Using Geospatial Information to Support Foresight and Technology Assessment for STI for SDGs Roadmaps

Working Paper by Wei Liu and Azeema Adam[*]

Prepared for the Session on Applying Strategic Foresight to STI Roadmaps for SIDS, Capacity Building Workshop for Small Island Developing States (SIDS): Leveraging Big Earth Data to Evaluate the SDGs Progress, Beijing, China,1-8, September 2025

2nd Oct. 2025

1. Context

The United Nations Futures Lab defines foresight as “an approach and a set of tools specifically designed to deal with uncertainty.”[1] In the language of UN 2.0, foresight requires capacities to discern emerging trends, anticipate potential shifts, and respond proactively. It contributes to long-term thinking, strategic planning, and readiness for a spectrum of possible futures. For policy-makers in Small Island Developing States (SIDS), this is particular critical: Science, Technology and Innovation (STI) for SDG Roadmaps provide a structured approach to accelerate progress on the Goals, enabling governments to align technology and innovation with their unique vulnerabilities and opportunities.[2]

Good data is central to this process. Policy roadmaps are only as strong as the evidence underpinning them, and geospatial information and data offers a distinctive advantage by adding the “where” dimension to the “what” and “why” of traditional data. This spatial lens

[*] Authors are grateful for inputs and feedback from Alfred Watkins, Astra Bonini, Bill Kelly, Charles William Noble Davies, Chen Deliang, Declan Kirrane, Manuel Ricardo Galindo Moreno, Monica Nogara, Gong Ke, Guo Huadong, Guillaume Le Sourd, He Changchui, Heide Hackmann, Jian Zhang, John Ouma Mugabe, Li Jinliang, Li Jinghai, Luis Gerardo Gonzalez Morales, Motoko Kotani, Quarraisha Abdool Karim, Richard A. Roehrl, Sai Navoti, Sun Zhongchang, Vanessa McBride, Veerle Vandeweerd, Xavier Estico, Xinyi Zhang, and Xu Zhengzhong. Authors would like to thank Gregory Mcgann and Xiangyi Zhang for their research assistance. The views expressed in this paper are the personal views of the authors and do not necessarily represent the views of the United Nations or its Member States. Any mistake or omission in this working paper is the sole responsibility of the authors.

[1] https://un-futureslab.org/wp-content/uploads/2025/01/UN-Futures-Lab_UN-Strategic-Foresight-Guide-2023.pdf

[2] This work responds to global mandates for anticipatory governance and realizing full potential of STI, including: The Pact for the Future's call to leverage "science, data, statistics, and strategic foresight to ensure long-term thinking and planning" and make governance "more anticipatory, adaptive, and responsive to future opportunities, risks, and challenges" (A/RES/79/1, para. 16). Its emphasis on "investing in capacity to better prepare for [...] future global shocks" using "evidence-based planning and foresight" (A/RES/79/1, para. 17). The Global Sustainable Development Report 2023 finding that "anticipatory approaches to governance and the use of foresight are needed to deal with [...] interconnected crises". FfD4 (Compromiso de Sevilla) call to support “countries to develop and implement mission-oriented, country-led national innovation strategies, including STI4SDG roadmaps and national roadmaps for digitalization involving relevant stakeholders […]”.

helps identify location-specific challenges and opportunities—such as coastal erosion, freshwater scarcity, or urban expansion—that are particularly relevant for SIDS. By integrating geospatial data with socio-economic datasets, policy-makers gain a unified, place-based understanding of development challenges (the "what is") that can facilitate targeted and effective STI investments.

At the same time, foresight analysis is becoming increasingly important in the UN 2.0 era and within the framework of the Pact for the Future. Foresight helps predict feedback loops, anticipate shocks, and identify long-term trade-offs and synergies among Goals and Targets (exploring the "what could be")—ensuring that short-term solutions do not create long-term risks. This capacity to anticipate and prepare strengthens the ability of governments to navigate uncertainty and plan for resilience.

The benefits of combining foresight and geospatial information/data are particularly powerful for STI for SDG Roadmaps. Together, they ensure that strategies are both evidence-based and future-oriented, helping countries avoid lock-in to unsustainable pathways while taking advantage of near-term opportunities. This integration of foresight, reinforced by geospatial data, strengthens the long-term policy relevance and impact of STI for SDG Roadmaps, making them actionable tools to advance sustainable development in SIDS and beyond.

This integrated approach is critical for addressing the specific sustainable development challenges faced by SIDS. By systematically applying geospatial foresight, policymakers can directly tackle problems such as coastal erosion and sea-level rise (SDGs 13 and 14), freshwater scarcity and saltwater intrusion (SDG 6), food insecurity exacerbated by climate change (SDG 2), and unplanned urban expansion (SDG 11). The potential contribution is significant; for instance, targeting investments in AI-powered early warning systems could reduce agricultural losses from pests by an estimated 20-30%, directly supporting SDG 2. Similarly, deploying geospatial tools for sustainable coastal zone management could protect the livelihoods of millions in coastal communities, contributing to SDGs 1, 8, and 14. This paper provides a framework to quantify these impacts and channel STI investments where they are most needed.

The following sections compile some options for using strategic foresight and geospatial information/datasets in the development of STI4SDG roadmaps. They provide some examples of how this combined approach leveraging geospatial information to operationalize foresight, can be operationalized in a coherent and practical manner.

