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Exploring the evolution of global trends and knowledge structure in intangible cultural heritage: insights from topic modeling

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Intangible cultural heritage (ICH) research is increasingly interdisciplinary, yet its evolving knowledge structure remains insufficiently mapped. This study applies Structural Topic Modeling to ICH-labelled publications indexed in the Web of Science Core Collection. Eight latent topics are identified and synthesized into three thematic domains, revealing shifting scholarly priorities across technology, sustainability, and spatial governance within ICH-labelled research. The findings provide a structured overview of recent developments in this field.

Intangible cultural heritage (ICH) encompasses the non-physical, non-material components of a culture, which are transmitted through oral traditions, social practices, and performances across generations¹. It constitutes a rich and valuable repository of cultural knowledge and information², serving as a vital reflection of the social, cultural, and historical contexts of a particular region and time period, and providing a unique insight into the lives and practices of the communities that inhabit it³. As a fundamental aspect of a culture's identity and legacy, the preservation and promotion of ICH are indispensable for maintaining cultural diversity and fostering cross-cultural understanding⁴.

The widely accepted definition of ICH is rooted in the UNESCO Convention for the Safeguarding of the ICH, which emphasizes that ICH is a dynamic, living legacy maintained by its custodians⁵. In line with this perspective, UNESCO underscores the significance of ICH as a vital component of cultural diversity, which is increasingly threatened by globalization⁶. The organization has delineated five primary categories of ICH, which encompasses a range of heritage elements, including traditions practices, oral expressions, festive rituals, handicraft skills, music and dance forms, and other cultural artifacts.

Over the past few years, scholarly research on ICH has increased steadily, reflecting its growing prominence across academic disciplines. The preservation, inheritance, and utilization of ICH have emerged as pressing global priorities, sparking extensive research and practical exploration⁷. Some scholars argue that communities are essential stakeholders in the protection of heritage and should be actively engaged in its safeguarding⁸; others contend that protecting the inheritors of ICH is crucial, and that archives should be established to preserve heritage⁹. Since the recognition of ICH's significance has been internationally acknowledged, a substantial body of valuable research has been produced on the topic of safeguarding

ICH¹⁰. Furthermore, the challenge of preserving ICH that cannot be reflected in contemporary times, such as local music¹¹, opera¹², and handicrafts¹³, has also been a subject of research. Since the adoption of the UNESCO Convention of 2003, numerous scholars have investigated the tension between the safeguarding and utilization of ICH¹⁴. A significant aspect of these studies is related to ICH's potential contribution to local society and economy. For instance, ICH-related tourism is commonly recognized as a traditional and effective method for generating economic and social benefits¹⁵. Additionally, the application of advanced digital technologies, such as virtual reality, has also been explored as a means of providing visitors with an immersive and engaging experience while better preserving and disseminating ICH¹⁶. In parallel with these developments, researchers have increasingly examined the environmental, social, and economic dimensions of ICH within sustainability frameworks¹⁷.

In recent years, ICH has received significant attention from researchers across a diverse array of disciplines, leading to substantial advancements and meaningful contributions to the scientific literature. This proliferation of research has resulted in a broad spectrum of topics being explored, underscoring the complexity and multifaceted nature of ICH studies. Consequently, gaining a clearer understanding of how research themes have evolved over time has become increasingly important for scholars and practitioners alike.

Some studies have examined the evolution of global trends and the knowledge structure of ICH. For instance, research by Su et al.³ utilized the Web of Science core database to collect and analyze papers on ICH, shedding light on literature clustering, scientific research collaboration, and co-citations. Similarly, Yulong Chen et al.¹⁸ conducted an analysis of papers on ICH from the co-citation network of authors, research institutions, and journals, revealing the evolution and distribution of publications in the field

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of ICH across the globe. Furthermore, studies have demonstrated the ICH research from the perspective of intellectual property rights. For example, to examine the trends and dynamics of Intellectual Property Protection of ICH in China, Hu et al.² analyzed literature from the CNKI database across multiple dimensions, such as article count, institutional affiliations, and keyword co-occurrence. These studies undoubtedly enhance our comprehension of the subject, but a conspicuous omission of comprehensive topic modeling analysis remains a significant lacuna in the current literature. Given the multidisciplinary nature of ICH and its diverse areas of study, it is essential to gain a more comprehensive understanding of its global status, trends, and key topics across the field. To address this gap, computational text-mining methods, particularly topic modeling, offer the capability to uncover latent thematic structures across large bodies of literature.

This study explores an in-depth understanding of the dynamic evolution of global trends in ICH by leveraging topic modeling analysis. Specifically, structural topic model (STM) is utilized to uncover latent topics and their temporal distribution, thereby facilitating the identification of emergent patterns and trends that may not be discernible through traditional methodologies. The study period of 2014 to 2024 was selected because the scholarly use of the term “intangible cultural heritage” became increasingly standardized during this decade, following expansions in global and national ICH registries; earlier publications often employed inconsistent terminology unsuitable for probabilistic topic modeling. This innovative application of topic modeling serves to differentiate this study from existing retrospectives of the field, offering a novel perspective on the evolution of ICH.

The findings of this study provide significant contributions to our understanding of the evolution of ICH, elucidating the emergence of latent topics over time and shedding light on the factors that have influenced these changes. Furthermore, this research offers valuable insights and recommendations for stakeholders within ICH, underscoring the significance of this study for advancing ICH. The primary focus of this study encompasses two key areas of inquiry: (1) an assessment of the current research interests and priorities within the ICH community, including the identification of key topics and trends shaping their focus; and (2) an examination of the temporal evolution of research topics and priorities in ICH, with a particular emphasis on the factors that have driven these changes. By providing a data-driven view of thematic evolution, this study contributes to both academic understanding and practical decision-making related to the safeguarding and sustainable development of intangible cultural heritage.

Methods

Overview

This study followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines in its design, implementation, and reporting¹⁹. Although other guidelines exist for conducting systematic or scoping review, the detailed reporting guideline and best practices provided by PRISMA-ScR were particularly well-suited for this large-scale topic modeling analysis on ICH. The complete methodology of this study comprised four distinct phases: data collection, data preprocessing, structural topic modeling, and outcome analysis. Figure 1 provides a visual overview to illustrate the research methodology. Specifically, the data collection phase involves the introduction of the database and the selection of a relevant search strategy. Data preprocessing phase consists of two sequential steps, namely manual data cleansing and STM systematic preprocessing. The structural topic modeling phase involves the implementation of the modeling process. The outcome analysis phase provides an in-depth examination of the insight derived from topic modeling results.

Data collection and selection criteria

The study's literature search was conducted using the Web of Science Core Collection (WoSCC), which was deemed the most suitable database due to its comprehensive collection of multidisciplinary academic journals, its higher quality compared to other databases, and its status as an authoritative

source for citation information, making it a primary scientific database and the preferred destination for researchers across various disciplines²⁰.

To concentrate the search on the central theme of ICH, the term ‘intangible cultural heritage’ was employed as the primary search term in WoSCC. By utilizing the term as a ‘topic’ in WoSCC, all relevant documents containing the term in their titles, abstracts, or keywords can be identified²¹. This is an effective search strategy that has been demonstrated in previous studies³. This study restricted the search to the period of 2014 to 2024 because the standardized and internationally recognized use of the term “intangible cultural heritage” in scholarly publications became more consistent during this decade. Earlier literature often employed heterogeneous terminologies (e.g., folklore, traditional culture, vernacular practices), which could compromise terminological consistency and reduce topic modeling accuracy.

