Geospatial Technologies in Geographical Research and Planning in Twenty-First Century: A Review

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Abstract

Geospatial technologies have transformed the scope, methodology, and application of geographical research and planning. The integration of Geographic Information Systems (GIS), Remote Sensing (RS), Global Positioning System (GPS), and emerging geospatial tools such as drones, LiDAR, and artificial intelligence has enabled researchers and planners to analyse spatial patterns with unprecedented accuracy and efficiency. These technologies now underpin a wide range of applications in urban and regional planning, environmental management, disaster risk reduction, transport, public health, agriculture, and monitoring of the Sustainable Development Goals (SDGs) (Kitchin, 2013; Masser, 2019). This paper examines the conceptual foundations, components, data sources, analytical techniques, and applications of geospatial technologies in geographical research and planning. It also discusses recent advancements, challenges, and future prospects, emphasizing the growing importance of geospatial thinking in sustainable development and spatial governance.

Keywords: Geospatial technologies, Geographical research, GIS, GPS, Remote sensing.

1. Introduction

Geospatial technologies understood here as the group of digital tools and infrastructures for capturing, managing, analysing, and communicating spatially referenced information have undergone profound transformation since the turn of the century (Masser, 2005, 2019). They encompass GIS, remote sensing, GNSS (Global Navigation Satellite Systems), web mapping platforms, spatial big data, UAV-based sensing, mobile and location-based services (LBS), and, increasingly, AI and machine learning methods for spatial analysis and prediction (Kitchin, 2013; UNOOSA, 2014).

In planning practice, geospatial technologies have become central to evidence-based decision-making and scenario analysis. Planning agencies routinely use GIS for zoning, infrastructure location, environmental impact assessment, and transport modelling, while web-based platforms increasingly support participatory planning and transparency (Esri, 2012; Masser, 2005). Smart city initiatives, integrated climate-resilience toolkits, and SDG monitoring frameworks depend heavily on web GIS, and spatial analytics (Batty, 2013; UN-GGIM, 2016). Applications now span urban master planning, transport and mobility planning, climate adaptation and disaster risk management, health service accessibility, and agricultural and natural resource planning across both Global North and Global South settings (Das et al., 2023; Parvin et al., 2021; Scott, 2016).

The aim of this review is fourfold. First, it maps the evolution of geospatial technologies and associated paradigms in geography and planning since 2000, highlighting the move toward web-based, cloud-enabled, real-time, and participatory spatial information infrastructures (Masser, 2019; UN-GGIM, 2016). Second, it synthesises major application domains in geographical research, including physical and environmental geography, human geography and spatial analysis, urban and regional planning, agriculture and natural resources, and public health and disaster management (Elliott et al., 2004; Singh, 2024). Third, it examines methodological advances in data, sensors, models, platforms, and participatory approaches, including the integration of AI and ML in spatial analytics (Sun et al., 2021; Yang et al., 2025). Fourth, it evaluates strengths and limitations, identifies cross-cutting challenges and ethical concerns, and outlines emerging research gaps and future directions (Kitchin, 2013; Brown & Kyttä, 2014).

2. Conceptual and Technological Background

2.1 From desktop GIS to web- and cloud-based geospatial infrastructures

In the late twentieth century, GIS was largely a desktop technology, used by specialist analysts within government agencies, utilities, and research institutions. Since around 2000, GIS serves as the foundational platform for spatial data integration and analysis in geographical research. Patel et al. (2025) introduce GIS alongside remote sensing for smart buildings and cities, emphasizing its role in layering multi-source data for urban planning. Bharambe et al. (2024) outline recent trends, including cloud-based GIS for real-time decision-making in resource management. In disaster contexts, Ghosh et al. (2023) Flood hazard mapping using GIS applications for vulnerability mapping and response coordination. AbdelRahman and Afifi (2024) demonstrate GIS integration with GPS and remote sensing for digital soil mapping, achieving high-accuracy predictions of properties like pH and organic matter. Jitta et al. (2025) extend this to smart cities, where GIS optimizes traffic and infrastructure via AI-driven simulations.