2. Introductory Steps

Building on this policy rationale, this section outlines practical resources on how foresight and geospatial approaches can be applied in STI for SDG Roadmaps. In this context, it is important to recognize that STI foresight (STIF) and technology assessment (TA) are distinct yet complementary approaches to understanding and managing technological change.[3] STI foresight focuses on identifying and anticipating emerging scientific advances, technologies, and innovation pathways and their potential long-term impacts, exploring "what could be" (guiding strategic vision). It examines cross-disciplinary trends that may dominate in 10-20 years. As educated estimates about future science and technological landscapes, these exercises help developing countries – who may not influence long-term trajectories – prepare to harness benefits and mitigate impacts for their development objectives. Modern data science, including predictive modeling and machine learning, is crucial here, allowing policymakers to simulate the potential impact of different STI policies and interventions under various future scenarios.

Technology assessment (TA), in contrast, focuses specifically on currently available technologies to determine their suitability for solving specific socio-economic problems within a country's unique context. Whether technologies originate internationally or locally, TA evaluates near-term feasibility and consequences, providing evidence-based insights into "what is" or "what will likely be" (ensuring implementability) with greater certainty.

Integrating both STIF and TA into the roadmapping process, ensures that STI roadmaps are both future-oriented and pragmatically aligned with current capacities, policy contexts, and societal needs. It helps craft STI roadmaps that solve development challenges through context-appropriate adoption. Critically, geospatial information/data serves as the connection tissue between these approaches, enabling evidence-based exploration of "what could be" (through STIF) and "what is feasible" (through TA)." Geospatial information management, inclusive of data from in situ collection and remote Earth observations, is critical for a whole-of-government that promotes collaboration and coordination across all government ministries, departments, and agencies to effectively use data for national development. Geospatial information enables to break down "silos" and integrate data to create more coherent and effective policy, planning, and service delivery.[4]

The following steps provide a practical starting point for leveraging geospatial information to integrate STIF and TA in national Science, Technology, and Innovation (STI) roadmap development to support progress on the SDGs. This approach ensures roadmaps are visionary yet grounded in reality. Geospatial information is essential because it could use real-world locations to test whether long-term plans are realistic and if specific technologies will work in the places they're needed.

---

[3] UNIDO. (2005). *Technology Foresight Manual: Organization and Methods*. United Nations Industrial Development Organization. And European Parliamentary Technology Assessment (EPTA) Network website: https://www.eptanet.eu/what-is-ta

[4] The United Nations Integrated Geospatial Information Framework (UN-IGIF) and the Global Statistical Geospatial Framework (GSGF) are frameworks to leverage all forms of geospatially integrated data to support evidence-based decision-making and STI foresight.

While geospatial information offers immense potential, users must also be aware of its unique challenges. These include ensuring data quality, resolution, and interoperability; addressing issues of availability and bandwidth, particularly in SIDS and remote areas; and building the specific technical expertise needed to process, analyze, and interpret complex spatial datasets effectively. Acknowledging these challenges is the first step towards mitigating them through targeted investment and partnerships. Countries or local governments may adopt these steps to their unique contexts, considering local implementation capacities (technical expertise, data infrastructure); policy cultures (centralized vs. decentralized governance); development priorities (e.g. SIDS vs. landlocked nations); and resource constraints (financial, human, technical). The following steps are presented for illustrating and structuring the information. Flexibility in sequencing, scaling, or combining steps is encouraged to ensure relevance and ownership.

Step 1 – Define the Purpose and Scope

Begin by setting or clarifying the national STI objectives in relation to the SDGs. Identify thematic focus areas where geospatial datasets can bridge STIF and Technology Assessment (TA) (e.g. climate resilience, renewable energy).

Step 2 – Assemble Relevant Geospatial and Contextual Datasets

Collect and curate relevant geospatial and contextual datasets (e.g., from the International Research Center of Big Data for Sustainable Development Goals (CBAS)) covering environmental, demographic, and socio-economic variables with infrastructure including dedicated satellites.[5] Complement these with non-spatial datasets addressing contextual factors critical to roadmap implementation, such as workforce skills training, local supply chain development, implementation arrangements, business models, and financial viability. Ensure all datasets meet standards for quality, compatibility, and granularity for meaningful analysis.

There is a wealth of existing geospatial datasets and tools, and the priority should be enabling countries to access and utilize these resources effectively. For example, the NOAA Digital Coast platform provides coastal management data and tools that could be particularly useful for SIDS. A key question for policymakers is: What would it take to make Digital Coast, or a similar tool, available and adapted to SIDS?

[5] The Global Fundamental Geospatial Data Themes as the foundation of the 'Data and Evidence Base' themes offer a practical environment for understanding and modelling emerging technologies, trends, risks, and opportunities over the 10-20-year horizon.

Step 3 – Apply STI Foresight to Anticipate Long-Term Pathways[6]

Use geospatial and other contextual analysis to identify emerging trends, risks, and opportunities over 10–20-year horizons.[7] Explore potential technological solutions and innovation pathways through scenario development. Leverage modern data science and analytics, such as machine learning and predictive modeling, to move beyond observing patterns to simulating the potential impact of different policy choices.[8]

Suggestions were also made to focus on practical foresight tools rather than abstract definitions. By showcasing specific methods, countries can identify tools suited to their contexts and capacities. A useful reference in this regard is the Guide to Anticipation: Tools and Methods of Horizon Scanning and Foresight, which provides practical entry points for integrating foresight approaches into national planning.

While foresight can be used to prevent technological lock-in for long-term infrastructure/ policy decisions,[9] immediate objectives (e.g., currently available solutions with High Technology Readiness Level (High-TRL))[10] require outcomes of near-term technology assessment (Step 4). Countries balance this tension through staged roadmaps: using foresight to safeguard long-term flexibility and avoid path dependency, while employing rapid TA to identify and deploy proven technologies for tangible short-term gains.

[6] The processes in Step 3 (foresight) and Step 4 (technology assessment) are often iterative and interchangeable. Insights from assessing current technologies (Step 4) can refine long-term scenarios, while foresight exercises (Step 3) can help prioritize which technologies to assess.

