Recent Developments in Cartography: An Analytical Review of Research for the Period 2015-2025

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Abstract
The science of cartography has undergone substantial methodological, technological, and epistemological transformation during the period 2015-2025. This review article analyzes recent developments in contemporary cartography, with particular attention to emerging cartographic frameworks, interactive maps and user experience, artificial intelligence and machine learning, volunteered geographic information, virtual and augmented reality, and critical cartography. The review is based on selected peer-reviewed literature from cartography and geographic information science, including studies published in the International Journal of Cartography, The Cartographic Journal, Cartography and Geographic Information Science, Cartographica, the International Journal of Geographical Information Science, the ISPRS International Journal of Geo-Information, Geocarto International, and KN - Journal of Cartography and Geographic Information. The findings show that cartography has shifted from a discipline focused mainly on static spatial representation toward a dynamic field that integrates computation, social participation, immersive visualization, and critical analysis. At the same time, the review highlights persistent challenges, including data reliability, ethical governance of artificial intelligence, unequal participation in collaborative mapping, and the need to decolonize cartographic practice. The article concludes that contemporary cartography requires a new interdisciplinary orientation that combines technical competence, visual communication, spatial reasoning, and critical awareness.

1. Introduction

Cartography has historically been understood as both a science and an art concerned with representing spatial phenomena through maps. Traditional cartography emphasized the construction of reliable spatial representations, often in paper-based or two-dimensional digital form. However, recent scholarship argues that cartography can no longer be limited to the production of final visual outputs. Instead, contemporary cartography must be understood as an integrative discipline concerned with geographic modeling, spatial data infrastructures, user interaction, and spatial citizenship (Basaraner, 2016; Silva et al., 2014).

The last decade has been particularly important for the transformation of cartography. Since 2015, scholarly discussions in cartography and geographic information science have increasingly addressed interactive mapping, cloud-based spatial data, mobile devices equipped with GPS, volunteered geographic information (VGI), machine learning, augmented reality (AR), virtual reality (VR), and the political function of maps. The International Journal of Cartography editorial review of a decade of publishing indicates that the discipline has witnessed major shifts in both theory and practice (International Journal of Cartography Editorial, 2024). Similarly, recent reviews of modern cartographic trends show that big data, real-time information processing, and machine learning have changed the ways maps are produced, used, and disseminated (Habib & Okayli, 2023).

This article reviews and synthesizes the most important developments in cartography between 2015 and 2025. It focuses on six interrelated themes: the redefinition of cartography, interactive maps and user experience, artificial intelligence and machine learning, volunteered geographic information, immersive cartography through VR and AR, and critical cartography. By bringing these

themes together, the article demonstrates that cartography is not merely a technical field but also a social, cognitive, political, and creative practice.

2. Method

This article uses a qualitative literature review approach. The reviewed literature was drawn from major scientific databases and publishers, including Web of Science, Scopus, Google Scholar, Taylor & Francis, Springer, Elsevier, and MDPI. The inclusion criteria were that the publication had to be a peer-reviewed scientific article, published primarily between 2015 and 2025, and directly related to cartography or geographic information science. Foundational studies published before 2015 were included when they provided important conceptual background, such as early discussions of volunteered geographic information and critical cartography.

The initial corpus included studies from specialist journals such as the International Journal of Cartography, The Cartographic Journal, Cartography and Geographic Information Science, Cartographica: The International Journal for Geographic Information and Geovisualization, the International Journal of Geographical Information Science, the ISPRS International Journal of Geo-Information, Geocarto International, and KN - Journal of Cartography and Geographic Information. After screening for relevance and methodological rigor, the final synthesis focused on studies that best represent major developments in cartographic theory, technology, participation, and critique.

3. Results and Discussion

This article uses a qualitative literature review approach. The reviewed literature was drawn from major scientific databases and publishers, including Web of Science, Scopus, Google Scholar, Taylor & Francis, Springer, Elsevier, and MDPI. The inclusion criteria were that the publication had to be a peer-reviewed scientific article, published primarily between 2015 and 2025, and directly related to cartography or geographic information science. Foundational studies published before 2015 were included when they provided important conceptual background, such as early discussions of volunteered geographic information and critical cartography.

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3.1. Redefining Cartography: New Theoretical Foundations

One of the most important developments in recent cartography is the redefinition of the discipline itself. Basaraner (2016) argues that modern cartography should not be reduced to map drawing or final geographic visualization. Instead, it should be understood as a comprehensive framework that includes spatial configuration, social interaction, geographic modeling, and location-based applications. This view broadens the role of cartography from representation to the organization and communication of geographic knowledge.

The rise of Web 2.0 has also changed the relationship between mapmakers and map users. Lin (2015) explains that digital platforms have moved map production beyond official institutions and opened mapping to broader publics. In this context, maps are no longer merely instruments of documentation; they are interactive media through which spatial meaning is created, negotiated, and contested. This shift is consistent with the broader recognition that cartography supports public communication, policy, and sustainable development. Le Sourd and Ricker (2025) demonstrate that cartography and geospatial information are central to global sustainable development agendas, including climate change monitoring, resource management, and urban planning.

