. It finds any word that contains the stem or the letters preceding the asterisk.)

IPCC global mountain classification (Hock et al 2019)	Boolean operators for publication searches "*settlement system**" *AND "X"* and *urbanisation OR urbanization AND "X"*
Rocky Mountains	Rocky Mountain*, Rocky Mountain* region*, Rocky Mountain area, Rocky Mountain range, Alaska Mountains, Alaska Mountain range, Alaska Mountain chain, Alaska range, Alaska chain
Andes	Andes, Andes region, Andean region, Andes Mountain*, Andean area, Andes area, Andes Mountain range, Andean Mountain*, Andean Mountain range, Andes range, Andean range, Andes Mountain chain, Andean Mountain chain, Andes Mountain belt, Andean Mountain belt
Scandinavian Mountains	Scandinavian Mountain*, Scandinavian Mountain range, Scandinavian Mountain area, Scandinavian Mountain chain, Scandens Mountains, Scandens mountain range, Scandens, Scandens region, Scandens range, Scandinavian range, Scandens mountain chain
European Alps	European Alps, Alps, Alpine region, Alpine Mountain*, European Alpine region, European Alpine range
Caucasus	Caucasus, Caucasus Mountain*, Caucasus region*, Caucasus area, Caucasus countries, Caucasia, Caucasus range, Caucasus Mountain belt
Pontic Mountains	Pontic Mountain*, Pontic region, Pontic Alps, Pontic Mountain range
East African Mountains	East African Mountain*, mountainous east Africa, Eastern rift mountains
High Mountain Asia	High Mountain Asia, High Mountain Asia region, Himalaya, Himalaya* region, Himalaya* Mountain*, Himalayan Mountain range, Himalayan Mountain belt, HKH, HKH region, HKH mountain*, HKH mountain range (also with HKH as Hindu Kush Himalaya)
Southern Alps	Southern Alps, Southern Alps New Zealand, Southern Alps of New Zealand, Southern Alps region, Southern Alps Mountain range, New Zealand Alps, New Zealand Alpine region

terms of sectoral challenges in the field of spatial development and planning, the topic of water management has been a relevant research strand (Jerves-Cobo et al 2020; Singh et al 2020).

By conducting a scoping review, our aim was to examine the extent to which mountain settlement systems have been discussed in the global debates on sustainable spatial development in a comprehensive and systematic manner.

Methods: a scoping review

Scoping reviews serve to quantify and qualify the research output on a given topic. They also help to identify knowledge gaps, set research agendas, and determine potential avenues for decision-making (Tricco et al 2016). As such, the review requires transparent, systematic, and replicable methods to ensure trustworthy results (Grant and Booth 2009; Munn et al 2018; Sutton et al 2023). The main steps include defining the subject and developing the search strategy, selecting studies based on predefined inclusion criteria, extracting data, and then collating, summarizing, and reporting the results (Peters et al 2015; Casali et al 2022). Although presented as a series of stages, the process does not have to be linear; instead, it is typically iterative.