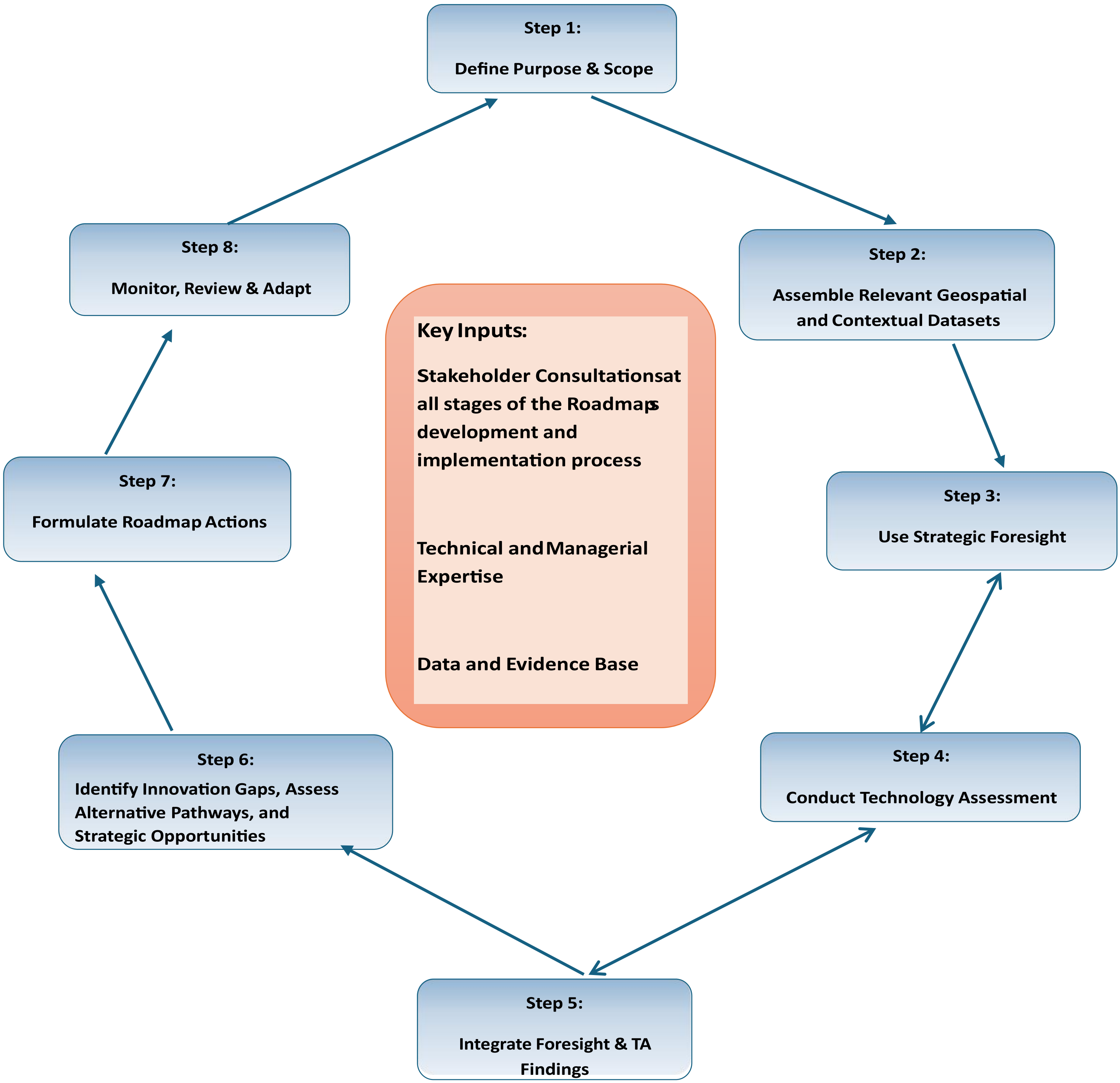
[7] See for example, SDG Geospatial Roadmaps: https://ggim.un.org/meetings/GGIM-committee/11thSession/documents/The_Geospatial_SDGs_Roadmap_WGGI_IAEG_SDGs_20210804.pdf

[8] This is a significant undertaking that lies at the heart of using geospatial data to inform long-term policy. However, it is also a step for which many Small Island Developing States (SIDS) may have limited in-house capacity. This underscores the importance of strategic partnerships with research institutions, international organizations, and other technical partners to co-develop these critical analyses. Section 4.6 outlines first few steps. Dedicated tutorial or 'playbook' needs to be developed.

[9] Technological lock-in is an economic and strategic concept where a market, industry, or society becomes dependent on a specific technology or system, making it difficult, expensive, or impractical to switch to a superior alternative, even when one becomes available (UNIDO, 2005).

[10] High Technology Readiness Level (High-TRL) refers to technologies that are demonstrated, validated, and ready for near-term deployment – typically aligning with immediate objectives like off-grid power within 2-5 years. Low Technology Readiness Level (Low-TRL) refers to early-stage technologies requiring further R&D and validation before scaling, typically at lab or prototype phase (such as experimental nano-filters), with deployment timelines of 5+ years. Low-TRL innovations require patient investment for long-term impact. Countries need to prioritize low-TRL technologies in foresight exercises to prepare for future opportunities/risks.

Diagram 1: Using STI Foresight, Technology Assessment and Geospatial Datasets for National STI Roadmaps



Source: authors elaboration, and United Nations Inter-Agency Task Team on Science, Technology and Innovation for the SDGs (UN IATT) and European Commission, Joint Research Centre, *Guidebook for the Preparation of Science, Technology and Innovation (STI) for SDGs Roadmaps*, 2021.

