State of National Spatial Data Infrastructure (NSDI) Globally

Addendum 1: National Case Studies

Research Paper

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1 INTRODUCTION

Spatial Data Infrastructure (SDI) programs are foundational to modern governance and sustainable development, enabling the effective integration, sharing, and use of geospatial data across sectors. This paper presents a global review of SDI programs, analyzing their current status, governance structures, technological trends, economic impacts, and future directions. Drawing on international frameworks and country case studies, it highlights key lessons, innovations, and strategic imperatives to support the transformation of SDI, and National SDI (NSDI) in particular, into a driver of inclusive, resilient, and digitally integrated

The report features national case studies from the United States, European Union, Australia, Kenya, and Saudi Arabia, offering practical insights into the diversity of approaches and lessons learned across different institutional and regional contexts. These case studies highlight the importance of sustained political leadership, clear mandates, robust legal frameworks, strong coordination mechanisms, and partnerships with the private sector, academia, and communities.

Case Studies

1.1 UNITED STATES: FEDERAL GEOGRAPHIC DATA COMMITTEE (FGDC) AND NGDA FRAMEWORK

The United States has long been a leader in the development and promotion of geospatial data infrastructure with its NSDI framework serving as a foundational model for many other nations. At the heart of this effort is the Federal Geographic Data Committee (FGDC), a government-wide body established by Executive Order in 1994 and reaffirmed through legislation in the Geospatial Data Act of 2018.

The FGDC is responsible for coordinating the development, maintenance, and use of geospatial data across federal agencies, in close collaboration with tribal, state and local governments, the private sector, academia, and non-governmental organizations. One of its key tools is the National Geospatial Data Asset (NGDA) framework, which identifies and governs a set of priority datasets deemed essential to the functioning of government and society.

Key Milestones and Achievements

- The **Geospatial Data Act of 2018** gave the FGDC a formal legislative mandate, strengthening its ability to enforce standards and drive interagency collaboration.
- The **NGDA portfolio** currently includes over 150 datasets categorized under 18 thematic data domains (e.g., transportation, land use, water resources, and cadastral data).
- The **GeoPlatform.gov**, managed by FGDC, provides a central hub for accessing NGDA data and associated tools, supporting government transparency, public access, and collaboration.
- FGDC also oversees the implementation of metadata standards, data lifecycle management, and performance reporting for federal geospatial assets.

Challenges

Despite notable progress, the U.S. NSDI faces several enduring challenges:

- **Interoperability Across Jurisdictions**: The decentralized nature of U.S. governance means that tribal, federal, state, and local agencies often collect data using different standards and formats. Aligning these data and systems remains a complex and resource-intensive process.
- **Sustained Investment and Modernization**: While the Geospatial Data Act provides a solid legal foundation, funding for NSDI modernization is inconsistent. Upgrading legacy systems and expanding cloud-based capabilities require sustained financial and political commitment.
- **Security and Privacy**: As agencies push for more open data and real-time sharing, concerns around data privacy, national security, and cyber threats become more prominent. Aligning openness with protection is a continual balancing act.

Opportunities
The U.S. is well-positioned to capitalize on several emerging opportunities:

- **Public-Private Collaboration**: By partnering with the private sector, especially cloud service providers, satellite imagery companies, and analytics firms, the FGDC can enhance data richness and application versatility. Collaborations with tech leaders like Esri, Microsoft, and Google have already shown promise.
- **Leveraging Emerging Technologies**: The integration of cloud computing, AI/ML, and big data analytics offers powerful tools for automating feature extraction, improving data quality, and enabling predictive insights for decision-makers.
- **Risk and Resilience Applications:** The NSDI is increasingly important in addressing environmental and disaster-related challenges. Geospatial datasets are being applied to support flood risk mapping, emergency response to wildfires, coastal planning, and assessments of infrastructure exposure to natural hazards.