Web GIS allows spatial data to be hosted on servers and accessed via browsers or application programming interfaces (APIs), enabling collaborative editing, real-time visualisation, and integration of heterogeneous datasets (Esri, 2012). Commercial platforms and open-source stacks such as QGIS, PostGIS, and GeoServer now support multi-user editing, versioning, and the publication of interactive map services (Masser, 2019). These infrastructures are increasingly linked to global frameworks such as the UN's Integrated Geospatial Information Framework and the SDGs geospatial roadmap (UN-GGIM, 2016; Scott, 2016). Overall, 21st-century GIS evolves from static mapping to dynamic, predictive systems for sustainable planning.

2.2 Remote sensing: from moderate resolution to high resolution, hyperspectral, and open data

Remote sensing has long underpinned physical geography and environmental monitoring, but the early twenty-first century has seen important advances in spatial resolution, temporal frequency, spectral richness, and accessibility (Reis, 2008; Potapov et al., 2022). Remote sensing has advanced from satellite imagery to hyperspectral and multi-sensor platforms, powering large-scale geographical monitoring. Dritsas and Trigka (2025) survey its role in the big data era, handling petabyte-scale datasets for land-use classification and climate analysis. Szafarczyk and Agbasi (2025) highlight emerging trends like SAR and LiDAR for environmental monitoring, predicting deforestation with 95% accuracy. Patel et al. (2025) provide an entry point, linking it to GIS for urban heat island detection. In agriculture, Mitran et al. (2020) overview its use for crop health via NDVI indices, while Chaurasia et al. (2026) integrate it with machine learning for yield forecasting. Chatrabhuj et al. (2024) apply it to river management, fusing Landsat data with GIS for erosion modelling.

Methodologically, there has been a decisive move from purely pixel-based classification methods to object-based image analysis. Reviews of land use/land cover (LULC) classification highlight the growing role of convolutional neural networks and related architectures in extracting complex spatial features and improving classification accuracy (Li et al., 2022; Sun et al., 2023). Remote sensing in 21st-century shift toward real-time, AI-enhanced analytics bridges data gaps in remote terrains.

2.3 Global Navigation Satellite Systems (GNSS), mobile GIS, and location-based services(LBS)

GNSS has become ubiquitous in everyday life, from navigation apps to precision agriculture and logistics. Originally dominated by the United States' GPS, the GNSS landscape now includes GLONASS, Galileo, BeiDou, and regional systems such as India's NavIC and Japan's QZSS (UNOOSA, 2014; Taoglas, 2024). Once these systems are fully operational and integrated in multi-constellation receivers, users can access signals from a large constellation of satellites, enhancing positioning accuracy, reliability, and resilience (UNOOSA, 2014; Liu & Zhang, 2020). GNSS can be used to position survey markers, buildings, and road construction. Lechner et al. (2000) showcase Field mapping, yield mapping, and farm management are all done with GNSS in conjunction with a Geographic Information System (GIS).

Mobile GIS and location-based services build on this positioning capability to deliver map-based services on smartphones and tablets. Mobile GIS applications support field data collection, ground truthing, and real-time mapping, extending GIS functions from office desktops into the field (Tsou, 2011; University of Wisconsin–Madison, 2018).

LBS provide personalised information—such as nearby points of interest, navigation guidance, and contextual alerts—based on users' locations (Techtarget, 2022; Zappter, 2023). These technologies also generate vast amounts of locational data, which, when anonymised and aggregated, are used in research on human mobility, transport planning, and spatial epidemiology (Williams et al., 2015; Panigutti et al., 2017).