3.2. Interactive Maps and User Experience

Interactivity has become a central feature of contemporary cartography. Roth (2015) defines cartographic interaction as a dialogue between the user and the map mediated through computing

technologies. Based on qualitative interviews with geospatial professionals, Roth argues that interactivity is not an optional technical feature but a fundamental element that reshapes the cognitive relationship between maps and users. This development requires cartographers to consider not only map accuracy and design but also interface structure, usability, and user experience.

Research on interactive map users has expanded the empirical basis of cartographic design. Roth et al. (2017) call for greater attention to user studies in cartography, especially because users differ in cognitive ability, digital literacy, cultural background, motivation, and task orientation. These differences affect how users interpret, navigate, and evaluate interactive maps. Therefore, contemporary cartographic design must be user-centered rather than solely mapmaker-centered.

Several empirical studies have deepened this discussion. Horbinsky and Cybulski (2020) used eye-tracking methods to study how users interact with graphical interfaces in web maps. Their findings suggest that users tend to scan screen corners for control buttons, indicating the need to group similar functions and reduce cognitive load. Song et al. (2022) show that visual storytelling with maps is more effective when narrative structure, long-form content, scrollytelling, and visual guidance are carefully designed. Roth (2021) further develops this area by framing cartographic design as visual storytelling, arguing that maps can generate emotional engagement and geographic persuasion, not merely transmit spatial information.

3.3. Artificial Intelligence and Machine Learning in Cartography

Artificial intelligence (AI) and machine learning have become defining forces in contemporary cartography. Kang et al. (2024) show that AI is increasingly applied to automate and enhance cartographic tasks such as classification, generalization, symbolization, and design support. AI also opens creative possibilities in map production, although it raises ethical questions about transparency, accountability, and bias.

Machine learning has had a particularly strong influence on cartographic generalization. Harrie et al. (2024) identify several major applications, including the recognition of cartographic patterns, the design of generalization algorithms, style transfer, and automated labeling. These developments indicate that machine learning can assist cartographers in handling complex spatial datasets and producing maps at multiple scales.

Recent studies on deep learning demonstrate both progress and limitations. Fang et al. (2025) report that neural network architectures such as U-Net, generative adversarial networks, and graph convolutional networks have shown promise in tasks such as building segmentation, road network extraction, and object classification. However, these methods remain exploratory and cannot yet fully replace expert cartographic judgment. Fu et al. (2024) emphasize the importance of explainable artificial intelligence in deep learning-based map generalization, arguing that cartographers must understand why models produce particular outputs. Thus, AI should be treated as a tool that supports human reasoning, not as a substitute for methodological and aesthetic expertise.

3.4. Volunteered Geographic Information and Collaborative Mapping

Volunteered geographic information represents another major transformation in cartography. Goodchild (2007) introduced the concept of citizens as sensors, describing how ordinary users can contribute geographic information. During 2015-2025, this idea expanded significantly through platforms such as OpenStreetMap and other collaborative mapping systems. See et al. (2025) argue that crowdsourced geospatial data has become a cornerstone of geography and geographic information science because it shifts map production from traditional institutions toward distributed user communities.

Despite its potential, VGI raises important questions about accuracy, reliability, governance, and inequality. Yamashita et al. (2023) propose a framework for assessing the quality of VGI in outdoor activity contexts, highlighting indicators such as update frequency, number of contributors, and label edits. Foody et al. (2015) also show that data accuracy depends not only on the number of contributors but also on contributor expertise. A large number of participants does not automatically guarantee high-quality data.

The social and political dimensions of VGI are equally important. Lin (2018), in a study of OpenStreetMap in China, shows that collaborative mapping is shaped by legal, technical, political, and social conditions. VGI is therefore not a neutral form of data production; it is influenced by platform structures and local power relations. Zhang et al. (2024) further show that contributions to OpenStreetMap are unevenly distributed, with a small number of dedicated editors producing a large share of content. This finding challenges the assumption that collaborative mapping is automatically equal or democratic.

3.5. Virtual Reality, Augmented Reality, and Immersive Cartography

Virtual reality and augmented reality have expanded the spatial and sensory possibilities of cartography. Mietrik et al. (2019) demonstrate how VR can be used to create interactive three-dimensional visualization environments, such as a realistic representation of the Arctic Clyde Inlet. Such work shows that cartography can move beyond two-dimensional representation toward immersive spatial experience.

Edler and Kersten (2021) argue that VR and AR technologies transform spatial perception by combining game development environments, head-mounted displays, mobile devices, and real-scale three-dimensional visualization. These technologies allow users to experience geographic environments in more direct and embodied ways. However, they also require new cartographic design principles because visual variables developed for paper maps cannot be transferred directly into immersive environments.