Looking Ahead
As the FGDC moves to modernize the U.S. NSDI, its current emphasis includes:

- Strengthening the governance model to enhance collaboration among federal agencies and across sectors.
- Expanding the reach and use of the GeoPlatform, including enhancements to usability, data visualization, and integration with new APIs.
- Encouraging tribal, state and local participation in NGDA management through incentives and capacity-building.
- Focusing the NSDI to be more impact driven based on use cases and the application of emerging technologies like AI/ML, cloud computing and IoT to create a more federated and interoperable ecosystem and further enhance insights and decision-making.

The United States continues to demonstrate leadership in geospatial governance. However, its ability to fully realize the NSDI's potential depends on consistent funding, stakeholder engagement, and the strategic adoption of next-generation technologies.

1.2 EUROPEAN UNION: INSPIRE DIRECTIVE AND CROSS-BORDER SDI HARMONIZATION

The Infrastructure for Spatial Information in the European Community (INSPIRE) Directive is one of the most ambitious and influential regional SDI frameworks in the world. Enacted in 2007, INSPIRE was developed to address a key challenge: while many European countries had their own geospatial strategies and datasets, there was no coherent approach to sharing and using these datasets across national borders—a significant barrier in a union of 27 member states with interconnected economies, shared environmental challenges, and common policy objectives (European Commission, 2007).

INSPIRE provides a legal and technical framework to create a unified, interoperable European SDI that supports environmental policies and enables public access to geospatial information across the European Union (EU). Its implementation is underpinned by technical guidance documents, standardized metadata schemas, and a structured approach to data themes, which include over 34 domains ranging from administrative boundaries and elevation to land cover, transport networks, and environmental monitoring facilities.

Key Achievements

- INSPIRE has led to the standardization of geospatial data models and metadata across member states, improving the accessibility, comparability, and usability of geospatial data.
- It has established national geoportals in every member state and a central EU INSPIRE geoportal, which allows users to discover, view, and download data from across the continent.
- The directive mandates that geospatial data collected by public authorities must be documented, shared, and made accessible to other public bodies and to the public—unless there are overriding confidentiality or security concerns.
- INSPIRE has contributed to enhanced collaboration on issues like air quality, biodiversity conservation, marine spatial planning, and climate adaptation, providing common geospatial reference frameworks.

Challenges

Despite its strong legal foundation and strategic intent, INSPIRE's implementation has encountered several persistent challenges:

- **Inconsistent Implementation Across Member States**: Countries have varying degrees of geospatial maturity, financial resources, and institutional capacity, which has led to uneven progress in meeting INSPIRE obligations. Some nations have fully functional data infrastructures, while others lag behind.
- **Technical and Semantic Complexity**: The directive's requirements for data transformation and harmonization—especially for legacy datasets—are highly technical and resource-intensive, making it difficult for smaller or less-equipped agencies to comply.
- **Policy and Institutional Fragmentation**: Aligning national data governance models with the EU-level framework has proven complicated. National priorities, legal frameworks, and institutional responsibilities do not always align neatly with INSPIRE's vision of a pan-European SDI.

Opportunities

Despite these challenges, INSPIRE presents a number of compelling opportunities for both public and private stakeholders:

- **Cross-Border Data Sharing for Regional Integration**: INSPIRE enables seamless geospatial collaboration between countries on issues like transboundary water management, cross-border transportation networks, and disaster response. For example, joint flood risk management planning in river basins shared by multiple countries now benefits from shared datasets and aligned mapping standards.
- **Improved Environmental Governance**: The directive supports EU-wide policy implementation for climate resilience, sustainability, and biodiversity protection through better data availability, transparency, and comparability.
- **Public-Private Innovation**: INSPIRE's standardized, open-access geospatial data fosters the development of location-based services, real-time analytics platforms, and mobile apps for sectors such as agriculture, transportation, energy, and insurance. The private sector—particularly SMEs and startups—is increasingly using INSPIRE-compliant datasets for value-added services and new market creation.
  Digital and Green Transformation: INSPIRE is well-positioned to support the EU's broader

strategies, including the European Green Deal, Digital Europe, and the implementation of Sustainable Development Goals (SDGs). The integration of INSPIRE with initiatives like Copernicus (Earth Observation) and Eurostat (statistical data) further enhances its utility and relevance.