Definitions and search strategies

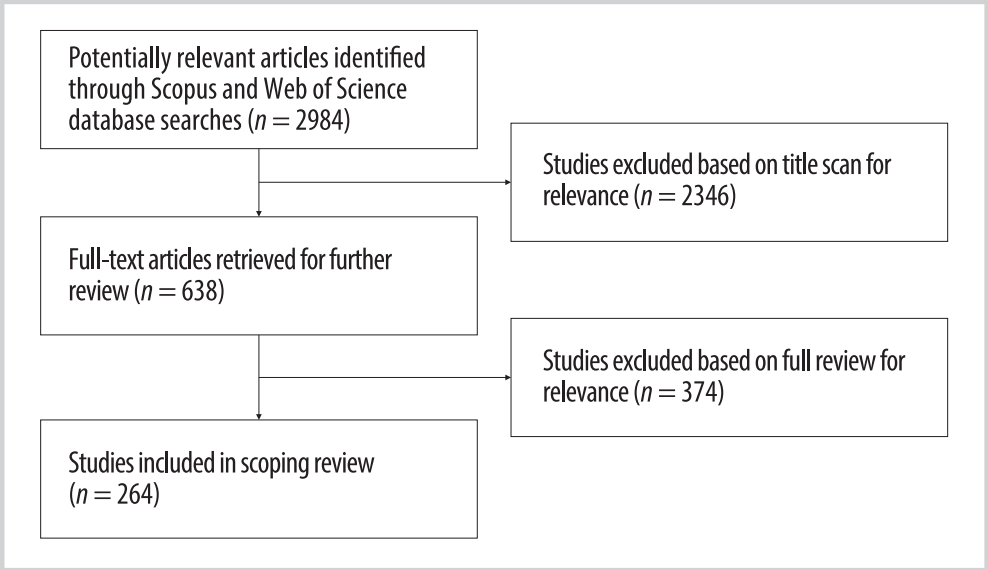
Our scoping review was based on Scopus and Web of Science (WoS). Scopus is the abstract and citation database of the Elsevier publishing company and is one of the largest such databases in the world (Singh et al 2021; Gurgiser et al 2022). WoS is one of the oldest and most widely used scientific online citation and literature databases and is hosted by Clarivate. Both focus on peer-reviewed articles in listed journals. According to Gusenbauer and Haddaway (2020), using Scopus and WoS ensures the reproducibility of results and, therefore, constitutes a sufficiently scientific approach. Relying on these databases means excluding nonacademic studies (such as government or nongovernmental publications) that may be relevant, especially for regional case studies. However, the strength of this approach is its systematic coverage of scientific publications that have undergone quality assurance processes and have international visibility.

The data query was carried out in January 2024. We chose the "all-time" timeframe and did not focus on any particular language, though the search terms were in English. The search was based on Boolean operators and performed within the "article title," "abstract," and "keywords" sections. The applied queries were then divided into 2 search approaches. First, the more general search terms "*settlement system**" *AND mountain** and *urbanisation OR urbanization AND mountain** resulted in 2584 matches. After extracting double matches, we identified 2553 potentially relevant articles.

Second, to get a regional specification, the terms of the official IPCC global mountain classification and possible synonyms were combined with the previous search terms: "*settlement system**" *AND* "*X*" and *urbanisation OR urbanization AND* "*X*," where "*X*" stands for the previous search terms (Table 1). The search resulted in 1201 hits. After removing double matches, a total of 756 potentially relevant articles were identified.

In total, our search resulted in a database with 3309 records. After excluding the double matches across the two searches, we finally identified 2984 articles as potentially relevant.

FIGURE 2 Scoping review process of the study selection.



The Scopus/WoS-based approach ensures institutionalized quality control, resulting in a comprehensive coverage of the scientific discourse. However, the approach also has some limitations. First, some applied and regional publications without peer review, project results, nonreviewed books, and other nonreviewed content are not covered, even though they would fit perfectly in terms of thematic coverage. Second, it is possible that some mountain regions may not be identified during the search process, especially if other words were used in the title, abstract, or keywords. Nevertheless, the overall strength of this methodology lies in its comprehensive coverage of scientific publications that are subject to peer-review quality assurance procedures.

Article selection process

The resulting body of potentially relevant publications had to be filtered in a standardized selection process. First, the thematic focus of the publication had to be settlement systems in mountain regions. Studies with a different focus (eg individual city case studies, intraurban processes, or articles with no spatial perspective) were excluded. Second, the spatial focus of the study had to be mountain regions according to the IPCC definition of high mountain regions (Hock et al 2019). Accordingly, case studies on contexts with relatively low elevation and less steep relief were excluded. Figure 2 provides an overview of the process.

The studies were screened for relevance by title scanning ("include," "exclude," or "maybe"). This was carried out independently by 4 reviewers (2346 articles were excluded). After double-checking, there were minimal discrepancies between the individual selection results. In cases where discrepancies did arise, the abstract was retrieved to resolve the incompatibility.