2.4 Drones (UAVs): From arial photogragraphy to landscape research in complex topographies

Drone-integrated systems represent a disruptive 21st-century innovation for high-resolution, on-demand data collection. Quamar et al. (2023) review drone-GIS synergies, from photogrammetry for 3D terrain models to real-time disaster assessment. Karahan et al. (2025) focus on landscape research, detailing multispectral drones for vegetation mapping and erosion studies in complex topographies. These low-cost, flexible tools democratize access, enhancing traditional satellite remote sensing in geographical planning.

3. Thematic Review of Applications in Geographical Research

3.1 Physical and environmental geography

Physical and environmental geographers have been at the forefront of exploiting advances in remote sensing and GIS. LULC change analysis remains a core application, with numerous case studies examining deforestation, urban expansion, agricultural intensification, and ecosystem degradation (Reis, 2008; Potapov et al., 2022). Reis (2008), for example, used supervised classification of Landsat images from 1976 and 2000 to map LULC changes in northeast Turkey, revealing dramatic increases in urban and agricultural land at the expense of pasture and forest, with implications for landslide risk and environmental management. Such products support assessments of progress toward SDGs related to land, climate, and biodiversity, and inform national land use policies and conservation strategies (UN-GGIM, 2016; Scott, 2016).

Hydrological and climate impact studies also depend heavily on geospatial technologies. Remote sensing-derived precipitation, soil moisture, snow cover, and evapotranspiration data are integrated with digital elevation models (DEM) and land cover maps in hydrological models, enabling analysis of flood risk, drought impacts, and water availability under changing climate conditions (Singh, 2024; Eminoğlu & Tarhan, 2025). GIS provides a platform for integrating these datasets, performing catchment delineation, and mapping vulnerability.

Urban environmental studies use LULC data, thermal imagery, and three-dimensional building models to examine urban heat islands, surface runoff, and green infrastructure scenarios, supporting adaptation planning in cities (Kazmierczak et al., 2015; Sahani et al., 2023).

Ecosystem services research examining the benefits derive from ecosystems has adopted GIS and remote sensing to map services such as carbon storage, flood regulation, and recreational values. Mapping of ecosystem service values has further integrated local knowledge into such analyses, linking environmental geography with PPGIS and PGIS traditions (Sieber, 2006; Brown & Kyttä, 2014).

Overall, physical and environmental applications demonstrate how remote sensing and GIS can provide spatially explicit evidence of environmental change, inform risk assessments, and support policy interventions. Yet they also highlight persistent challenges around uncertainty quantification, temporal comparability, and integration with socio-economic data and qualitative knowledge (Reis, 2008; Potapov et al., 2022).

3.2 Human geography and spatial analysis

Human geographers have increasingly drawn on geospatial technologies to analyse socio-spatial inequalities, mobility, and spatial patterns of cultural and economic life.

The proliferation of mobile phone data and social media has opened new avenues for studying human mobility and activity spaces. Williams et al. (2015) propose measures of human mobility derived from mobile phone call detail records enhanced with GIS data, addressing earlier limitations of such measures and demonstrating their utility for examining the spatial nature of movement and its relationship to social context. Panigutti et al. (2017) similarly assess the use of mobile phone data to model recurrent mobility patterns in spatial epidemic models, highlighting both the potential and limitations of such data for representing travel behaviour relevant to disease spread. Beyond epidemiology, mobile phone and other digital traces have been used to analyse commuting, tourism, urban rhythms, and land use classification, often within emerging "urban analytics" frameworks (Batty, 2013; Rowe, 2019).

Geodemographic classification and spatial segmentation techniques, long established in market research and public service planning, have been revitalised by access to richer spatial datasets. GIS-based cluster analyses and multivariate classification methods are used to delineate neighbourhood types, classify rural-urban gradients, and identify "hotspots" of deprivation in health, education, or social services (Elliott et al., 2004; Parvin et al., 2021).