Step 4 – Conduct Technology Assessment (TA) on Priority Options

For the technologies highlighted in step 3, assess their near-term feasibility of STIF identified technologies, using location-specific geospatial constrains[11]. Consider local capacities, regulatory frameworks, and socio-economic contexts to determine "what is" achievable and "what will likely be" The most effective and sustainable solutions for the specific national or local context.

It was stressed that high Technology Readiness Levels (TRLs) do not necessarily indicate a technology's usability in every context, particularly for SIDS. Even technologies that are technically mature may face barriers such as cost, infrastructure requirements, regulatory environments, or limited local capacity. Therefore, context-specific assessments remain critical to ensure that technologies are not only available but also implementable and sustainable in SIDS and other developing contexts.

Step 5 – Integrate Foresight and TA Findings

Synthesize long-term visions with near-term feasibility to create a strategic pathway. Employ methods like back-casting – working backward from a desired future – to identify immediate, evidence-based actions that lay the foundation for long-term aspirations. This ensures today's investments in viable technologies directly enable the transition toward tomorrow's strategic goals.

Step 6 – Identify Innovation Gaps, Assess Alternative Pathways, and Strategic Opportunities

Highlight areas where R&D, skills development, policy adjustments, or market incentives are needed. Systematically assess alternative pathways and scenarios to address these gaps, evaluating their potential impacts, resource requirements, and alignment with long-term strategic visions. Use combined foresight, TA insights to prioritize interventions with the greatest short- and long-term impact. Critically, these gaps are not only technological but also datarelated. A key strategic opportunity often involves addressing the gap in local capacity to collect, analyze, maintain, and utilize geospatially-enabled datasets effectively.[12]

[11] See for example, Future Geospatial Information Ecosystem https://ggim.un.org/meetings/GGIMcommittee/15th-session/documents/25-00062_UNGGIM_GeospatialEcosystem_report.pdf

[12] ECOSOC Resolution 2022/3 "Emphasizes the importance for Member States to build resilient, agile, relevant, responsive and robust statistical and data systems adhering to the Fundamental Principles of Official Statistics that fully integrate geospatial information and to seek improved coordination across national statistical and data systems through an expanded role of the national statistical offices in the changing data landscape". ECOSOC Resolution 2022/24 "Reiterates the importance of strengthening and enhancing the effectiveness of the Committee of Experts, particularly for the achievement of its operations focused on the Sustainable Development Goals and the Integrated Geospatial Information Framework, to strengthen and ensure its continued effectiveness and benefits to all Member States"

Step 7 – Formulate STI Roadmap Actions[13]

Translate foresight and technology assessment insights into concrete policy measures. Specifically, develop policy reforms such as R&D incentives, regulatory standards adjustments, and targeted funding mechanisms to enable technology deployment. Establish implementation capacity through workforce development programs aligned with emerging technological needs, local supply chain strengthening, and operational systems for maintaining technologies at scale. Design sustainable business models that address deployment costs and income generation potential to improve affordability and financial viability. Embed cross-cutting priorities including gender equality—ensuring women's participation in STEM training and technology access—and inclusivity for marginalized communities across all actions.[14]

Step 8 – Monitor, Review, and Adapt

Define measurable indicators (including those derived from geospatial datasets) to track roadmap progress. Schedule regular reviews to revisit both foresight scenarios and TA results, adjusting course as new developments arise.

3. Examples of Aligning STI Foresight and Technology Assessment with STI Roadmapping

Integrating STI foresight and technology assessment into STI roadmapping enables countries to systematically anticipate emerging challenges – converting potential accidental events in technological transformation into manageable trends – while taking practical action on near-term opportunities. To make the connection to foresight explicit, these examples demonstrate not only how data can highlight gaps, but also how foresight can be applied to anticipate future needs, risks, and externalities. By doing so, they shift from merely diagnosing present gaps to inspiring long-term planning and future-oriented action. This foresight allows possible future trends (e.g., ecological damage, often perceived as unanticipated outcomes) to be considered systematically, helping ensure that short-term investments (e.g. AI-powered early warning systems and smart infrastructure) are robust in the face of possible long-term changes and contribute to possible long-term priorities. In other words, the value of linking these data-driven insights to foresights lies in identifying not only "what is" but also "what could be" if trends

---

[13] Also see: United Nations Inter-Agency Task Team on Science, Technology and Innovation for the SDGs (UN IATT) and European Commission, Joint Research Centre, *Guidebook for the Preparation of Science, Technology and Innovation (STI) for SDGs Roadmaps*, 2021. It provides guidance for developing Science, Technology, and Innovation (STI) roadmaps to achieve Sustainable Development Goals (SDGs), offering frameworks, methodologies, and pilot country insights to strengthen national and international efforts.

[14] A more detailed discussion of these deployment, implementation and roadmap issues is available in the synthesis and summaries of the 2018, 2019, and 2023 Global Solutions Summits which convened at UN Headquarters in New York City at the margins of the annual Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs. The overarching theme of each Summit was Scaling Technology Deployment for Achieving the SDGs in Emerging Markets.

continue, evolve, or converge with external drivers. This distinction between diagnosing present states ("what is") and anticipating future scenarios ("what could be") is central to robust policymaking. By linking these data-driven insights to identified gaps and technology readiness levels, policymakers can prioritize interventions that are both forward-looking and immediately actionable.

The table below presents illustrative examples of how this alignment can be achieved. It demonstrates how geospatial data serves both functions, and how deliberately applying a foresight lens shifts the focus from reactive gap-filling to inspiring proactive, future-oriented strategy. A single data insight can often reveal multiple, context-dependent gaps and opportunities; the examples provided are entry points for consideration rather than an exhaustive list. It is important to clarify, however, that some cases in the table (such as cropping intensity data) represent the use of data primarily to diagnose current SDG gaps and inform near-term policy responses, rather than foresight per se. In contrast, foresight requires deliberate anticipation of future scenarios, risks, and opportunities. For example, linking cropping intensity data with long-term projection or demographic shifts transforms the analysis into a foresight exercise that can inspire broader roadmapping efforts.