Studies published in English were included. To ensure the selection of relevant articles, those that did not focus on a specific issue related to ICH practices, such as protocols, meta-analyses, or perspectives, were excluded. To guarantee the accuracy and reliability of the topic modeling analysis, articles that were not peer-reviewed, like meeting abstracts, review articles, editorial material, letters, and book chapters were deliberately excluded from the dataset. Specifically, the search was conducted using a targeted query:

TS=(intangible cultural heritage) AND DOP = (2014-01-01/2024-12-31) AND LA=(English) AND DT=(Article)

The titles and abstracts of the identified articles were manually screened by three reviewers independently for eligibility according to the inclusion and exclusion criteria. Any discrepancies regarding eligibility were resolved through a discussion among the reviewers. Following the completion of screening process, 634 articles were assessed for eligibility. 2 without abstracts, 2 retracted articles, and 8 unrelated articles were excluded from consideration, resulting in a total of 622 relevant articles for topic modeling analysis.

Data preprocessing

To facilitate the implementation of topic modeling on the corpus, a series of data preprocessing steps were undertaken. Initially, relevant terms were extracted from the titles, keywords, and abstracts, and subsequently converted to lowercase to ensure uniformity in processing. Furthermore, a thorough removal of non-alphanumeric characters was carried out, as these can compromise the accuracy of topic modeling. The targeted characters for removal included periods, exclamation points, question marks, double points, semi-colons, colon, and brackets, as these can interfere with the modeling process. A pre-defined list of stop words was also utilized to systematically eliminate common symbols and stop words (e.g., ‘a’, ‘can’, ‘do’, ‘from’, ‘I’, ‘or’, ‘they’, ‘with’, and ‘will’), which are frequently used in text and may influence topic modeling. Additionally, specific terms such as ‘purpose’, ‘objective’, ‘methodology’, ‘results’, and ‘implications’ were targeted for removal due to their perceived lack of relevance to the topic. To further refine the dataset, the terms were converted to their singular forms, followed by tokenization, lemmatization, and synonym identification procedures, to optimize the dataset for further analysis.

Topic modeling analysis

Topic modeling establishes a correspondence between documents and topics, quantifying the degree to which a document aligns with a particular topic. Topic models typically uncover recurring patterns of co-occurring words across documents, where a topic is defined as a cluster of words that consistently co-occur together. The mapping between a topic and a document is based on the correlation between the word distribution within the document and the identified topics, which are algorithmically derived groups of co-occurring words²².

STM is a type of topic modeling technique, providing a more sophisticated understanding of the underlying topics and their relationships. It is an extension of traditional topic modeling methods, which aim to identify underlying topics or themes in a large corpus of text. In traditional topic modeling, topics are represented as a set of words or phrases, and the

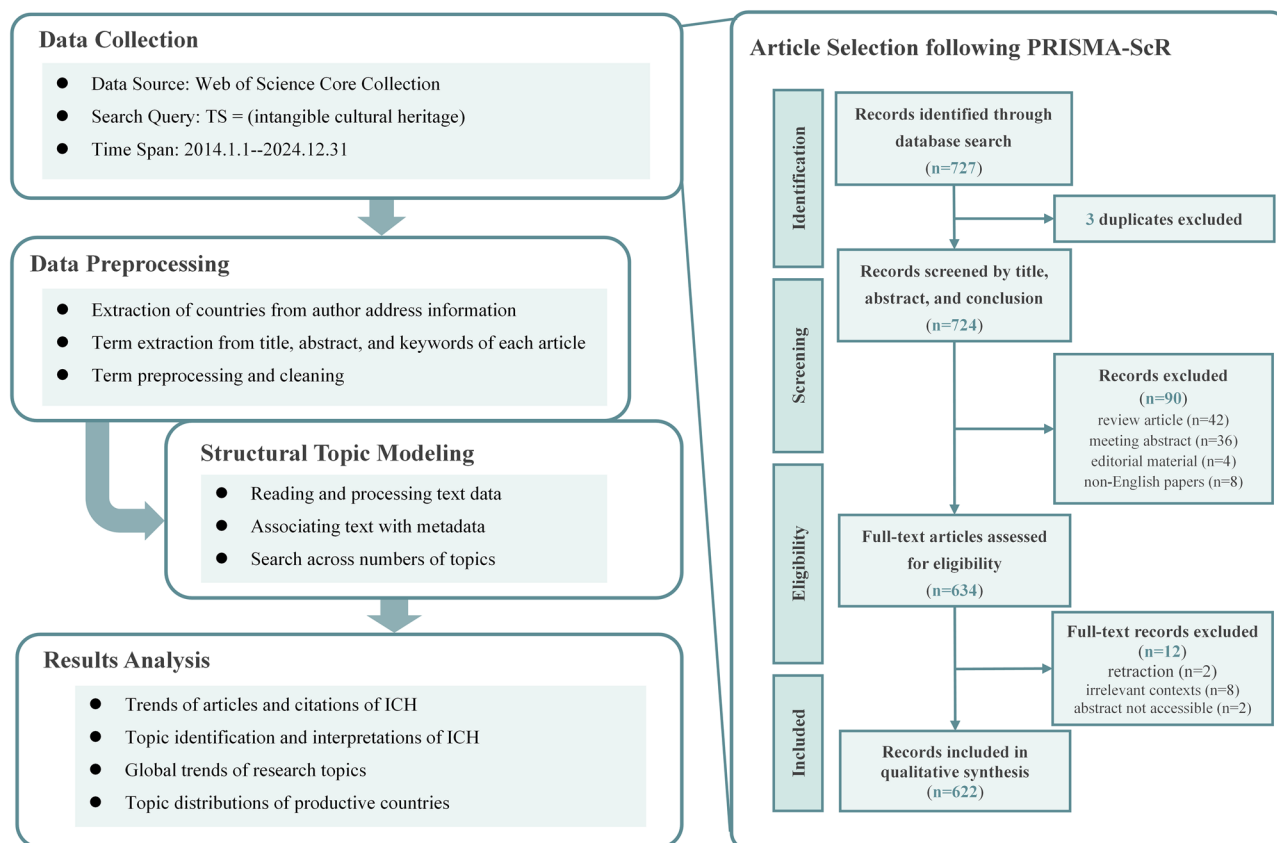


Fig. 1 | Topic modeling framework of ICH. The framework illustrates the overall analytical pipeline, including literature retrieval, article selection, text preprocessing, Structural Topic Modeling, and subsequent analyses of publication trends, topic evolution, and geographical research distribution in ICH.

probability of a document belonging to a particular topic is calculated based on the presence of these words. However, this approach has limitations, as it does not capture the underlying structure of the topics or the relationships between them. STM, on the other hand, use a more sophisticated approach to represent topics as a set of hierarchical or network structures²¹. These models aim to capture the relationships between topics, such as how one topic may be related to another or how topics may be nested within each other.

Conceptually, STM is a hierarchical, mixed-membership framework for analyzing topical content within documents. A key innovation of STM lies in its capacity to automatically identify topics from a corpus of papers via a fast variant of non-conjugate variational expectation-maximization, thereby enabling users to extract meaningful insights from large volumes of textual data. The determination of topics is primarily driven by the inherent content of the papers, rendering the approach inherently objective. A major advantage of STM is its ability to incorporate a wide range of structural information into analysis, including temporal and spatial data, thereby facilitating the discovery of potential topics, the analysis of their content, and the examination of changes in topic prevalence over time²³. For example, STM can seamlessly integrate structured information from papers, such as publication dates, author demographics, and publication venue, and conduct multidimensional analysis to gain a deeper understanding of the relationships between topics and their associated structural attributes. This capability also enables examination of how topics vary across covariates such as publication year, aligning with the study’s objective of analyzing temporal evolution.