In cultural and social geography, digital mapping and web GIS have facilitated new forms of qualitative and mixed-methods research, including story mapping, participatory web atlases, and critical counter-mapping by marginalised groups. Such work often intersects with PPGIS and VGI, foregrounding questions of representation, power, and the politics of spatial data (Sieber, 2006; Brown & Kyttä, 2014).

3.3 Urban and regional planning

Urban and regional planning is one of the domains where geospatial technologies are most deeply institutionalised. GIS supports core planning functions such as land use planning, zoning, infrastructure siting, environmental impact assessment, and transport planning (Esri, 2012; Masser, 2005). Esri's (2012) documentation of GIS solutions for urban and regional planning illustrates how agencies integrate cadastral, demographic, environmental, and infrastructure data in multi-layered GIS environments to support design review, scenario testing, and long-term monitoring of plan implementation.

Transport planning applications make extensive use of network analysis tools in GIS. Accessibility mapping measuring travel times or distances to key services has informed evaluations of public transport coverage, identification of underserved areas, and assessment of equity in access to jobs, health care, and education (Parvin et al., 2021; Das et al., 2023). Increasingly, such analyses incorporate real-time or high-frequency data from smart cards, GPS-enabled vehicles, or mobile phones, enabling dynamic modelling of congestion and travel behaviour (Batty, 2013; Williams et al., 2015).

"Smart city" initiatives represent a newer frontier, seeking to integrate geospatial data, sensor networks, and analytics to manage energy, transport, safety, and environmental quality. Batty's (2013) work on big data, smart cities, and city planning underscores how streaming sensor data (e.g., from transport systems) shifts emphasis toward shorter time horizons and real-time management, while still requiring new forms of theory and modelling to make sense of complex urban systems.

3.4 Agriculture, natural resources, and rural development

In agriculture and natural resource management, geospatial technologies underpin precision and climate-smart approaches. UAV-based remote sensing has emerged as a flexible, cost-effective means of acquiring high-resolution imagery for crop monitoring, providing data on plant health, water stress, nutrient status, and pest or disease outbreaks (Sun et al., 2021; Yang et al., 2025).

UAV applications in plant ecology and agriculture highlight the use of multispectral, and thermal sensors to derive indices such as the Normalised Difference Vegetation Index (NDVI) and canopy temperature, feeding into yield prediction and management decisions (Sun et al., 2021; Yang et al., 2025). UAV or satellite imagery are increasingly applied to classify crops, estimate biomass, and detect diseases, often outperforming traditional classifiers but requiring substantial training data and careful validation (Li et al., 2022; Sun et al., 2023).

GIS and remote sensing support land suitability analysis for different crops, assessment of soil erosion risk, and planning of irrigation infrastructure and watershed management interventions. In forestry, Lidar and high-resolution imagery are used to estimate biomass, monitor logging, and design sustainable harvesting and restoration strategies (Singh, 2024).

In rural development, GIS supports planning of rural services such as schools, health centres, and markets, often focusing on accessibility and service coverage in sparsely populated or remote areas (Parvin et al., 2021; Luqman et al., 2021).

3.5 Public health and disaster management

Public health has become a major domain of geospatial application, under the banner of spatial epidemiology and health geography. GIS is used to map disease incidence, identify clusters, analyse associations with environmental and socio-economic risk factors, and assess accessibility to health care services (Elliott et al., 2004; Kauhl, 2017). Reviews of GIS in public health surveillance highlight its role in disease tracking, hotspot identification, and integration of diverse datasets to support early warning and targeted interventions (Mandal et al., 2023; Kauhl, 2017).

Studies in Indian districts such as Murshidabad and Midnapore demonstrate the use of network and raster-based accessibility models to identify underserved slum populations and recommend optimal locations for new facilities (Parvin et al., 2021; Das et al., 2023).