Thus, Table 1 should be read as containing both diagnostic uses of data and opportunities for foresight integration. Where foresight is applied, the examples show how externalities, uncertainties, or long-term systemic risks can be incorporated into decision-making, making STI4SDG roadmaps more resilient and adaptive.

Table 1: Aligning STI Foresight and Technology Assessment with STI Roadmapping

Data Insight / Problem	Foresight Component	STI Gap or Opportunity	Priority Action[15]
Cropping intensity data (SDG 2) reveals regions with low agricultural productivity.[16]	Anticipate long-term stress on food security from climate change (e.g., more frequent droughts). Explores scenarios where current practices become unsustainable.	Need to enhance productivity through advanced agricultural practices.	Invest in precision agriculture (drones, IoT sensors) and R&D for drought-resistant crops.

[15] Financial and implementation viability must be explicitly addressed for all proposed actions. This requires: **Defining financing mechanisms** (e.g., blended public-private funding, impact investment, or targeted subsidies); **Identifying deployment entities** (e.g., social enterprises, utility companies, or farmer cooperatives); and **Validating business models** (e.g., fee-for-service, output-based contracts, or cross-subsidization). Roadmap actions should specify these elements during stakeholder engagement (Step 5) and feasibility testing (Step 6) to ensure real-world execution.

[16] GAEZ data from FAO on suitable zone for agricultural production https://www.fao.org/gaez/en

Data Insight / Problem	Foresight Component	STI Gap or Opportunity	Priority Action[15]
Desert locust outbreaks (SDG 2) threaten food security.	Anticipates that climate change may increase the frequency and geographic range of pest outbreaks.	High-TRL opportunity to improve pest management.	Deploy existing AI-driven pest-warning systems at scale.
High algal bloom frequency (SDG 6) indicates inadequate water treatment.	Anticipate worsening water quality due to agricultural runoff and rising ocean temperatures.	Low-TRL gap in effective water treatment solutions.	Advance bio-remediation or nano-filtration technologies from lab to pilot scale.
Global photovoltaic affordability and distribution data of photovoltaic power plants (SDG7) reveal the global expansion pattern of photovoltaic power plants.	Anticipates future energy access gaps and explores scenarios for decentralized, smart, resilient energy systems to power sustainable development.	Need to improve global renewable energy accessibility and transformation processes.	Fund in urban distributed rooftop photovoltaic systems and off-grid solar systems
Urban impervious surface area data (SDG 11) indicates unplanned urban expansion.	Anticipates future strains on housing, transportation, and public services from rapid urbanization. Scenarios model livability under different growth patterns.	Gap in affordable housing and equitable access to urban services.	Invest in innovative construction technologies (e.g. 3D printing) and data-driven public service allocation tools, such as AI-based traffic management.

Source: authors' elaboration.

Box 1: How to Interpret Table 1: Diagnostic vs. Foresight Examples

Diagnostic examples: Cases where data highlights a present SDG gap and suggests immediate policy or technology responses (e.g., cropping intensity data, algal bloom frequency).

Foresight examples: Cases where data is used to anticipate future risks, externalities, or long-term trends that require proactive planning (e.g., desert locust outbreaks as a recurring risk, or urban expansion linked with future demographic pressures).

Blended opportunities: Several examples can serve both functions depending on whether they are interpreted solely as diagnostics or integrated into foresight-driven scenarios (e.g., PV expansion data analyzed alongside long-term energy transition pathways).

This distinction helps policymakers understand that the same dataset can either inform today's action or be leveraged for foresight, depending on how it is applied.

Source: authors' elaboration.

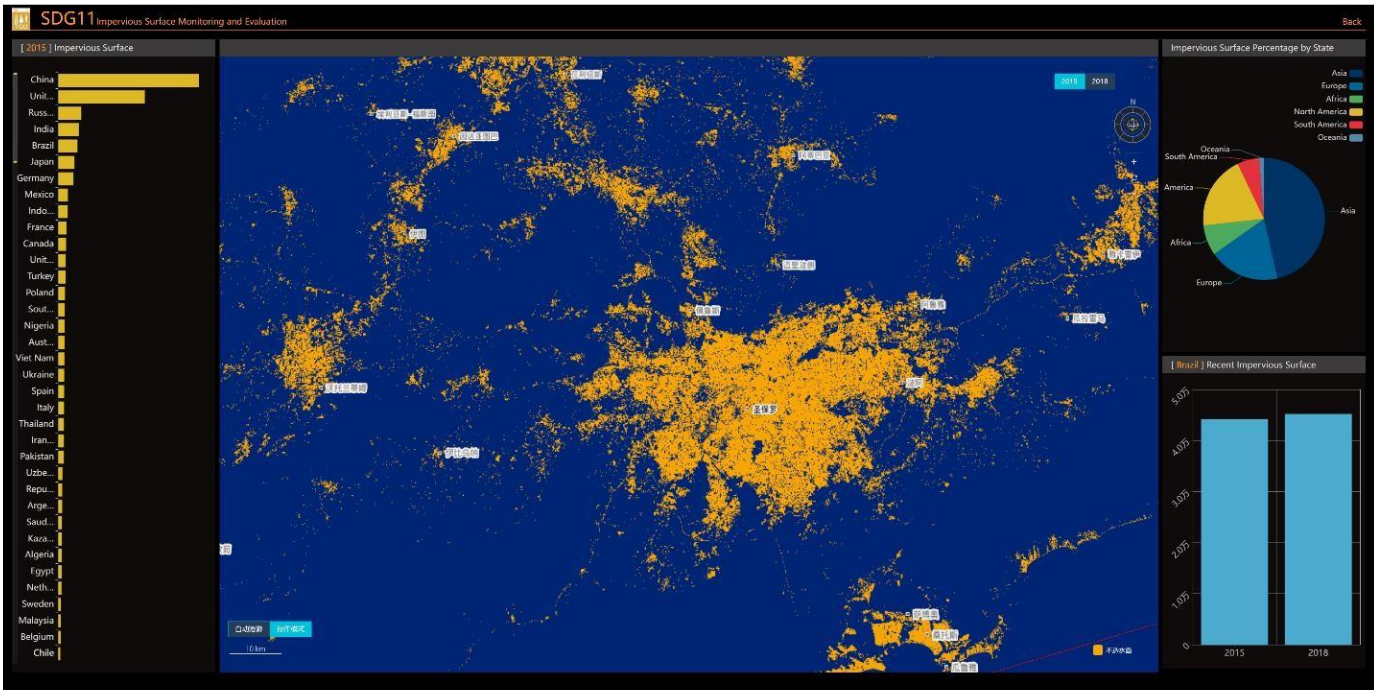
3.1. Identify Critical STI Gaps and Opportunities