Figure 2 illustrates the graphical representation of STM. The R package named STM is utilized in this study to perform structural topic modeling²⁴. The STM is comprised of three sub-models: the topic prevalence model, the topic content model, and the core language model. The matrices X and Y depicted in Fig. 2 represent the topic prevalence

matrix and the topical content covariates matrix, respectively. The probability matrix θ ($D \times K$) represents the probability of all documents across defined topics, while the multinomial logistic topic word matrix β ($K \times V$) incorporates covariates. The STM identifies high-frequency words across all papers in the dataset, which are subsequently classified into various topics. Specifically, distinct high-frequency words can appear in a single paper, and the same paper can correspond to multiple topics. By conducting topic statistics on all papers, the proportions of each topic can be determined. To further refine the topic analysis, covariates are attached to each paper as labels, enabling the division of papers based on these attributes. Subsequently, the popularity of each topic is inferred based on the proportions of each topic and the covariates. The primary analysis materials employed in this study include the titles, abstracts, and keywords of the included papers. Additionally, the publication time of each paper, journal, number of authors, and the attributes defined during dataset preprocessing were assigned as covariate labels to all materials. This comprehensive approach enables the derivation of a detailed understanding of the topic structure within the dataset.

Results

Publication trends

An in-depth examination of the trends in publications within the field of ICH is presented in Fig. 3, which illustrates the annual growth rate of published articles from 2014 to 2024, with a significant increase of 37.3% per year. The number of publications has consistently risen year-on-year since 2014, while the body of literature has expanded significantly from 2017 onwards, exhibiting a substantial acceleration in growth. Furthermore, the growth rate has experienced three peaks: 155.56% in 2017, 81.8% in 2019, and 69.4% in 2021. The dotted line in Fig. 3 represents the trend of citations, which indicates an upward trajectory over time. It should be noted that these

Fig. 2 | Graphical representation of the Structural Topic Model. The diagram illustrates the generative structure of Structural Topic Model, showing how document-level covariates influence topic prevalence and topic content. Latent topic distributions generate word assignments within documents, while topic content covariates allow the word distributions of topics to vary across documents.

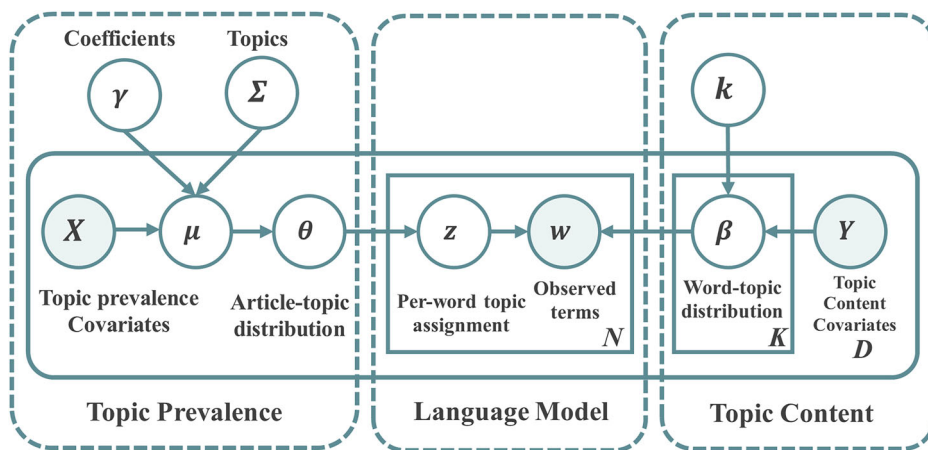
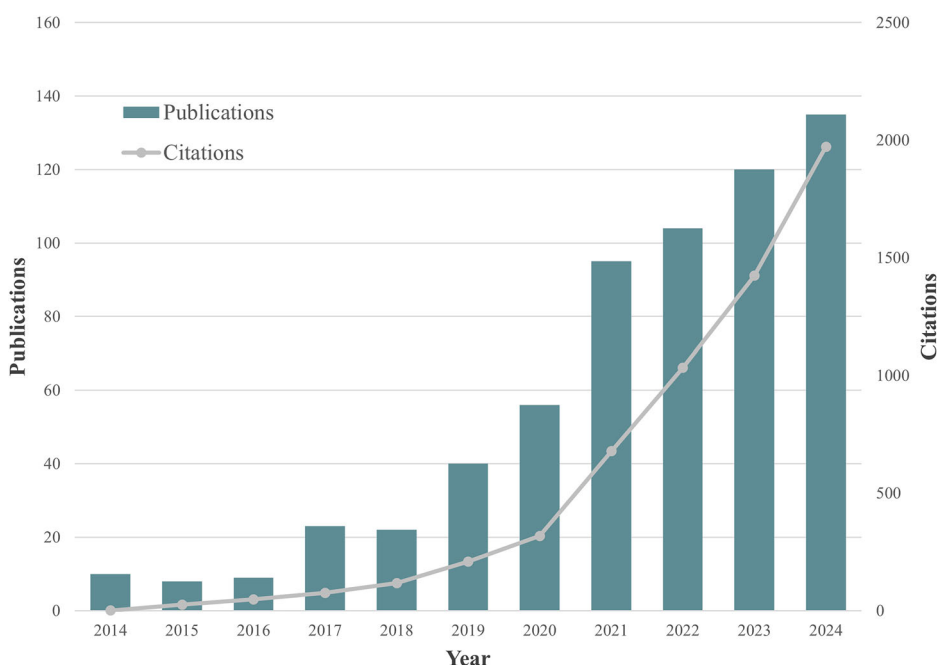


Fig. 3 | Number of articles published and citation count during 2014 to 2024 in WoSCC. The figure illustrates the growth trend of scholarly attention to ICH over the study period.



trends reflect articles explicitly labelled with the term “intangible cultural heritage” and indexed in WoSCC, rather than all possible ICH-related research. The data suggests that ICH has attracted considerable scholarly attention and interest over the past decade, highlighting its growing importance within the academic discourse on cultural heritage.

Major research topics of ICH

The number of topics. Selecting the optimal number of topics in a STM-based study is a critical step. The primary indicators for determining the number of topics in STM are semantic coherence and exclusivity. Semantic coherence refers to the cohesive representation of words within the topics, indicating that the assigned words frequently co-occur in the paper and exhibit a thematic connection to its content. High semantic coherence is characterized by the frequent occurrence of topic-relevant terms in the document, which signifies a strong and meaningful relationship between the topic and the overall content of the paper. Exclusivity, on the other hand, denotes the specificity of a topic, with words exhibiting high exclusivity of a topic rarely appearing in other papers that do not align with this topic. A model with a predetermined number of topics exhibits enhanced semantic coherence and exclusivity. This is

reflected in the frequent co-occurrence of topic-relevant terms within documents and the concentrated distribution of high-probability words across distinct topics. The present study capitalizes on the inherent trade-off between semantic coherence and exclusivity to evaluate the distinctiveness of the derived latent topics, thereby identifying the optimal number of topics²⁵.

Based on a corpus of 622 articles related to the ICH published between 2014 and 2024, this study implemented 10 candidate STM models, varying the number of topics from 4 to 15. Ultimately, an 8-topic STM was selected as the final model, as it demonstrated superior semantic coherence within topics and greater exclusivity between topics. The semantic coherence and exclusivity scores for all models are presented in Fig. 4. Specifically, the semantic coherence scores range from -103.25 to -47.00, while exclusivity scores range from 8.82 to 9.45. In addition to these quantitative diagnostics, the 8-topic solution also provided the best qualitative interpretability, in the sense that each topic could be meaningfully summarized and distinguished from the others based on its highest-probability and most exclusive terms.