Disaster risk management and humanitarian planning similarly rely heavily on geospatial tools. GIS and remote sensing are used to map hazards (floods, landslides, earthquakes, cyclones), exposure (population, infrastructure), and vulnerability (socio-economic indicators, building quality), forming the basis for risk assessments and contingency planning (Singh, 2024; Eminoğlu & Tarhan, 2025). Geospatial tools support early warning systems, evacuation planning, relief logistics, and post-disaster damage assessment, often integrating near-real-time satellite imagery and in situ data (Singh, 2024; Esri, 2025).

4. Geospatial Technologies in Planning Practice and Policy

Geospatial technologies have reshaped planning practice and governance in several interrelated ways. First, they support more evidence-based, spatially explicit planning processes. Urban master plans increasingly rest on detailed spatial analyses of land use, infrastructure capacity, environmental constraints, and demographic trends, through GIS layers and dashboards (Esri, 2012; Masser, 2005).

GIS supports the delineation of zones, assessment of compliance, and monitoring of changes. Planners can rapidly evaluate the likely impacts of proposed developments on traffic, environmental conditions, or service demand, and adjust zoning regulations or development conditions accordingly (Maptionnaire, 2023; HP, 2024).

Transport and mobility planning makes extensive use of network-based GIS analysis to design and evaluate public transport routes, cycling networks, and pedestrian infrastructure. Accessibility metrics, visualised as isochrones or catchment areas, help planners assess equity in access to jobs, services, and amenities, informing location decisions for new facilities or targeted improvements in underserved areas (Parvin et al., 2021; Das et al., 2023).

Climate adaptation and resilience planning rely on integrated geospatial assessments of hazards, exposure, and vulnerability. Web GIS tools such as those developed in the GRaBS project enable municipalities to assess climate change impacts on temperature and runoff, evaluate green infrastructure scenarios, and communicate risks and adaptation options to a range of stakeholders (Kazmierczak et al., 2015; UCCRN, 2025). Similarly, decision support models have been developed to map spatial opportunities for climate adaptation, emphasising the importance of high-resolution data on land use, topography, and socio-economic conditions (Sahani et al., 2023).

Resource allocation and service delivery planning use GIS to optimise the distribution of schools, health facilities, water points, and other public services. In low- and middle-income countries, where service inequalities are often stark, GIS-based accessibility analyses help target investments to areas with the poorest access, as illustrated by studies in Indian districts that model health facility accessibility for slum and non-slum populations (Parvin et al., 2021; Das et al., 2023; Luqman et al., 2021). Tools like AccessMod operationalise these methods for national planning, framing geospatial analysis as a key component of moving toward universal health coverage and SDG 3 (WHO, 2015).

At the global policy level, UN-GGIM and related initiatives have pushed for integration of geospatial information into implementation and monitoring of the SDGs, the Sendai Framework for Disaster Risk Reduction, and the Paris Agreement on climate change (UN-GGIM, 2016; Scott, 2016). The SDGs geospatial roadmap outlines how geospatial data and infrastructures can support countries in measuring and reporting indicators, highlighting the need for stronger coordination between national statistical offices and geospatial agencies (UN-GGIM, 2016). This has stimulated investment in SDIs, capacity building, and integration of earth observation and administrative data for policy-relevant indicators (Masser, 2019; Scott, 2016).

Despite these advances, adoption of geospatial technologies in planning remains uneven. Barriers include limited institutional capacity, lack of up-to-date and accessible data, insufficient technical skills among planners, and legal or regulatory constraints (Masser, 2005, 2019; UN-GGIM, 2016). In many Global South contexts, basic datasets such as parcel maps, building footprints, or street networks are incomplete or outdated, and organisational silos impede data sharing (Scott, 2016; Coastal Wiki, 2010). Moreover, while web GIS and open data portals promise greater transparency and accountability, they can also obscure underlying power relations if not accompanied by genuine opportunities for public deliberation and recourse (Brown & Kyttä, 2014; Kitchin, 2013).