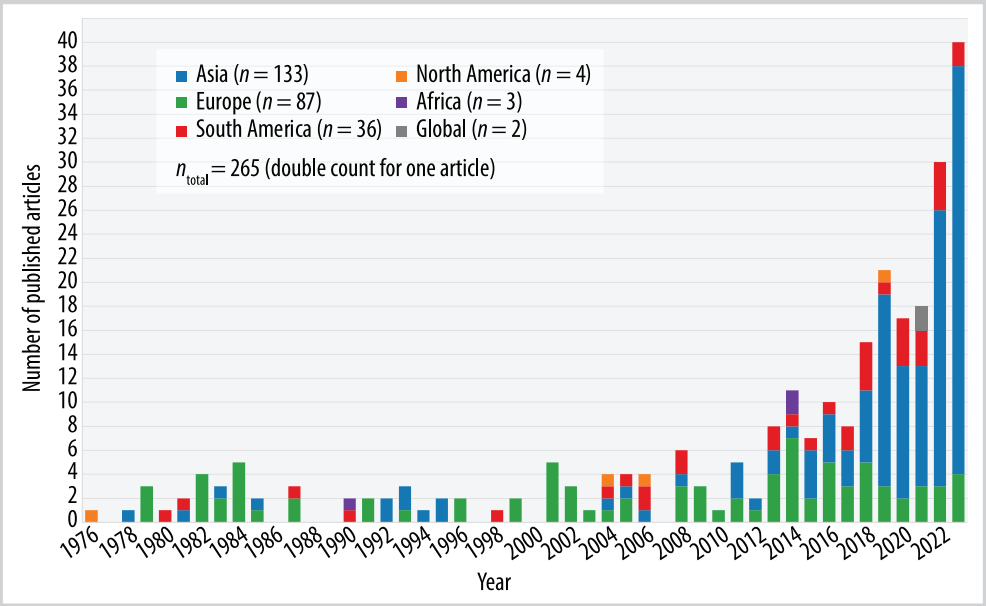
This process resulted in 638 articles being included in the subsequent full-text review. In this step, the full texts were screened, and relevance was categorized as before. This was carried out independently by 2 reviewers. Here the interrater reliability was high. Individual inconsistencies between "maybe" and "include" were discussed and resolved by jointly scanning the full text. In this step, an additional 374 studies were excluded. In total, 264 studies are finally included in the scoping review.

Data extraction and coding

Overall, we extracted the year of publication and geographical affiliation (the continent of the mountain region being analyzed). For the thematic analysis, we used a standard coding template to assign the information from each article. Thus, we developed qualitative codes to capture the focus of each article in an inductive manner (Mayring and Fenzl 2019). Here again, 2 reviewers were involved in quality assurance, and they independently extracted the data for all articles ($n_{total} = 264$). The publications were assigned to the following codes (multiple entries were possible):

- *Archaeological settlement patterns* included publications focusing on ancient settlement structures, particularly those of earlier advanced civilizations, as well as former trade route networks.
- *Centrality and functions* encompassed spatial organization and functional links between local units (eg relevance beyond size, commuting zones, and polycentric urban networks).
- *Demographic development and migration patterns* focused on issues such as patterns of residential growth and shrinkage, depopulation processes, or rural–urban migration.
- *Economic development* included publications on topics ranging from agricultural transformation and polarization effects to structural change.
- *Governance, politics, and planning* covered articles on multilevel governance systems and planning instruments, as well as regulations and stakeholder relations.
- *Green and blue infrastructure* featured publications on land use dynamics, climate change adaptation, ecological connectivity and fragmentation, and disaster risk

FIGURE 3 Publication density over time and spatial distribution of continent affiliation of analyzed mountain regions. (Data source: Scopus and Web of Science, 2024)



reduction with a particular focus on water management and flooding.
- *Housing and real estate* included topics such as second homes, amenity migration, and building regulations.
- *Spatial monitoring, methods, and new data* covered novel approaches to data collection, management, and processing for monitoring land use dynamics (eg remote sensing, nighttime analysis, and lidar analysis).
- *Topographic implications* included publications on high elevations or steepness of the relief (eg valley-type agglomerations and connections between mountain areas and adjacent lowlands).
- *Touristic implications* grouped together topics on tourism-related impacts (eg overtourism, tourism infrastructure, and the impacts of tourism on regional economies and biodiversity).
- *Transport and mobility* addressed issues such as infrastructure development, public transportation, accessibility, and mobility networks.
- *Urbanization dynamics* concentrated on the links between local units (intraurban effects were not included) and encompassed issues such as counter-urbanization, urban sprawl, and uncoordinated settlement expansion.