Looking Ahead
The European Commission and the INSPIRE Maintenance and Implementation Group (MIG) are now looking to simplify implementation by:

- Encouraging the use of APIs and cloud-based services to make data access easier.
- Updating guidance documents to better reflect evolving technologies and user needs.
- Promoting greater synergy between INSPIRE and new digital policy frameworks, such as the EU Data Governance Act and European Spatial Data Strategy.
- Enhancing user-centric design and fostering co-creation with stakeholders to improve adoption and utility.

In conclusion, the INSPIRE Directive remains a cornerstone of the EU's digital and environmental data infrastructure. While the path to full implementation has been complex, its long-term impact on cross-border interoperability, transparency, and innovation is significant. INSPIRE offers a robust example of how regional cooperation, when underpinned by legal mandates and technical standards, can transform fragmented national systems into an integrated, future-ready geospatial ecosystem.

1.3 AUSTRALIA: FEDERATED GOVERNANCE AND THE EVOLUTION OF NSDI

Australia has been a pioneer in the advancement of geospatial infrastructure, with a strong tradition of geospatial data sharing, open data policies, and institutional coordination. However, as noted by Maree Wilson of Geoscience Australia, the term "NSDI" is no longer widely used outside of the geospatial community. Instead, the country has shifted toward operational frameworks such as the Foundation Spatial Data Framework (FSDF), which now serves as the central organizing mechanism for national geospatial data efforts.

The FSDF, developed by the Intergovernmental Committee on Surveying and Mapping (ICSM), provides a standardized national structure across 10 key themes (e.g., positioning, transport, land parcels). It enables practical, theme-based coordination among federal, state, and territory governments. Strategic coordination occurs primarily through inter-jurisdictional working groups and peer networks, rather than through a centralized authority or formal national program manager.

Australia's governance model is deeply federated and collaborative, relying on goodwill and trusted relationships rather than formal mandates. Each jurisdiction retains its own data responsibilities while contributing to national coherence through voluntary alignment. This model works well in practice but introduces vulnerabilities, such as dependence on informal coordination and lack of sustained national funding for NSDI innovation or infrastructure.

Australia has also pivoted toward service delivery and user-centered design. Rather than promoting a single NSDI brand, platforms like data.gov.au and the Digital Atlas of Australia focus on usability, discoverability, and alignment with real-world needs. These tools are designed to serve practitioners and decision-makers more effectively, rather than enforcing uniform infrastructure models.

Standards adoption in Australia is pragmatic. While international standards like those from OGC and ISO are referenced, implementation varies by jurisdiction, with some states and agencies preferring lightweight, fit-for-purpose interoperability approaches. Community practice and peer learning often drive adoption more than national mandates.

Looking ahead, Australia has an opportunity to build on its federated strengths by investing in a shared national vision for future geospatial capability. This includes fostering co-investment in national infrastructure, developing leadership to coordinate across jurisdictions, and supporting innovation through stable, long-term funding. Addressing these needs will be critical as the country navigates demands such as integrating AI, enabling digital twins, supporting environmental resilience, and expanding citizen engagement.

In summary, Australia's NSDI evolution reflects a shift from centralized strategy to decentralized, service-based delivery. The FSDF has become the cornerstone of geospatial data alignment, but long-term success will depend on maintaining collaborative energy, investing in innovation, and strengthening national coordination mechanisms as demands grow more complex.

Key Achievements

- Implementation of the Foundation Spatial Data Framework (FSDF) as the primary coordination mechanism.
- The Digital Atlas of Australia, bringing together curated and trusted national datasets.
- Strong intergovernmental collaboration via ICSM and jurisdictional working groups.
- Broad adoption of operational platforms like data.gov.au and the Digital Atlas of Australia.
- Promotion of user-centered service design over infrastructure branding.

Challenges

- No central NSDI authority or program manager.
- Dependence on informal governance and voluntary coordination.
- Lack of sustained national funding for long-term innovation or infrastructure.
- Variable adoption of standards and uneven capacity across jurisdictions.