Geospatial data can reveal not just current critical gaps but, when use in foresight, helps anticipate future deficits, and direct STI investments toward specific SDGs. For example, cropping intensity data (SDG 2) does more than pinpoint low agricultural productivity today; it helps model future food insecurity under climate change scenarios. In such cases, the STI priority could be to invest in precision agriculture technologies—such as drones and IoT-based sensors—or to support research and development for drought-resistant crop varieties.

Similarly, analyzing global photovoltaic (PV) affordability and distribution data (SDG 7) can reveal expansion patterns of PV power plants. Insights from this analysis could direct technology innovation investment toward green energy technologies, such as urban distributed rooftop PV systems and off-grid solar systems, to improve global energy accessibility and transformation.

Another example is the analysis of urban impervious surface area data (SDG 11) – a classic foresight exercise. It isn't just about mapping out current sprawl patterns of unplanned urban expansion (see Figure below), but about modeling future and population growth, infrastructure strain, and climate vulnerabilities (e.g. heat islands). This anticipatory analysis justifies STI roadmap actions for smart city technologies today to build resilience for the cities tomorrow.

Figure 1: Using Impervious Surface Data to Target STI Investments in Smart City Technologies



Note: Global Urban Watch System (High-resolution Global Impervious Area (Hi-GISA) products, provided by CBAS.

3.2. Map Data Trends to Technology Readiness Levels (TRLs)

The foresight process is crucial for strategically allocating resources between near-term and long-term technologies. It helps avoid locking into solutions that may be obsolete tomorrow while still capitalizing on ready-to-deploy technologies today. For low-TRL gaps, foresight identifies emerging future challenges that lack ready solutions. One example is the high frequency of algal blooms (seaweed proliferation) observed in certain regions (SDG 6), which is not only a current problem but one that is expected to worsen. This justifies patient R&D investment in advanced solutions like bio-remediation or nanofiltration to pilot-scale demonstrations.

For high-TRL opportunities, foresight helps scale preparedness. A relevant example is the recurrence of desert locust outbreaks (SDG 2). Foresight anticipates these events becoming more common and severe. This urgency prioritize the roadmap action of scaling up existing AI-driven pest-warning systems now to build resilience against future shocks.

In summary, the examples in this section move beyond using data for simple gap analysis. They demonstrate how geospatial insights are integrated into a foresight process to anticipate future risks and opportunities, thereby ensure that the resulting STI roadmaps is a dynamic, strategic plan for navigating uncertainty and achieving long-term SDG goals.

3.3. Illustrative Pilot Cases and Implementation Considerations

To move from theory to practice, it is instructive to examine pilot cases that demonstrate the tangible benefits and implementation requirements of this approach.

- **Case Example: Barbados Water Security (SDG 6).** Facing severe water scarcity, the government used satellite-based data on groundwater depletion and rainfall patterns to model future stress scenarios. This foresight exercise justified a major investment in a solar-powered desalination plant. The Water Sector Resilience Nexus project, which required significant initial capital expenditure and technical partnership with international firms, is now projected to increase the nation's resilient water supply by 20%, reducing vulnerability to droughts. Key resources needed included: **data** (NASA GRACE satellite data, local hydrogeological surveys), **funding** (blended finance from national budget and green climate funds), and **capacity** (training for water authority staff in GIS and plant maintenance).
- **Case Example: Fiji's Digital Agriculture initiatives (SDGs 2 & 9).** A pilot program used drone and satellite imagery to map soil moisture and crop health for sugarcane farmers. By providing this data via a mobile app, the project helped optimize irrigation, boosting yields by an estimated 15% and reducing water use by 25%. The implementation challenge involved **data acquisition** (partnering with a regional space agency), **addressing the capacity gap** (training local agronomists to interpret data), and ensuring **digital inclusion** (developing low-bandwidth apps accessible to rural communities). This case shows how a targeted geospatial intervention can simultaneously advance multiple SDGs.

These cases underscore that successful implementation requires more than data; it necessitates dedicated resources for **data acquisition and licensing, funding for technology procurement and piloting, and crucially, investments in building local government capacity** for data analysis, technology management, and maintaining public-private partnerships. More concrete cases from various regions with different contexts should be surveyed and shared with practitioners.

4. Prioritizing Research & Innovation Investments, and Context Specific Areas

4.1 Examples of Thematic Focus Areas

Geospatial information can reveal critical environmental and socio-economic challenges to be accounted for in national STI investment planning. By linking observed spatial patterns to targeted innovation responses, decision-makers can better allocate resources, accelerate technological deployment, and address pressing development needs. The table below illustrates how specific geospatial information can be translated into STI priorities and includes examples of relevant technologies that could be deployed.[17] It is important to note that a single geospatial insight can often lead to multiple, valid investment priorities depending on the specific national and local context.