This approach allowed us to identify temporal and geographical patterns, thematic development and trends, and geographical patterns and thematic foci.

Results and discussion

Temporal and geographical patterns

Figure 3 illustrates publication intensity over time, with the horizontal axis covering the years from 1976 to 2023 and the vertical axis showing the number of published articles. The colors represent the geographical reference of the publications (ie the continent affiliation of the analyzed mountain regions).

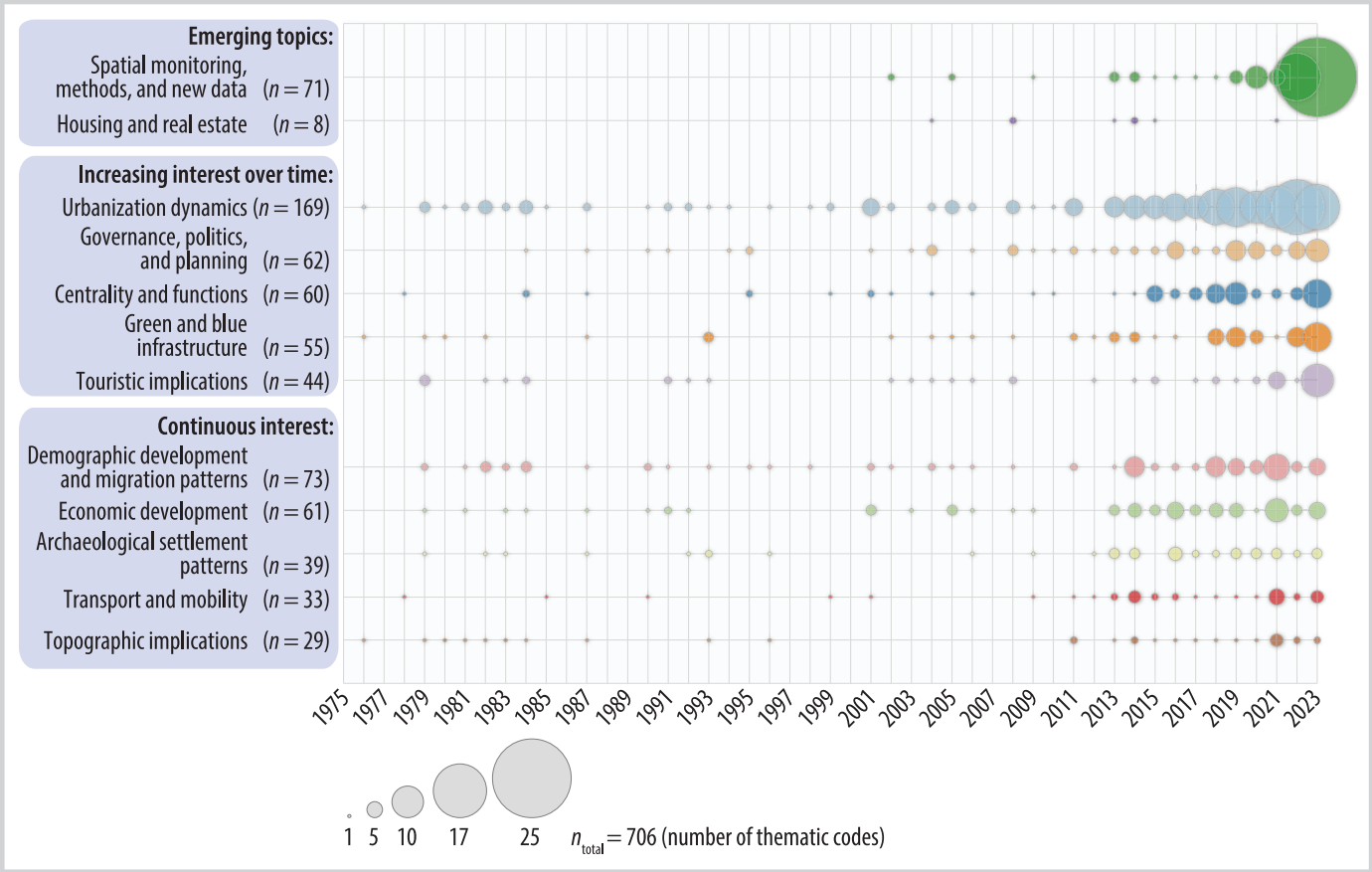
The overall picture shows a density of publications in small "waves." A growing research interest appears in the early 2000s, with a sharp increase from 2013 onwards. An increasing number of publications focus primarily on mountain regions in Asia and Europe, as well as those in South America. Several articles concentrate on North America and Africa, and a few others adopt a global perspective. In our review, we identify no publications on mountain ranges in Australia and Oceania.