Topic correlations. Topic correlations reflect the relationships and connections among different topics. Visualizing these correlations

facilitates a deeper understanding of the interplay and interdependence between topics. Utilizing the topicCorr function within the STM package, topic correlation coefficients were computed based on the topic weights assigned to each document. These coefficients range from -1 to 1 , with smaller absolute values indicating weaker correlations between topic pairs. Figure 5 illustrates the correlations among topics of ICH, where each intersecting square along the x- and y-axes represents the relationship between a pair of topics. According to existing literature, correlation coefficients above 0.7 are typically interpreted as strong, while those between 0.3 and 0.7 are considered moderate²⁶. The visualized results show that all correlation values fall below 0.3 , suggesting minimal or no correlation among the identified topics of ICH. This indicates that, at the level of statistical co-occurrence, the eight topics capture relatively distinct dimensions of ICH-labelled research, even though some con-

ceptual overlaps may still exist and are further synthesized at the domain level in the Discussion.

Topic interpretation. Topic interpretation focuses on elucidating the representative words associated with each topic. These topic words encapsulate the core content of a given topic and assist researchers in understanding its primary themes and direction. The STM identifies eight distinct topics of ICH by analyzing high-frequency terms, with each topic characterized by a set of topic words evaluated under four distinct metrics. ‘Highest Prob’ refers to the words with the highest probability of appearing within a specific topic, indicating their strong association with that topic. ‘FREQ’ is a composite metric that balances word frequency and exclusivity. It identifies topic-specific terms by calculating the harmonic mean of a word’s frequency and its exclusivity relative to a topic, thus emphasizing both semantic coherence and uniqueness. ‘Lift’ adjusts word frequency by dividing it by the word’s frequency in other topics. This metric highlights words that are particularly common within a topic but rare across the broader corpus, thereby revealing more distinctive and topic-specific terms. ‘Score’ is a normalized measure that calculates the ratio of the logarithmic frequency of a word within the topic to its logarithmic frequency in other topics. This provides a standardized and objective indication of a word’s relevance to the topic²⁴.

Table 1 presents the results of the 8-topic STM, including ten representative terms identified under four distinct metrics for each topic, the proportion of each topic within the entire corpus, concise topic labels, and a brief synopsis for each topic. Each topic’s representative terms serve as a concise and informative label for each topic, offering a clear and intuitive summary of the key concepts involved. For example, terms such as restoration, chemical, science, and production indicate a strong emphasis on scientific and technological processes involved in the preservation and analysis of cultural heritage. Simultaneously, terms like fabric, silk, paintings, drawings, material, and paper refer to traditional cultural artifacts and practices that are often subjects of such exploration. Together, these terms suggest a topic focus on the intersection of ICH and technological or scientific methods, justifying the label of Topic 1 that emphasizes technological exploration within the context of ICH. Similarly, for topic 3, terms such as model, method, system, neural network, deep learning, machine learning, training, and knowledge graph point directly to the domain of artificial intelligence (AI) and data-driven technologies. The presence of both AI-related and cultural-specific terminology suggests an intersectional focus on

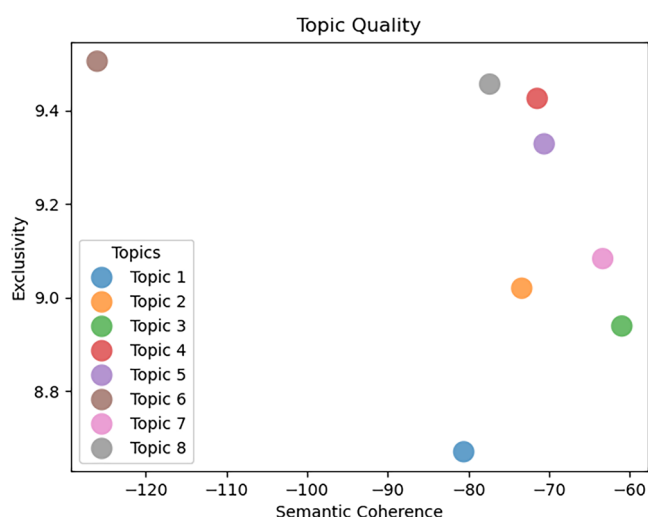


Fig. 4 | Semantic coherence and exclusivity of the 8 topics. Each point represents a topic estimated by the STM. Semantic coherence reflects the interpretability of topic words, while exclusivity indicates the uniqueness of words within each topic. The balance between these metrics supports the selection and evaluation of the 8-topic model.

Fig. 5 | Correlations among the 8 topics. Heatmap showing pairwise correlations among topics estimated by the STM. Each cell represents the correlation in topic prevalence between two topics across documents, with color intensity indicating the strength and direction of the correlation.

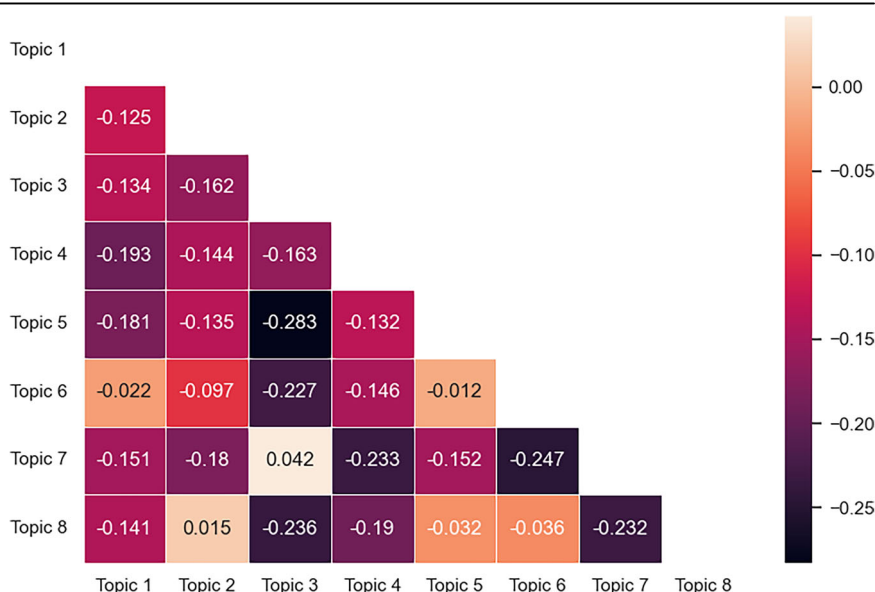


Table 1 | The 8-topic STM results with topic labels, representative terms, and topic proportions