Table 2: Geospatial insights and STI investment area

Geospatial Insight	STI Investment Area	Example Technologies
Groundwater depletion (SDG6)	Affordable desalination/ recharge technologies; policy and governance for sustainable extraction	Solar-powered groundwater recharge systems; AI-powered monitoring systems for compliance and aquifer management
Urban heat islands (SDG11)	Cool roofing materials & urban greening R&D; public health strategies for heat-vulnerable communities	Phase-change materials, Satellite thermal infrared; early warming systems, GIS for targeting community cooling centers
Coastal erosion due to sea-level rise (SDGs 13 and 14)	Coastal monitoring, early warning, and adaptive infrastructure	Satellite-based shoreline change detection, nature-based solutions (e.g., mangrove restoration), climate-resilient coastal engineering
Coral reef degradation (coral bleaching) (SDGs 13 and 14)	Coral reef health monitoring and restoration	Remote sensing of coral bleaching, coral reef restoration techniques, selective breeding of climate-resilient coral species
Groundwater depletion, saltwater intrusion, and coastal subsidence (SDG 6, SDG 13, SDG 14)	Integrated groundwater management, saline intrusion monitoring, and land subsidence assessment	Remote sensing combined with in-situ groundwater monitoring, coupled hydrological– geophysical models, satellite-based InSAR for land subsidence
Declining land productivity (SDG15)	Soil health monitoring & regenerative agriculture	Satellite-guided biochar application, microbial fertilizers

Source: authors' elaboration. **Note:** Effective execution requires not only technical capacity but also robust governance and institutional arrangements to ensure inclusivity and local ownership. This involves a whole-of-society implementation capacity – integrating public, private, NGO, and civil society actors.[18] Key lessons from UN STI Roadmaps pilot countries' approach include:

Establish coordination bodies (e.g., national or provincial STI committees) to align priorities across sectors;

Develop specialized implementation units (e.g., "Technology Extension Centers") for field deployment;

Run phased pilot programs to build local skills before national scaling; and

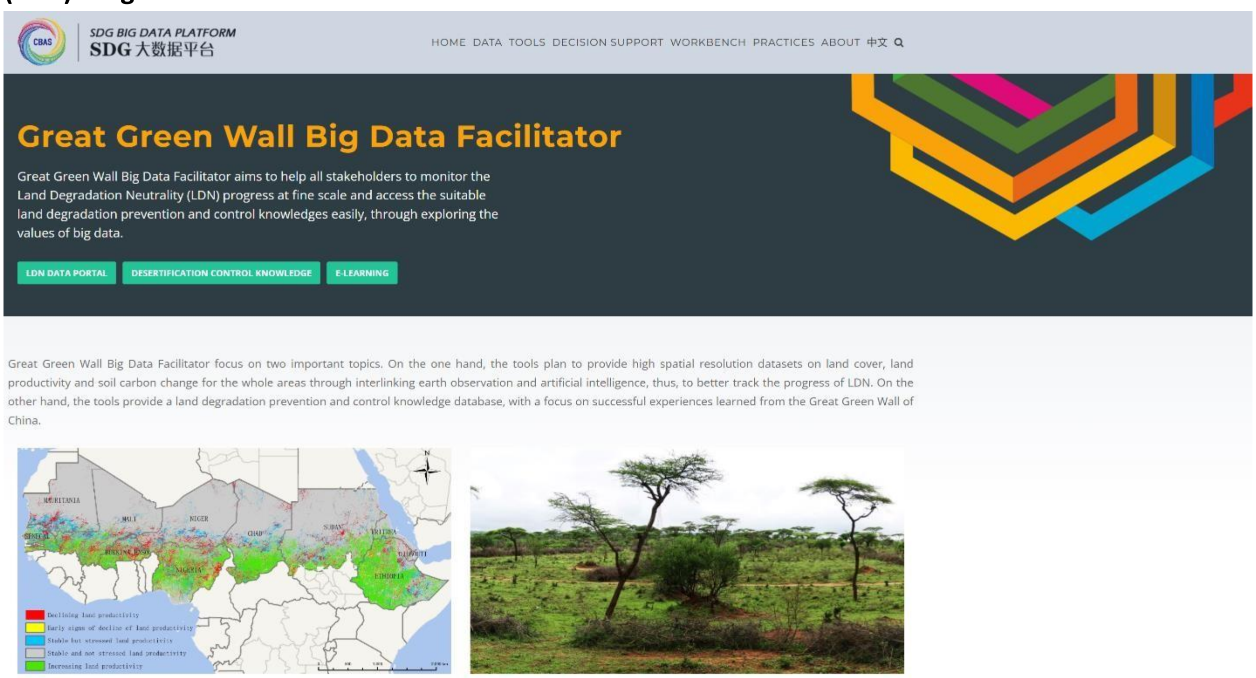
Create accountability frameworks with clear KPIs for each stakeholder group. Roadmaps should detail these capacity-building mechanisms during action formulation (Step 7) to ensure timely execution of all proposed interventions.

[17] Also see examples from UN Global Geospatial Knowledge and Innovation Centre: https://ggim.un.org/UNGGKIC/
[18] Also see: UN-IGIF https://ggim.un.org/UN-IGIF/

For instance, groundwater is a critical source of potable water for many SIDS. Remote sensing is increasingly applied to groundwater management, and future directions include combining satellite and ground-based data with groundwater modeling (Adams et al., 2022). Saltwater intrusion is a significant issue for islands and coastal regions, and remote sensing—especially when coupled with modeling—can help monitor and predict this phenomenon. Satellite data are also used to track related hydrological variables such as soil salinity and vegetation stress. In addition, in some coastal areas, subsidence exacerbates sea level rise, and remote sensing has proven valuable in quantifying this contribution, which is also relevant to certain SIDS.