We see a large variation in the number of studies for each region, with 133 publications focusing on Asia, 87 on Europe, 36 on South America, 4 on North America, and 3 on Africa, along with 2 articles that adopt a global perspective. The trends over time are as follows:

- *Europe* shows the most consistent publication activity. However, we find a gap between 1986 and 2000, with only 9 articles being published in this period.
- *Asia* demonstrates an emerging trend. Before 2011, we find only 15 publications, which is relatively low compared to Europe. Since then, however, a substantial number of articles have been published. In the full-text review, we identify a remarkably high number of studies with similar methodological approaches despite having different spatial foci.
- *South America* has fewer published articles compared to Europe and Asia, though an increase in publication density occurres at the beginning of the 2000s.
- *North America*, *Africa*, and *global perspectives* appear sporadically and infrequently over time, and, therefore, no specific trend or regularity can be identified.

For several decades, the academic debate on mountain settlement systems has focused predominantly on European contexts, characterized by a modest level of intensity. In recent years, however, the discussion has become much livelier because of a significant number of contributions on mountain regions in Asia. This is in line with the economic

FIGURE 4 Thematic distribution of papers on mountain settlement systems over time (1976–2023). (Data source: Scopus and Web of Science, 2024)



dynamics in Asia, accompanied by an expansion of the academic sector across the continent.

The relative scarcity of publications on mountain settlement systems in South America is surprising, given the large number of important cities in the Andes. Even more striking is the dearth of research on settlement systems in North America, as both the United States and Canada have mountain cities and towns that play a significant role in regional development. However, it should be noted that in the full-text review, we had to exclude many South and North American publications on single mountain cities that did not focus specifically on settlement system research.

Thematic development and trends

Figure 4 visualizes the thematic development and overarching trends in research on mountain settlement systems. This overview includes 264 publications and a total of 706 thematic code assignments—one article could have up to 12 thematic foci. Most publications have 1–7 code classifications, and, on average, we found 2.6 thematic codes per article.

The results can be grouped into 3 categories. First, we identify thematic fields of *continuous interest* over time. In particular, the topics of "demographic development and migration patterns," "economic development," "archaeological settlement patterns," "transport and mobility," and "topographic implications" show a constant publication intensity from the 1970s to 2023. In this group, socioeconomic topics are the most assigned.