Opportunities

- Establishing shared national vision and leadership to sustain alignment.
- Coordinating national investment in innovation, infrastructure, and training.
- Leveraging user-focused platforms for expanded citizen and private sector engagement.
- Strengthening Australia's position as a regional leader in federated geospatial governance.

Looking Ahead

- Develop long-term co-investment mechanisms to support cross-jurisdictional geospatial infrastructure.
- Increase visibility of NSDI principles beyond the geospatial sector to gain broader political and public support.
- Build resilience into governance by formalizing coordination mechanisms where appropriate.
- Expand innovation capabilities, including integration of AI, digital twins, and climate applications.

1.4 KENYA: DEVELOPMENT OF NSDI FOR LAND GOVERNANCE AND URBAN PLANNING

Kenya is one of the leading examples in Sub-Saharan Africa of a country taking deliberate steps to establish an NSDI to address pressing national development priorities, particularly in land governance, urban planning, and disaster management. The country's NSDI efforts are anchored in its long-term National Spatial Plan (NSP) 2015–2045, a strategic framework designed to guide sustainable geospatial development and the efficient use of land and natural resources over a 30-year horizon (Ministry of Lands and Physical Planning, 2015).

The NSP envisions a spatially enabled Kenya, where geospatial information underpins policies and investments in infrastructure, housing, agriculture, environmental conservation, and industrial growth. It

also aims to enhance public service delivery, transparency, and citizen participation, particularly in land management—a sector historically plagued by inefficiencies and disputes.

Key Achievements

- The government, through the Ministry of Lands and Physical Planning and the Kenya National Bureau of Statistics, has digitized key land records and administrative boundaries, forming the backbone of a national cadastral database.
- Kenya has made strides in integrating geospatial technologies into urban planning, including in metropolitan areas like Nairobi and Mombasa, where geospatial planning tools are used for zoning, informal settlement upgrading, and transport network design.
- The NSDI has supported the development of disaster preparedness frameworks, including flood risk mapping and drought monitoring, in partnership with agencies such as the National Disaster Operations Centre (NDOC) and international donors.
- Kenya's NSDI efforts are aligned with its Vision 2030 development agenda, which emphasizes data-driven governance and digital transformation.

Challenges

Despite this progress, Kenya faces several significant challenges in scaling its NSDI:

- **Limited Financial Resources**: NSDI development is capital-intensive, and Kenya has had to rely heavily on external funding from multilateral development banks and international donors. Domestic budget allocations remain insufficient to fully support infrastructure development, data acquisition, and maintenance.
- **Technological Constraints**: Access to high-resolution satellite data, robust cloud infrastructure, and advanced processing tools remains limited, particularly outside urban centers.
- **Capacity Gaps**: There is a shortage of skilled geospatial professionals in the public sector, and limited opportunities for continuous training in data science, GIS, and remote sensing.
- **Fragmented Institutional Arrangements**: Multiple agencies collect geospatial data independently, often using different formats and standards, leading to data duplication and poor interoperability.

Opportunities

Nonetheless, Kenya's NSDI presents promising opportunities to transform how the country manages land and urban growth:

- **International Collaboration and Funding**: Kenya has received support from institutions such as the World Bank, United Nations Development Programme (UNDP), United Nations Habitat, and the U.S. Agency for International Development (USAID), which have funded projects in land information management, disaster resilience, and urban planning. Strengthening such partnerships can bring both technical and financial resources.
- **Leveraging Mobile and Cloud Technology**: Kenya's leadership in mobile innovation (e.g., M-Pesa) offers a strong foundation to integrate mobile platforms into land governance. Mobile GIS tools can be used for citizen reporting, crowdsourced mapping, and participatory planning, especially in informal settlements.
- **Regional Leadership**: Kenya's growing role in regional initiatives, such as the Eastern Africa NSDI Consortium, African Union's geospatial programs and Digital Earth Africa, positions it to benefit from shared infrastructure, knowledge exchange, and harmonized policy frameworks.
- **Open Data and Civic Engagement**: The Kenyan government has launched initiatives like the National Land Information Management System (NLIMS) and eCitizen portal, which improve public access to land records and enable greater transparency in land transactions and planning processes.