Research on augmented reality mapping supports this argument. Dickmann et al. (2021) show that overlaying digital layers onto the real world creates a hybrid visual environment requiring different cartographic constraints. Qiu et al. (2023) find that Bertin's traditional visual variables must be reconsidered for outdoor AR geovisualization because perception in AR differs substantially from perception in flat two-dimensional maps. Edler et al. (2023) also show that dynamic three-dimensional cartographic symbols in VR can create more immersive spatial experiences than desktop applications. Cheng et al. (2022) conclude that augmented map research still requires standardized design guidelines to address issues such as visual interference and aesthetic integration between physical and digital layers.

3.6. Critical Cartography and Decolonizing Maps

Contemporary cartography is also shaped by critical debates about power, representation, and colonial knowledge. Critical cartography challenges the assumption that maps are neutral technical objects. Crampton (2009) highlights how Cartography 2.0 intensified debates about authority, participation, and digital mapping. Rose-Redwood (2015) argues that deconstructive approaches reveal the limits of conventional map authority, while also noting the need for constructive alternatives.

The decolonization of cartography has become a particularly important area of research. Rose-Redwood et al. (2020) propose a framework for decolonizing maps that recenters Indigenous mapping, respects local knowledge systems, and involves Indigenous peoples in the mapping process itself. This approach moves beyond correcting map content and instead calls for a renewal of the logic and institutions of cartographic production.

Empirical studies extend this argument. Araujo et al. (2022) analyze Indigenous maps in the Amazon and argue that Indigenous peoples should be recognized as producers of geographic knowledge, not merely as objects to be mapped. Moreno-Quintero et al. (2022) show how new social cartography can make Black geographies visible in local planning in Colombia. Duggan and Gutierrez-Ujaque (2025) further develop counter-mapping as a praxis that combines participation, pedagogy, creativity, and radical spatial representation. Together, these studies show that cartography is inseparable from struggles over identity, land, justice, and representation.

The reviewed literature shows that the development of cartography between 2015 and 2025 followed three parallel pathways. The first pathway is technological, represented by the integration of AI, machine learning, VR, AR, big data, and user-centered digital interfaces. These technologies

have improved the speed, interactivity, and expressive capacity of maps. However, they also create new challenges related to transparency, data quality, privacy, and ethical governance.

The second pathway is social and participatory. Through VGI and collaborative platforms, the ability to produce geographic information has expanded beyond official institutions. This shift has democratizing potential, especially when local communities can contribute knowledge about their own spaces. Nevertheless, participation remains uneven, and VGI systems can reproduce inequalities when a small number of contributors dominate the production of map content or when marginalized regions remain underrepresented.

The third pathway is critical and political. Recent cartographic scholarship increasingly recognizes that maps are not neutral mirrors of reality. They are shaped by institutional power, technical standards, cultural assumptions, and historical inequalities. Critical and decolonial approaches therefore call for cartography that is more reflexive, inclusive, and accountable to local knowledge systems.

These three pathways are not separate. Instead, they intersect in the practice of contemporary cartography. For example, AI-based map production must address not only technical efficiency but also ethical accountability and cultural bias. Similarly, immersive cartography must consider not only visual experience but also accessibility and cognitive interpretation. Collaborative mapping must combine openness with quality control, inclusive participation, and transparent governance.

4. Conclusion

This review concludes that cartography has undergone a radical methodological transformation during the period 2015-2025. The discipline has shifted from static spatial documentation to an interdisciplinary field where computation, visual design, social participation, immersive experience, and critical theory converge. AI and machine learning now support generalization, classification, and cartographic production, but they cannot replace the interpretive, ethical, and creative judgment of trained cartographers. Interactive maps and visual storytelling have made user experience central to cartographic communication. VGI and collaborative mapping have redistributed the capacity to produce maps, while also raising questions about reliability and inequality. VR and AR have opened new immersive forms of spatial visualization that require new design principles. Critical and decolonial cartography has expanded the field by emphasizing justice, local knowledge, and the politics of representation.

Several recommendations follow from this review. First, cartography curricula should be updated to integrate technical skills, visual communication, human-computer interaction, AI literacy, and critical spatial thinking. Second, international standards are needed for evaluating the quality and reliability of VGI while respecting cultural diversity and regional variation. Third, participatory digital platforms should enable local communities to review and edit spatial data in their own languages. Fourth, universities, national mapping agencies, and research centers should collaborate to establish quality management procedures for VGI and AI-supported cartographic production. Fifth, more research is needed on the role of Arabic-language scholarship and Middle Eastern geographic contexts in international cartography. Finally, immersive cartography should be developed for education, training, and professional practice, especially in regions where VR and AR remain underused in geospatial studies.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

All authors in this publication declare no conflict of interest regarding the title, data, location, and results of the research.

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Supplementary Materials

This study does not include any supplementary materials.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript. AI were used only to improve readability and language under strict human oversight; no content, ideas, analyses, or conclusions were generated by AI.

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