Topics	Topic Labels	Representative Terms	Topic Proportion (%)	Synopsis of Topic Labels
Topic 1	Technological Exploration on ICH	Highest Prob: diet, color, natural, paper, paintings, material, health, fabric, silk, production FREQ: color, diet, paintings, health, fabric, silk, production, drawings, raw, restoration Lift: silk, fabric, health, chemical, paintings, diet, color, raw, production, drawings Score: silk, diet, color, fabric, paintings, health, raw, chemical, production, science	10.03	Technological approaches to the preservation and innovation of ICH
Topic 2	Risk Assessment, Environmental Impact, and Adaptive Reuse of ICH	Highest Prob: buildings, cultural, assessment, music, evaluation, risk, model, acoustic, folk, song FREQ: acoustic, buildings, assessment, music, risk, damage, sound, evaluation, folk, simulation Lift: acoustic, damage, sound, risk, music, buildings, assessment, simulation, outcomes, aiding Score: acoustic, music, damage, risk, sound, buildings, assessment, simulation, folk, climate	9.50	Resilient and sustainable approaches to ICH protection in the face of environmental and social challenges
Topic 3	Artificial Intelligence in ICH	Highest Prob: model, method, dance, image, deep learning, system, human, features, knowledge graph, motion FREQ: image, dance, knowledge graph, deep learning, semantics, neural network, motion, machine learning, model, training Lift: knowledge graph, neural network, deep learning, semantics, machine learning, image, training, style, dance, motion Score: knowledge graph, dance, motion, deep learning, image, opera, neural network, machine learning, model, semantics	12.96	Integration of artificial intelligence, deep learning, computer vision, and knowledge graphs to safeguard, analyze, and promote ICH
Topic 4	Spatial Distribution and Influencing Factors of ICH	Highest Prob: cultural, ICH, factors, China, traditional, villages, Yellow River Basin, region, national, differentiation FREQ: ICH, factors, villages, Yellow River Basin, China, Beijing, region, utilization, minority, national Lift: Beijing, kernel, Yellow River Basin, villages, factors, Western China, ICH, minority, coupling, roads Score: Beijing, ICH, villages, Yellow River Basin, factors, China, traditional, area, coupling, GIS	13.01	Spatial geography, environmental context, cultural diversity, and socio-political dynamics interact to shape the distribution, value, and future of ICH
Topic 5	Sustainable Development of Intangible Cultural Heritage Tourism	Highest Prob: cultural identity, ICH, value, education, case, model, intention, impact, experience, residents FREQ: theory, intention, education, cultural identity, residents, value, ICH, group, policy, case Lift: women, intention, theory, residents, ritual, visit, evolved, belief, education, identity Score: cultural identity, intention, residents, ICH, education, policy, consumer, value, ritual, visit	17.49	Cultural identity, consumer behavior, and community participation in the sustainable development of intangible cultural heritage tourism
Topic 6	Traditional Knowledge, Food Heritage, and Rural Community Practices with ICH	Highest Prob: traditional, local, food, rural, weaving, plant, region, social, consumer, festival FREQ: food, rural, plant, local, festival, weaving, consumer, land, memories, forest Lift: house, food, festival, plant, root, rural, forest, land, memories Score: house, food, plant, rural, weaving, consumer, local, traditional, festival, vegetable	8.77	Traditional knowledge, food heritage, and rural community practices in promoting cultural sustainability, rural development, and community resilience

Table 1 (continued) | The 8-topic STM results with topic labels, representative terms, and topic proportions

Topics	Topic Labels	Representative Terms	Topic Proportion (%)	Synopsis of Topic Labels
Topic 7	Digital Innovation and Interactive Technologies for ICH	Highest Prob: digital, design, user experience, application, art, museum, innovation, system, game, craft FREX: user experience, digital, design, museum, application, game, clothing, VR, immersive, visualization Lift: clothing, VR, user experience, game, immersive, museum, digital, design, application, innovation Score: clothing, digital, user experience, design, game, VR, museum, immersive, weaving, application	15.99	Digital preservation, promotion, and experiential enhancement of ICH through the integration of emerging technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), Internet of Things (IoT), blockchain, and digital twin platforms.
Topic 8	Sustainable and Resilient ICH Governance	Highest Prob: management, historic, urban, site, cities, climate change, system, services, world, resilience FREX: management, urban, site, cities, services, climate change, resilience, temple, historic, world Lift: temple, management, urban, site, resilience, cities, services, political, climate change, mapping Score: temple, urban, services, management, site, cities, climate change, resilience, historic, adaptation	12.26	Management, climate adaptation, and multiscale conservation strategies for sustainable and resilient ICH

applying AI methods to analyze, preserve, simulate, or reinterpret intangible cultural practices and expressions. Therefore, this topic is aptly labeled as 'Artificial Intelligence in ICH' to capture this technological engagement with ICH. In practice, topic labeling was carried out by combining these quantitative outputs with close reading of a subset of highly weighted documents for each topic, ensuring that the assigned labels and synopses reflect both algorithmic patterns and substantive domain understanding rather than relying solely on word lists.

Each paper is assigned a weight for every topic in the STM, reflecting the degree to which the document is associated with that topic. A higher weight indicates a stronger association. By analyzing the frequency of topic occurrences across documents, the relative popularity of each topic can be determined, providing insights into which topics are widely discussed and which remain more niche. To quantify topic prevalence, the average weight for each topic across all papers was calculated. This yields the proportion of each topic's representation, with the total across all topics summing to 1. Topic 5 holds the highest proportion, followed by Topics 7 and 4. Furthermore, six topics exceed a 10% share, while Topics 2 and 6 exhibit the lowest proportions, at 9.50% and 8.77%, respectively. These proportions characterize the relative emphasis of different themes within the ICH literature corpus and should not be interpreted as measuring the overall importance of these themes in all real-world ICH practices.

Global trends and topic distributions of countries

The temporal trends of the eight topics from 2014 to 2024 reveal distinct patterns of evolution in scholarly attention, illustrating in Fig. 6. Topic 1 shows a sharp peak in 2016, suggesting a surge of interest during that year, followed by moderate fluctuations and a slight decline in recent years. Topic 2 demonstrates a steady presence throughout the decade, with relatively higher proportions in 2015 and slight increases again in 2024, indicating continued but moderate engagement. Topic 3 begins with a high proportion in 2014, dips to zero in 2016, and gradually rises again by 2023, suggesting a revival of interest in recent years. Topic 4 was absent in early years but gains noticeable traction from 2017 onward, reaching its peak in 2024, reflecting a growing emerging area of research. Topic 5 exhibits a relatively consistent presence, with minor peaks in 2015, 2018, and especially 2022, indicating sustained scholarly attention with periodic intensifications. Topic 6 maintains a low but stable trend across the years, with slight increases in 2020 and 2021, pointing to niche but ongoing interest. Topic 7 shows gradual growth, peaking in 2022, and maintaining high levels into 2024, highlighting a steadily expanding area of focus. Finally, Topic 8 starts strong in 2015 and 2016, remains relatively high in subsequent years, and maintains a stable presence through 2024, reflecting continuous interest and development over time. These trends collectively illustrate the dynamic and evolving landscape of research on ICH, and represent shifts in emphasis within the WoSCC ICH-labelled literature rather than absolute changes in global ICH practice itself.

A total of 90% (566) of the studies included in this study were published by researchers from China (*n* = 293, 47.11%), Italy (*n* = 64, 10.29%), Spain (*n* = 48, 7.72%), England (*n* = 28, 4.5%), Greece (*n* = 28, 4.5%), South Korea (*n* = 28, 4.5%), France (*n* = 20, 3.22%), USA (*n* = 20, 3.22%), Malaysia (*n* = 19, 3.05%), and Australia (*n* = 18, 2.39%). This concentration reflects both the research capacity of these countries and their policy emphasis on ICH documentation and promotion during the study period. The most common topics researched among these countries include Topic 5-Sustainable Development of Intangible Cultural Heritage Tourism, Topic 7-Digital Innovation and Interactive Technologies for ICH, and Topic 4-Spatial Distribution and Influencing Factors of ICH (Fig. 7). This suggests that issues related to tourism development, digital transformation, and spatial-cultural patterns are particularly salient in the ICH research agendas of the leading contributing countries.