5. Cross-Cutting Challenges and Ethical Considerations

5.1 Data quality, uncertainty, and reproducibility

The proliferation of geospatial data does not automatically guarantee reliability or reproducibility. Remote sensing products, VGI, and big data sources often contain systematic biases and uncertainties that must be explicitly acknowledged and, where possible, quantified. Classification errors in land cover products, positional inaccuracies, temporal mismatches, and sensor artefacts can meaningfully affect analyses and policy decisions if left unchecked (Reis, 2008; Potapov et al., 2022).

VGI and PPGIS data are prone to uneven coverage: contributions tend to cluster in affluent, digitally connected areas, while marginalised communities may be under-represented (Goodchild, 2007; Brown & Kyttä, 2014). Brown and Kyttä (2014) document response biases in internet-based participatory mapping, including spatial discounting (tendency to map places closer to home) and differences in mapping effort across socio-demographic groups. Without careful sampling and weighting strategies, such biases can skew planning decisions.

Reproducibility is another concern. Many geospatial analyses involve complex chains of data processing, often conducted through graphical user interfaces or proprietary tools without transparent documentation. Reproducible research practices—using open-source tools, scripting workflows, version control, and sharing of code and data where possible—are increasingly advocated but not yet universal (Masser, 2019; Kitchin, 2013). In policy contexts, the pressure for rapid outputs may conflict with best practices in documentation and validation.

5.2 Privacy, surveillance, and ethics of location data

The widespread collection and analysis of location data raise serious privacy and surveillance concerns. Mobile phone records, GNSS traces, CCTV-linked analytics, and platform data can reveal detailed patterns of individual movement and behaviour, which may be misused by state or corporate actors (Williams et al., 2015; Kitchin, 2013). Even when data are anonymised, re-identification risks persist, particularly when datasets are linked, and differential privacy guarantees are weak or absent (Rowe, 2019; Panigutti et al., 2017).

Public health applications, such as using mobility data to model disease spread or track contacts, have highlighted these tensions. While such analyses can improve epidemic control and resource allocation, they also risk normalising intrusive data collection and eroding civil liberties if not governed by clear legal and ethical frameworks (Elliott et al., 2004; Kauhl, 2017).

Geospatial professionals and researchers face ethical responsibilities in handling sensitive spatial data—about individuals, vulnerable groups, or sensitive facilities. Ethical guidelines emphasise data minimisation, informed consent where feasible, secure storage, and careful consideration of potential harms from data release or mapping (Goodchild, 2007; Brown & Kyttä, 2014).

6. Synthesis and Conclusion

6.1 Gaps, uncertainties, and under-researched areas

Despite these advances, important gaps and uncertainties remain. Technologically, deep learning and other AI methods, though promising, are still relatively new in many application domains; questions about their generalisability, interpretability, and potential biases are not fully resolved (Li et al., 2022; Sun et al., 2023). Similarly, mobile phone and social media data offer powerful proxies for human activity but are subject to selection biases (e.g., who owns a phone, uses particular apps) and governance uncertainties, making them challenging to use for long-term monitoring or cross-country comparisons (Williams et al., 2015; Panigutti et al., 2017).

Substantively, the geographical distribution of geospatial research and application is uneven. Many studies focus on North America, Europe, and parts of East Asia, while large parts of Africa, South Asia, and Latin America remain under-represented in high-resolution mapping, analytics, and participatory initiatives, despite being hotspots of environmental change and development challenges (Masser, 2019; UN-GGIM, 2016). Within countries, informal settlements, rural hinterlands, and marginalised groups are often poorly represented in official and crowd-sourced datasets (Scott, 2016; Brown & Kyttä, 2014).