Looking Ahead
Kenya's NSDI is a work in progress, but it reflects a strong political will to integrate geospatial intelligence into national development planning. The country's focus on using geospatial data to resolve land tenure issues, manage urban expansion, and build climate resilience aligns with global SDGs and the United Nations Global Geospatial Information Management (UN-GGIM) Africa agenda.

Key next steps for Kenya's NSDI include:

- Developing a comprehensive geospatial data sharing policy across all levels of government.
- Expanding training programs and technical education in GIS and remote sensing at both university and civil service levels.
- Strengthening public-private partnerships to drive innovation in geospatial data applications, particularly in housing, transport, and agriculture.
- Investing in open-source platforms and regional data hubs to reduce reliance on expensive proprietary systems.

In conclusion, Kenya's journey in building an NSDI demonstrates both the potential and the hurdles faced by developing countries. Its commitment to integrating geospatial data into national policy, despite financial and institutional constraints, serves as an encouraging model for others across Africa and the Global South.

1.5 SAUDI ARABIA: NATIONAL GEOSPATIAL STRATEGY AND VISION 2030

Saudi Arabia's National Geospatial Strategy (NGS) is a central pillar of the country's ambitious Vision 2030 agenda—a national transformation initiative aimed at diversifying the economy, modernizing infrastructure, and positioning the Kingdom as a global leader in innovation (Saudi Vision 2030, 2025). The NGS represents a strategic shift in how Saudi Arabia collects, manages, and utilizes geospatial information to achieve its development goals.

The strategy is overseen by the General Authority for Survey and Geospatial Information (GASGI) and seeks to establish a comprehensive, interoperable, and secure geospatial data ecosystem. It focuses on leveraging AI, remote sensing, and geospatial analytics to support national priorities such as smart city development, infrastructure optimization, environmental sustainability, and national security.

Key Achievements
- Saudi Arabia has initiated efforts to harmonize geospatial data production across ministries, including transport, housing, energy, and defense, to eliminate duplication and improve data integration.
- Through the NGS, the country is developing geospatial infrastructure standards, metadata protocols, and a unified national geoportal to enhance accessibility and coordination.
- The strategy prioritizes the use of AI and machine learning to automate geospatial analytics for applications such as traffic modeling, energy grid optimization, water resource monitoring, and real-time environmental surveillance.
- Saudi Arabia has invested in building its space and Earth observation capabilities, including partnerships with regional and global space agencies to enhance access to satellite data and imagery.

Challenges
As with many NSDI implementations, Saudi Arabia faces several complex challenges in fully realizing the vision of its NGS:

- **Interoperability Across Stakeholders**: The Kingdom's highly siloed government structure means that data standards, platforms, and priorities vary widely between ministries, agencies, and municipalities. Achieving seamless data exchange across sectors—especially between defense, civil services, and private companies—is a major hurdle.
- **Balancing Openness with Security**: While there is growing emphasis on open data policies and digital transparency, these efforts are often tempered by national security and strategic infrastructure concerns, especially in defense, oil and gas, and border regions. Finding the right balance between data openness and protection remains a sensitive and complex issue.
- **Human Capital and Institutional Capacity**: Despite growing investment, there is still a limited pool of local geospatial professionals, and institutional knowledge varies widely. Building the workforce and geospatial literacy across all sectors is a continuing challenge.

Opportunities
Saudi Arabia's NGS opens numerous pathways for leadership and innovation:

- **Becoming a Global Geospatial Technology Leader**: With strong financial resources and policy commitment, Saudi Arabia is uniquely positioned to lead regional and global conversations on geospatial governance, digital transformation, and smart cities. Its investments in high-performance computing, cloud services, and space technology provide a powerful foundation for cutting-edge geospatial applications.
- **Accelerating Digital Transformation**: The NGS is a key enabler of Vision 2030's digital goals, including e-government services, smart infrastructure, urban mobility systems, and AI-powered public service delivery. Integrated geospatial data enhances situational awareness and real-time decision-making across sectors.
- **Smart City Development**: Flagship urban development projects such as NEOM, The Line, and Qiddiya are designed as fully integrated smart cities, where geospatial intelligence is embedded in everything from energy distribution and waste management to citizen services and autonomous transport.
- **Regional Collaboration and Influence**: Saudi Arabia has the opportunity to shape geospatial policy across the Gulf Cooperation Council (GCC) and broader Middle East and North Africa (MENA) region. By aligning with global standards (OGC, ISO) and contributing to international geospatial dialogues (e.g., UN-GGIM), the Kingdom can strengthen regional interoperability and leadership.

Looking Ahead
To sustain momentum and maximize the impact of its NGS, Saudi Arabia must:

- Finalize and enforce national geospatial data standards across all sectors and levels of government.
- Develop robust data governance frameworks that clarify roles, responsibilities, and protocols for data sharing, licensing, and security.
- Invest in geospatial education and professional development programs to grow a domestic talent pipeline and reduce dependency on international consultants.
- Promote public-private partnerships that encourage co-creation of geospatial services, especially in infrastructure, logistics, and environmental monitoring.
- Ensure that open data initiatives are secure, scalable, and aligned with both economic and national security interests.

Saudi Arabia's case is a compelling example of how NSDI can serve as a catalyst for broader economic transformation. Its comprehensive vision, backed by financial and political capital, places it in a unique position to define the next generation of geospatial innovation—not just within its borders, but on the global stage.

2 SUMMARY OF CASE STUDIES

Country	Name of the Strategy	Key Achievements	Challenges	Opportunities	Looking Ahead
United States	Building the Geospatial Future Together – the NSDI Strategic Plan 2025-2035	- Formalized FGDC role through 2018 Act- 170+ NGDA datasets s 18 themes- atform.gov for open data s- Standardized metadata ecycle governance	- Jurisdictional interoperability- Inconsistent local funding- Balancing open data and security	- Public-private collaboration (e.g., Esri, Microsoft)- AI, cloud integration- NSDI support for climate resilience	- Strengthen federal governance and agency alignment- Enhance GeoPlatform usability- Expand local and global collaboration
European Union	INSPIRE Directive	- Legal foundation for cross-border SDI- Standardized metadata/data models- EU and national geoportals- Enabled data-sharing for environmental policy	- Uneven national implementation- Complex technical and semantic requirements- Institutional fragmentation	- Regional data-sharing for integration- Supports climate, biodiversity, disaster resilience- Fuels private sector innovation	- Simplify through APIs/cloud services- Align with EU data governance laws- Improve user design and engagement
Australia	Foundation Spatial Data Framework (FSDF)	- Federated coordination across 10 themes- Strong intergovernmental working groups- User-centered tools (data.gov.au, LIF)- Flexible adoption of standards	- No central NSDI authority- Informal governance- Inconsistent funding- Jurisdictional disparity in standards	- Co-investment in infrastructure- Broaden private/citizen engagement- Leverage regional leadership position	- Build formal governance mechanisms- Promote national vision for innovation- Integrate AI, digital twins, and climate tools
Kenya	National Spatial Plan (2015–2045)	- Digitized land and boundary records- Urban planning in major cities- Disaster risk mapping- Aligned with Vision 2030	- Reliance on donor funding- Limited cloud/data infrastructure- Skills shortages- Fragmented data practices	- Leverage mobile/cloud tech for land governance- Expand regional leadership roles- Use open data for transparency and participation	- Develop national data sharing policies- Expand GIS education- Strengthen PPPs and open-source infrastructure
Saudi Arabia	National Geospatial Strategy (NGS)	- Cross-ministry data harmonization- Unified geoportal and metadata protocols- AI/ML analytics for infrastructure and environment- Space agency partnerships	- Inter-ministerial silos- Security vs. openness tension- Low domestic geospatial capacity	- Regional/global leadership role- Smart city and digital government applications- Strong PPP and tech investments	- Enforce national standards- Grow domestic talent pool- Align open data with national security- Institutionalize PPP co-creation models