Discussion

Before presenting the thematic discussion, it is essential to clarify how the eight STM-derived topics were systematically synthesized into three

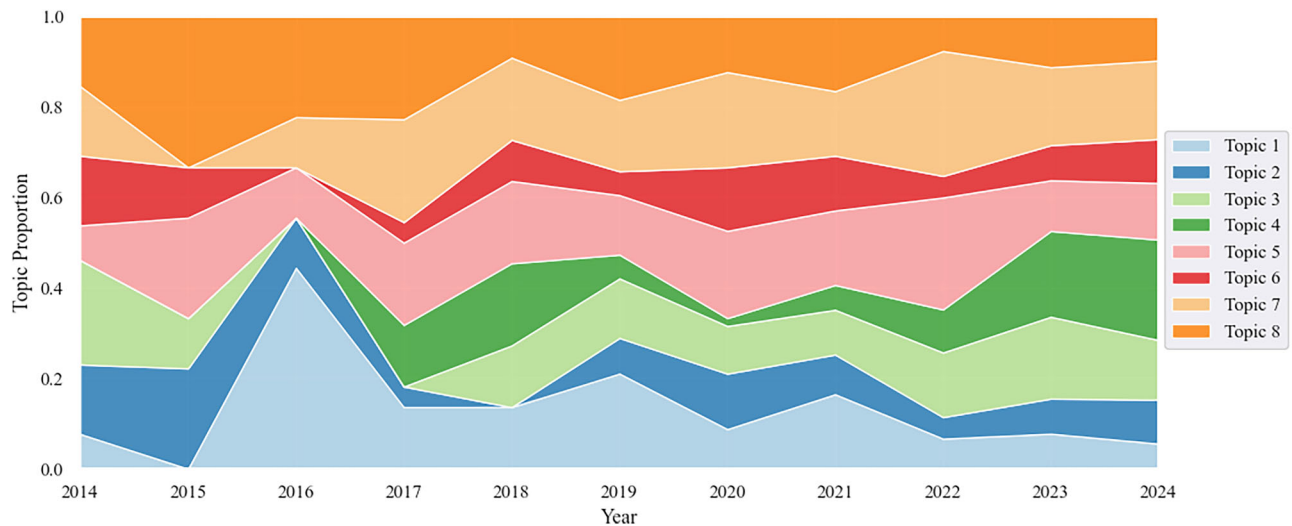


Fig. 6 | Global trends of topics in ICH from 2014 to 2024. Stacked area chart showing the relative proportion of the 8 topics identified by the STM across the study period.

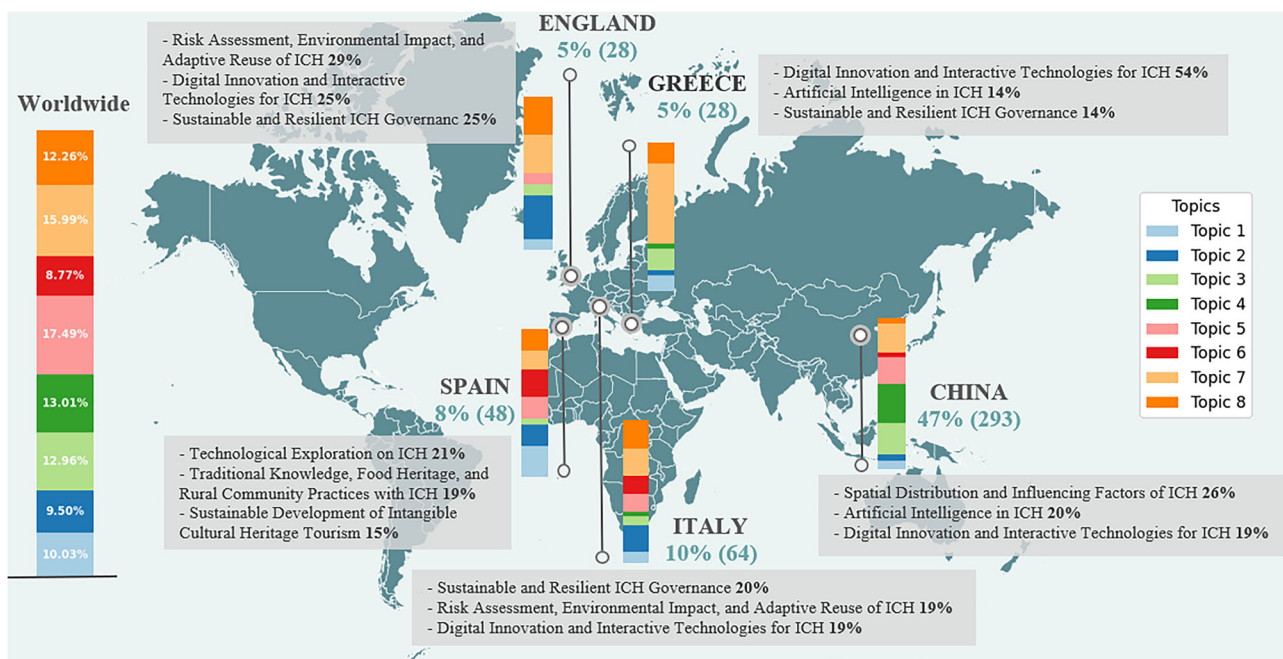


Fig. 7 | The distribution of studies based on country, mapped to different ICH topics. World map showing the distribution of publications across countries and their corresponding topic composition based on STM.

broader conceptual domains. Although STM outputs statistically distinct topics, several of these exhibit strong semantic proximity, shared methodological orientations, and overlapping application contexts. To ensure interpretability while remaining faithful to the model’s data-driven outputs, we conducted a qualitative synthesis based on three criteria: (1) similarity in representative terms, (2) conceptual alignment in topic summaries, and (3) convergence in the types of ICH practices addressed. Synthesizing the eight topics into these three thematic domains provides a structured interpretive framework that supports a more integrated and policy-relevant discussion, while preserving the empirical grounding of the STM results. This approach also facilitates clearer communication of the main directions shaping contemporary ICH scholarship. Topics 1, 3, and 7 collectively emphasize technological intervention, ranging from materials analysis and restoration science to artificial intelligence, virtual reality, and interactive digital design, thereby forming a coherent domain of technological and digital innovation.

Topics 5, 6, and 8 converge around sustainability, cultural identity, community participation, food heritage, rural development, and governance frameworks, which together suggest a socio-ecological and community-driven perspective on ICH. Topics 2 and 4 share a clear spatial and environmental focus, addressing risk assessment, climate impacts, geographical distribution, and adaptive strategies, thus forming a third domain centered on spatial analysis and risk-oriented heritage management. From a review perspective, this synthesis moves beyond a topic-by-topic description and instead highlights how contemporary ICH research is increasingly organized around broader epistemic orientations, reflecting shifts in research paradigms rather than isolated thematic interests.