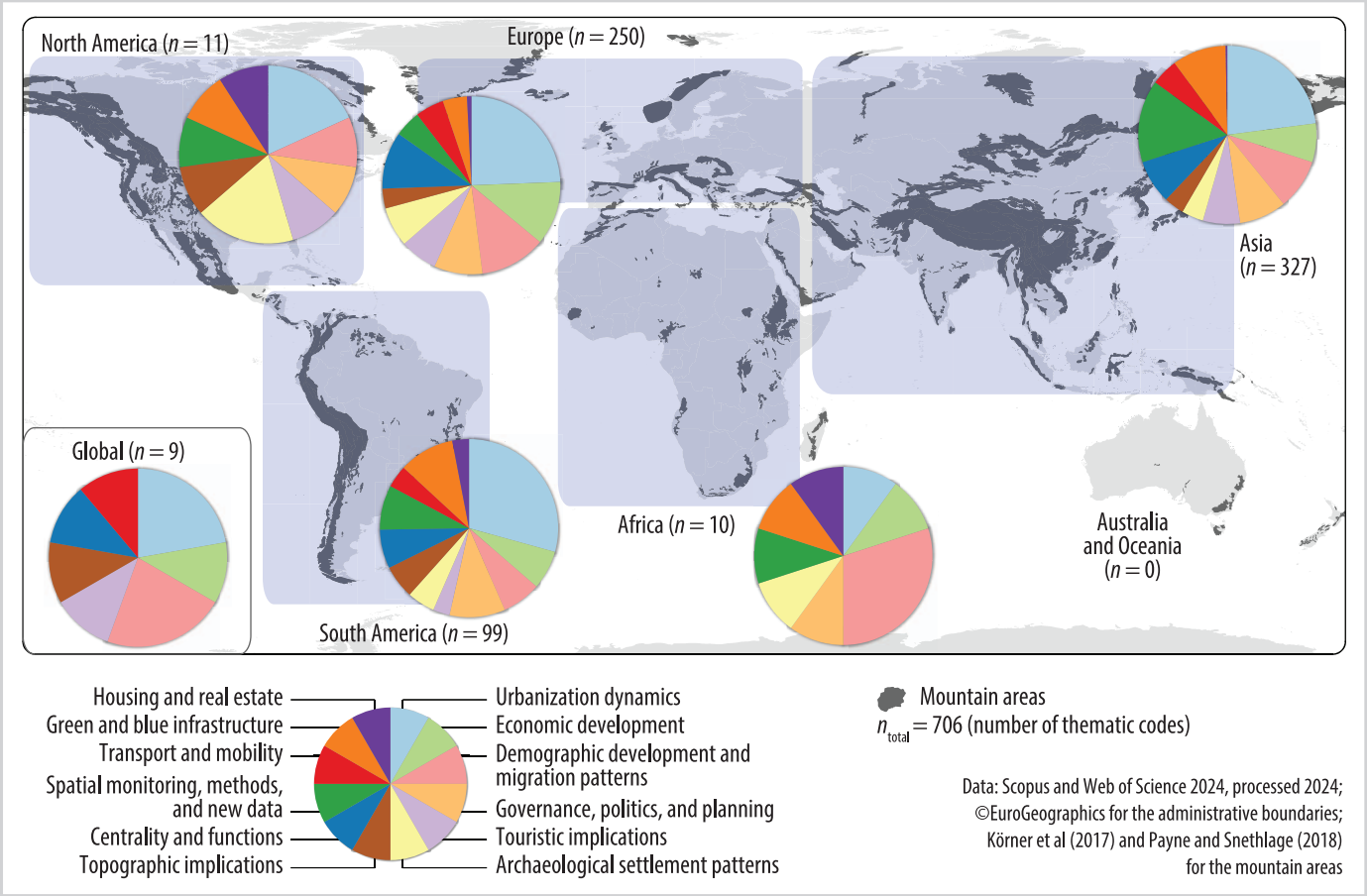
In the second category, we identify topics with *increasing interest over time*. Specifically, the research fields of "urbanization dynamics," "governance, politics, and planning," "centrality and functions," "green and blue infrastructure," and "touristic implications" show increasing publication relevance over time, becoming more prominent in the last decade. The field of "urbanization dynamics," with a specific focus on mountain settlement systems, is, by far, the research topic that increases the most (primarily from Asian affiliations), with a total of 169 code assignments.

Third, we detect a group of *emerging topics*. The research fields of "spatial monitoring, methods, and new data" and "housing and real estate" are not covered in research on mountain settlement systems before the 2000s. However, with 25 hits in 2023, "spatial monitoring, methods, and new data" has the highest number of code assignments for a single year. The reasons for the emergence of new topics or increased interest in this vein could be both scientific (eg data availability or paradigmatic changes) and de facto dynamic (eg social and political trends).

Geographical patterns and thematic foci

Figure 5 illustrates the geographical publication patterns and thematic foci for all continents (excluding Antarctica), as well as those with a global perspective. The map shows the

FIGURE 5 Thematic and spatial distribution of research on settlement systems in mountain regions (1976–2023). (Map by Dominik Bertram, Markus Lambracht, and Tobias Chilla)



IPCC high mountain regions in dark gray (Körner et al 2017, Payne and Snethlage, 2018). The pie charts illustrate the shares of the main topics addressed in the research articles.