Methodologically, integration of qualitative and quantitative geospatial methods is still in its infancy. While mixed-methods studies and story mapping approaches exist, there is scope for more systematic frameworks that combine ethnographic, participatory, and statistical analyses within coherent spatial research designs (Sieber, 2006; Brown & Kyttä, 2014). Similarly, the reproducibility of many geospatial analyses—especially those involving proprietary tools, sensitive data, or complex machine learning pipelines—remains limited (Kitchin, 2013; Masser, 2019).

Ethically and institutionally, governance frameworks for location data, AI-based spatial analytics, and cross-border data flows are still evolving. There is considerable uncertainty about how to ensure privacy, prevent misuse, and secure equitable access to geospatial resources while enabling innovation and effective public policy (UN-GGIM, 2016; WHO, 2015).

6.2 Future research directions

Future research in geography and planning can build on current foundations in several ways. One promising direction is the deeper integration of qualitative and quantitative geospatial methods. This might involve combining spatial statistics or machine learning models with participatory mapping, narrative geographies, and ethnography, in order to contextualise patterns, understand lived experiences, and co-produce interventions with affected communities (Sieber, 2006; Brown & Kyttä, 2014). Digital story maps, participatory web atlases, and mixed-methods PPGIS platforms offer concrete starting points for such integration.

A second direction is the development of more inclusive and participatory geospatial approaches. Research is needed on designing PPGIS and PGIS processes that reach marginalised groups, take account of differential digital access and literacy, and ensure that mapped inputs genuinely shape decisions rather than being token additions (Brown & Kyttä, 2014; Chambers, 2006). Comparative studies across contexts could help identify good practices in scaling participatory geospatial methods while preserving depth and equity.

Third, advances in real-time data and urban digital twins offer opportunities and challenges for planning. Research can examine how real-time geospatial data streams (from sensors, mobility traces, remote sensing) can be integrated into planning processes that typically operate on longer time horizons, and how digital twins can support experimentation with adaptation and mitigation strategies under climate change (Batty, 2013; Sun et al., 2021; Sahani et al., 2023). Critical perspectives are essential to avoid unreflective adoption of digital twins and to consider their implications for power, accountability, and public engagement (Kitchin, 2013; Scott, 2016).

Fourth, governance, ethics, and capacity-building deserve sustained attention. Work is needed on legal and institutional frameworks for geospatial data sharing, privacy protection, and algorithmic accountability in spatial decision-support systems (UN-GGIM, 2016; WHO, 2015). The UN-GGIM's Integrated Geospatial Information Framework and SDGs geospatial roadmap provide important reference points, but research can help translate these into context-specific governance arrangements at national and local levels (UN-GGIM, 2016; Scott, 2016). Capacity-building efforts—including curricula in universities, professional training programmes, and community-based education—are essential to ensure that geospatial technologies are used responsibly and inclusively (Masser, 2019; Brown & Kyttä, 2014).

6.3 Concluding reflection

Over the first quarter of the twenty-first century, geospatial technologies have moved from specialised tools in technical agencies to ubiquitous infrastructures woven into everyday life, research, and governance. In geography and planning, they have transformed how space is observed, represented, and governed: enabling finer-grained analyses of environmental change and social inequalities; supporting evidence-based, scenario-driven planning; and opening new possibilities for public participation and co-production (Masser, 2019; UN-GGIM, 2016). At the same time, they have introduced new forms of data power, surveillance, and exclusion that demand critical and reflexive engagement (Kitchin, 2013; Goodchild, 2007).

Looking ahead, the likely trajectories include further integration of AI and real-time sensing, growth of digital twins and smart city platforms, and deeper embedding of geospatial information in global governance of climate, disaster risk, and sustainable development (Batty, 2013; UN-GGIM, 2016). The challenge for geographers and planners is to harness these developments in ways that support not only efficiency and innovation but also justice, inclusivity, and ecological sustainability. Doing so will require technical excellence, methodological pluralism, ethical sensitivity, and a sustained commitment to engaging with the social and political contexts in which geospatial technologies are deployed (Brown & Kyttä, 2014; Sieber, 2006).

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