In recent years, technological advancement has emerged as a transformative force in the documentation, preservation, and reinterpretation of ICH²⁷. Topics related to Technological Exploration (Topic 1), Artificial Intelligence in ICH (Topic 3), and Digital Innovation and Interactive

Technologies (Topic 7) converge under this domain, highlighting a growing trend toward integrating science and technology with cultural practices. Representative studies in these topics reveal the increasing use of deep learning models, neural networks, and knowledge graphs to digitally reconstruct or analyze cultural elements such as dance movements²⁸, opera performances²⁹, traditional paintings³⁰, and crafts³¹. For example, motion capture and pose-estimation techniques have been used to model traditional dance sequences and gesture vocabularies, while computer vision and image-based methods support the analysis of shadow puppetry, glove puppetry, and other performative arts in virtual environments. Such applications not only enable the archiving and reproduction of ICH elements with high fidelity but also facilitate interactive experiences through immersive systems like virtual reality³² and motion capture³³. Meanwhile, studies under Topic 1 emphasize the use of materials science and restoration technologies to examine traditional resources, such as natural dyes³⁴, and silk fabric³⁵. This scientific approach supports both authentic conservation and the innovation of traditional techniques, often in combination with ecological concerns or health-related uses. Related research on Xuan paper³⁶, barkcloth³⁷, traditional pigments, and mineral-based coatings further illustrates how experimental characterization and material engineering can extend the durability and performance of heritage-related materials while respecting traditional knowledge³⁸.

These technological advancements also expand the creative and educational potential of ICH. AI-generated cultural content and digital storytelling platforms offer new avenues for cultural reinterpretation and public engagement. Serious games, immersive VR reconstructions, and metaverse-style platforms have been proposed for delivering experiential learning and time travel encounters with historical environments and practices³². Furthermore, semantic analysis³⁹, classification models⁴⁰, and system-level AI methods enhance knowledge organization and access for researchers and practitioners alike. For instance, sentiment analysis of museum user feedback⁴¹, metadata-driven knowledge organization for ICH collections⁴², and intelligent storage or rights-management systems for cultural resources have been explored as ways to improve user experience and digital sustainability⁴³. These studies suggest that digital technologies are no longer auxiliary tools, but increasingly shape how ICH is conceptualized, mediated, and legitimized within scholarly and institutional contexts. However, these innovations raise critical questions regarding authenticity, cultural ownership, and digital ethics⁴⁴. While digital methods enrich the ICH experience, they also risk detachment from the lived, contextual essence of intangible heritage. Scholars have begun to highlight concerns about the potential commodification of digital heritage, the risk of privileging technologically advanced institutions and regions, and the possibility that algorithmically generated representations may override community narratives. Thus, future research must critically examine how these tools can be designed and implemented to remain culturally sensitive, inclusive, and grounded, ensuring that digital technologies support rather than supplant the community-rooted nature of ICH.

From a synthetic perspective, the second domain signals a transition from treating ICH primarily as cultural assets toward understanding it as part of broader socio-ecological and community-based systems. The interconnection between ICH, sustainability, and community-based development has become increasingly prominent in recent scholarship. This thematic domain synthesizes insights from Topic 5 (Sustainable Development of ICH Tourism), Topic 6 (Traditional Knowledge, Food Heritage, and Rural Community Practices), and Topic 8 (Sustainable and Resilient ICH Governance). These strands of research highlight the pivotal role of ICH in promoting rural revitalization, community resilience, and culturally rooted forms of sustainable tourism. Many studies demonstrate how traditional knowledge systems are central to both cultural identity and ecological sustainability, including those related to food heritage⁴⁵, handicrafts⁴⁶, and healing practices⁴⁷. For example, research on ethnic soups in Romania⁴⁸ and fermented beverages in Mexico⁴⁹ illustrates the biocultural richness embedded in culinary traditions, emphasizing their relevance for sustainable food systems and local pride. Similarly, practices such as

bamboo weaving in Sansui⁵⁰, and Hakka weaving in Bobai⁵¹ serve as vehicles for preserving plant diversity, traditional ecological knowledge, and community livelihoods. These cases resonate with broader work on local agri-food systems, Mediterranean diet traditions⁵², and sea-salt farming⁵³, which position ICH as a lever for sustainable land use, social capital, and health-related cultural practices.

ICH also functions as a strategic asset in tourism development, particularly in rural and underrepresented regions. Projects like the Gastronomic Heritage⁵⁴ and the Marche Food and Wine Memories Project⁵⁵ exemplify how food-based heritage can attract visitors, stimulate local economies, and promote regional identity. Studies on niche festivals, performance traditions, and rural tourism routes further show how ICH can support place branding and create distinctive tourism offerings⁵⁶. Moreover, ICH has been positioned within broader governance and development frameworks aimed at enhancing cultural sustainability. Scholars advocate for community-centered heritage management, involving local stakeholders in decision-making and promoting adaptive reuse of cultural sites⁵⁷. The integration of ICH into sustainable development policies also reflects growing recognition of its value in ecosystem services⁵⁸ and climate resilience⁵⁹. This is consistent with emerging work that connects cultural landscapes, transhumance, and traditional pastoral or coastal practices to long-term environmental stewardship and socio-ecological resilience⁶⁰. This body of work collectively highlights a structural tension between heritage-based economic development and the long-term safeguarding of cultural meanings, practices, and community autonomy. Nonetheless, challenges persist, including the commercialization of culture, tensions between authenticity and marketability, and the risk of cultural homogenization in the face of global tourism trends. To address these issues, researchers emphasize the importance of cultural capital, social sustainability⁶¹, and capacity-building programs that empower local communities to manage their heritage on their own terms⁶². Future work should therefore pay closer attention to power relations, gender dimensions, and intergenerational dynamics in ICH-based development, ensuring that sustainability goals are aligned with local aspirations and rights⁶³.

The third major domain emerging from current ICH research centers on spatial distribution, risk assessment, and adaptive reuse strategies, reflecting the interdisciplinary integration of geography, urban planning, heritage studies, and disaster management. This domain integrates findings from Topic 2 (Risk Assessment, Environmental Impact, and Adaptive Reuse of ICH), Topic 4 (Spatial Distribution and Influencing Factors of ICH), and partially overlaps with Topic 8 in addressing policy-oriented responses to evolving environmental and socio-economic challenges. Research on the spatial dynamics of ICH explores the geographic clustering, cultural landscape patterns, and environmental influences that shape how ICH is preserved or eroded. Studies analyzing spatial distribution⁶⁴, for instance, reveal that regional culture, economic development, and policy support significantly influence the vitality of ICH practices⁶⁵. A growing body of work uses GIS-based tools, spatial statistics, and geodetectors to examine the distribution of ICH, traditional villages, minority cultural practices, and heritage-related resources across river basins, rocky desertification areas, and urban regions⁶⁶. Spatial visualization tools, including GIS mapping and spatial correlation models, are increasingly used to identify cultural hotspots, resource imbalances, and vulnerable heritage zones⁶⁷. Another key concern is the risk faced by ICH due to factors such as urbanization, climate change, tourism overdevelopment, and cultural homogenization. Case studies on the impacts of environmental stressors and social transformation highlight the need for more resilient ICH strategies, especially in heritage zones⁶⁵ or ecologically fragile areas⁶⁸. Research on flood risk⁶⁶, sea-level rise⁶⁸, seismic hazards, and extreme weather impacts on cultural heritage suggests that both tangible settings and intangible practices are exposed to multi-hazard threats. Such approaches mark a conceptual shift from reactive preservation toward anticipatory and adaptive governance of intangible heritage under conditions of environmental and socio-economic uncertainty.

Moreover, risk assessments and policy integration are increasingly emphasized in scholarly discourse⁶⁹. Researchers stress the importance of multi-level governance models, cross-sectoral coordination, and the incorporation of ICH considerations into disaster planning, urban policy, and land-use regulation⁷⁰. Frameworks such as multi-hazard risk prioritization⁷¹, climate-smart cultural heritage management⁵⁹, and resilience assessment for historic districts⁷² demonstrate how environmental and cultural data can be combined to guide decision-making. These efforts aim to ensure that heritage is not passively preserved but actively integrated into future-facing development strategies. Ultimately, this research domain advocates for an approach that is data-informed, spatially aware, and community-responsive, bridging the gap between cultural conservation and territorial planning in an era of accelerating change.