Research on mountain regions in Asia has the highest number of code assignments, with a total of 327, followed by those in Europe (n = 250) and South America (n = 99). Publications on African (n = 10) and North American (n = 11) mountain settlement systems, as well as articles with a global perspective (n = 9), have substantially fewer thematic assignments.

Overall, the research fields of "urbanization dynamics," "economic development," "demographic development and migration patterns," and "spatial monitoring, methods, and new data" are the dominant thematic foci of research dealing with mountain settlement systems. However, some of the differences between mountain regions warrant further discussion.

First, research on "green and blue infrastructure" from the perspective of settlement systems is not particularly prominent in Europe. We find this surprising, given the high number of Alpine towns and the general debate on ecological connectivity, climate change adaptation, and disaster risk reduction. This observation suggests that settlement systems have not been significantly included in this debate, which may instead have a more ecological focus.

Second, "governance, politics, and planning" is high on the agenda in mountain regions across contexts. This finding suggests the relevance of mountain-specific settlement issues that are difficult to resolve at the local or regional level. Comparative global studies focusing on common challenges could be a fruitful avenue for further research in this regard.

Finally, although the focus on "centrality and functions" is fairly sparse across contexts, it remains comparatively similar in European, Asian, and South American mountain regions. The provision of essential services in mountain areas is not a prominent issue of this debate.

Conclusion

Our results indicate that research on mountain settlement systems remains a relatively niche topic. The number of publications in the global discourse is rather limited, with 264 articles published in nearly 50 years of research. However, we find a modest level of interest, primarily in Europe and, increasingly, in Asia. Nevertheless, there are still several significant research gaps regarding sustainable spatial development in mountain regions. We argue that future research agendas should take into account the following 3 potential factors.

First, our findings illustrate a thematically selective debate on mountain settlement systems. Our results show emerging topics, such as innovative methods for spatial monitoring, and topics of increasing interest, such as

general urbanization dynamics. Moreover, some fields of research have met with continuous interest over time, such as socioeconomic development. In these articles, demographic and migration processes, economic transformation, and urban sprawl are the most prominent topics, leaving many other areas substantially underrepresented. Although research on housing and real estate (eg second homes and amenity migration) is an emerging topic, the total number of publications in this field remains low. Tourism, which is highly relevant for mountain spatial development, also shows increasing interest, but the overall publication density is still limited. The same applies to governance, centrality, and environmental issues. It is striking that topics like transport, accessibility, and morphological patterns do not factor more heavily into academic discussions, as these areas provide fundamental arguments for the organization of mountain settlement systems. From our point of view, articles on centrality based on functional arguments, such as transport and mobility analysis, and articles dealing with elevation and steepness are lacking in academic debates. As sustainable spatial development requires integrated approaches, the combination of sectoral issues with research on mountain settlement systems has a high potential on future research agendas.

Second, the potential of increased data availability and methodological innovation has not yet been fully realized. Although the monitoring of land use dynamics has become increasingly common, especially in Asian mountain regions, the focus has primarily been on describing the urban expansion of land use rather than investigating the functional dynamics within settlement systems. If one agrees that settlement systems are key to sustainable spatial development, then the potential for scientific reflection is significant. Future research could benefit from applying existing innovative methods in functional analyses.

Third, geographical foci have been selective, with a clear priority on European and, increasingly, Asian mountain settlement systems. Moreover, the near absence of comprehensive settlement systems in large mountain regions (eg the European Alps, the Andes, and the HKH region) from the academic debate in general and for certain thematic issues in particular is striking. This selective geographical focus has been mostly accompanied by a case study approach, which, in turn, leaves room for comparative studies, meta-analyses, and further systematic reflections.

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OPEN PEER REVIEW

This article was reviewed by Elisa Ravazzoli and a second reviewer who preferred to keep the review double blind. The peer review process for MountainAgenda articles is normally open. In shaping target knowledge, values are explicitly at stake. An open review process offers authors and reviewers the opportunity to engage in a discussion about these values.

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