The three identified thematic domains highlight the increasingly interdisciplinary and applied nature of ICH research. While each domain addresses distinct aspects of ICH preservation and development, they are deeply interwoven in practice. For instance, digital technologies not only enhance the documentation and dissemination of cultural expressions⁷³ but also play a pivotal role in building sustainable cultural tourism models⁷⁴. Immersive and personalized digital museum experiences, ecomuseums, and participatory platforms for cultural heritage in smart city environments exemplify this convergence of technology, tourism, and local engagement⁴¹. Community participation and traditional knowledge serve as both the foundation and beneficiaries of these technological and spatial strategies, reinforcing the need for heritage approaches that are not only innovative but also inclusive and place-sensitive. These intersections point to a future research agenda that must be systematically integrative⁷⁵. Technological advancements such as artificial intelligence, knowledge graphs, and interactive media should be further explored not as isolated tools but as part of socio-technical ecosystems that respond to cultural, environmental, and governance needs⁷⁶. Likewise, sustainability initiatives and community-based practices will benefit from stronger institutional linkages, policy frameworks, and cross-disciplinary methodologies that embed ICH into broader agendas such as rural revitalization⁵¹, climate adaptation⁵⁹, and smart city planning⁴³. Spatial and environmental analyses should increasingly draw on real-time data and community-based sensing, moving toward predictive models that can inform early-warning systems and proactive conservation policies⁷⁷. In addition, comparative and longitudinal studies across regions and cultural contexts are needed to better understand how different governance regimes, economic structures, and digital infrastructures shape ICH evolution over time. However, several challenges remain. Firstly, the digital divide and unequal access to technological infrastructure can exacerbate existing disparities in the ability of communities to participate in or benefit from the digitization and innovation of ICH. Secondly, the tension between tourism-driven development and cultural preservation remains a pressing concern that necessitates careful balancing through participatory governance and local empowerment. Thirdly, while advances in spatial models and policy tools are underway, the integration of intangible cultural values into quantitative planning systems poses a significant methodological and philosophical hurdle. Finally, as highlighted by recent debates in heritage and sustainability science, there is a risk that universal sustainability frameworks may not adequately reflect localized understandings of value, spirituality, or identity associated with ICH⁷⁸. To effectively address these challenges, future research must prioritize inclusive innovation, community empowerment, and policy alignment, fostering collaborative platforms that bring together cultural bearers, technologists, urban planners, and policymakers on an equal footing.

This study demonstrates the utility of STM as a powerful method for uncovering latent thematic structures in large volumes of academic literature related to ICH. While STM may not offer the same depth and precision as manual qualitative coding, it provides significant advantages in terms of efficiency, scalability, and the ability to uncover macro-level patterns that would be difficult to identify through manual analysis alone. These strengths make topic modeling particularly suitable for research areas, such as ICH,

where interdisciplinary contributions and growing publication volumes pose challenges for synthesis. However, several limitations should be acknowledged. First, the analysis was conducted using literature retrieved exclusively from the WoSCC. While WoSCC is recognized for its rigorous indexing standards and high-quality academic content, relying solely on a single database may result in the exclusion of relevant studies indexed in other major databases such as Scopus, IEEE Xplore, or Google Scholar. Expanding database coverage in future research could improve the comprehensiveness and representativeness of the dataset. Second, this study employed “intangible cultural heritage” as the primary topic search term. This choice yielded a focused and high-quality corpus aligned with the research objective. However, the use of a single, explicit keyword may limit the capture of conceptually relevant but terminologically diverse publications. As demonstrated in prior work⁷⁹, natural language processing (NLP) techniques such as lexical association and statistical language modeling can be used to expand and refine search queries, thus improving coverage and semantic richness in future studies. Third, topic modeling techniques such as STM inherently require the predefinition of topic numbers, a task that is often non-trivial and potentially subjective. In this study, performance metrics—specifically semantic coherence and exclusivity—were used to determine an optimal model structure. Nevertheless, some topics still exhibited trade-offs between these metrics. For instance, Topic 1 displayed high semantic coherence but low exclusivity, suggesting topic overlap, whereas Topic 6 had high exclusivity but low coherence, indicating less internal semantic consistency. These limitations highlight the necessity of triangulating STM results with manual validation or complementary methods, such as keyword co-occurrence analysis, to ensure interpretative robustness. In conclusion, while STM provides a valuable tool for exploring the knowledge landscape of ICH research, the interpretability and accuracy of its outputs depend on methodological choices including database selection, search strategy design, and model calibration. Future research should consider integrating more diverse data sources, advanced NLP-based query expansion techniques, and multi-method triangulation to enhance both the depth and breadth of topic modeling applications in cultural heritage studies.

As a multidisciplinary and interdisciplinary domain, ICH requires the integration of diverse academic perspectives to address its complex and evolving challenges. This study employed STM to systematically analyze a decade of scholarly literature from the WoSCC, identifying the most productive countries and uncovering latent thematic patterns and their temporal evolution. Through this approach, the study offers a data-driven understanding of global trends in ICH research, highlighting how scientific focus areas have shifted over time. By synthesizing these trends, this work provides one of the first large-scale empirical mappings of how technology, sustainability, governance, and cultural practices intersect across the global ICH research landscape. The insights gained from this analysis can inform research governance and policy-making, enabling funding agencies and academic institutions to better recognize emerging research frontiers and strategically allocate resources. By identifying key themes and geographic contributors, the study also provides a roadmap for enhancing international collaboration and fostering capacity-building in underrepresented regions. As awareness and expertise in ICH continue to grow, a broader range of specialists is expected to contribute to the field, enriching both its theoretical foundations and practical applications. In particular, the findings underscore the growing importance of digital methods, spatial analysis, and sustainability-oriented frameworks, which can guide institutions in aligning research agendas with global cultural and environmental challenges. In summary, this study presents a comprehensive overview of the topical landscape, evolution, and distribution of ICH research at the global level. The findings contribute to a deeper understanding of the knowledge structure of the field, offering valuable guidance for scholars, practitioners, and policymakers. Nonetheless, given that the analysis is based solely on WoSCC indexed publications and a single explicit search term, the results should be interpreted as reflective of the ICH research corpus

within this specific bibliographic boundary rather than as a complete representation of all global ICH scholarship. Future studies may benefit from integrating additional databases, multilingual literature, or NLP-enhanced query expansion to broaden coverage and improve representativeness. Moreover, STM-based insights should be viewed as complementary to qualitative and community-centered approaches that remain essential in ICH research, particularly given the culturally situated and practice-dependent nature of intangible heritage. Integrating computational findings with ethnographic, participatory, and policy-oriented perspectives will be crucial for advancing a more holistic understanding of ICH. Ultimately, this work lays a solid foundation for future investigations into the dynamic interplay between technology, sustainability, community engagement, and cultural preservation in the context of intangible heritage. By revealing how research priorities evolve and where conceptual gaps persist, the study opens new avenues for interdisciplinary collaboration and supports the development of evidence-based strategies for the safeguarding and innovative revitalization of intangible cultural heritage worldwide.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to licensing restrictions associated with the Web of Science Core Collection database but are available from the corresponding author on reasonable request. All search queries, inclusion criteria, and screening procedures are described in the Methods section to enable independent retrieval of the dataset. This study does not involve biological sequence data; therefore, no accession numbers are applicable.

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Q.H.: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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The author declares no competing interests.

Additional information

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