Figure 2 illustrates that a Big Data Facilitator would use satellite-derived vegetation indices (like NDVI) as its primary data source to track changes in productivity over time. The insights from this tool would be used almost in real-time to target interventions exactly where they are needed most, making the investment in soil health monitoring & regenerative agriculture a direct, evidence-based outcome.

Figure 2: The Great Green Wall Big Data Facilitator: A Tool for Tracking Land Degradation Neutrality (LDN) Progress.



Source and credit: CBAS.

4.2 Cross-Sectoral Synergies

The greatest value of geospatial insights arises from multimodal data fusion across sectors. This integration unlocks innovative solutions that address multiple SDGs simultaneously by transforming potentially accidental data associations into a smart, robust basis for decision-making.

For example, table 3 below illustrates that a multivariate modeling framework fusing forest cover data (SDG 15) with precipitation patterns, soil properties, topography, land use history, evapotranspiration rates (SDG 6), and other relevant datasets, can systematically identify "water-smart" reforestation areas. This AI-driven fusion not only identifies collaborative opportunities across environmental domains but also enables a qualitative leap in resource efficiency. The resulting insights empower targeted interventions that maximize both carbon sequestration and water resource sustainability. The corresponding STI policies would be funding agroforestry technologies – such as AI-powered forest species selection tools and modeling platforms optimizing the carbon–water balance – ensuring reforestation efforts are both climate-resilient and resource-efficient.

Table 3: Geospatial insights and STI investment priority (continue)

Geospatial Insight	STI Investment Area	Example Technologies
Multivariate modeling integrating forest cover, precipitation, soil properties, topography, land use history (SDG 15) and evapotranspiration data (SDG 6) to identify "water-smart" reforestation areas.	Fund agroforestry technologies that optimize both carbon sequestration and water resource sustainability.	Forest species selection tools, carbon–water balance modeling platforms, climate-resilient agroforestry systems.

Source: authors' elaboration.

Quantitative methods like Multi-Criteria Evaluation (MCE) and Data Envelopment Analysis (DEA) can further optimize these synergies quantitatively, and systematically weighing trade-offs (e.g., carbon vs. water security) and evaluating efficiency across SDG targets.

4.3. Bridging Technology Access Gaps

A. Local Capacity Building

Geospatial electrification data from Africa (SDG 7) highlights persistent pockets of energy poverty, particularly in rural areas. Empowering and building the capacity of local innovators and communities to design and deploy modular solar microgrids is one way of addressing this challenge. This ensures that solutions are not only deployed by are also owned, maintained, and adapted locally, fostering inclusivity and long-term sustainability. By using geospatial analytics to identify optimal sites, deployment can be faster, more efficient, and better aligned with community needs. However, successful technology deployment also requires resources—such as financing, technical training, supply chains, and policy support—to translate geospatial insights into sustainable energy access.

B. Public–Private Partnerships (PPPs)

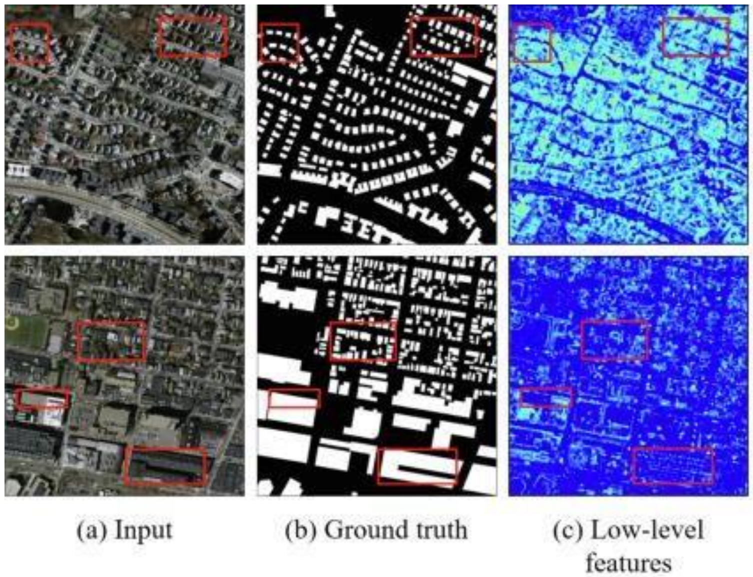
The rapid expansion of aquaculture (SDG 14) can generate economic opportunities but also poses risks to fragile coastal ecosystems. Governments can mitigate these risks by incentivizing private sector research and development in sustainable aquaculture systems—such as AI-enabled, closed-loop feeding systems—that improve productivity while protecting marine biodiversity.

C. Open Data Platforms

Establishing a national open-data portal that integrates geospatial datasets with foresight driven online tools—such as AI applications developed by DPIDG/DESA, One UN Geospatial Situation Room, CBAS's big data platform and SDGSAT Open Data system—can significantly broaden access to actionable intelligence. Linking these efforts to global initiatives like the Group on Earth Observations (GEO) ensure alignment with international standards and allows SIDS to tap into a vast ecosystem of shared data, tools, and best practices.

To manage the immense complexity and file size of modern geospatial data formats (e.g. GeoTIFF, NetCDF), a two-stage process can be employed. First, pre-processing and feature extraction are applied for information simplification. This involves advanced spatial aggregation and dimensionality reduction techniques, analogous to convolutional and pooling layers in deep learning, to distill vast, multi-spectral satellite imagery and sensor data into optimized, feature-rich datasets. A machine learning model is then trained on this simplified data to efficiently identify and extract specific indicators relevant to development challenges, such as tracking deforestation, mapping urban expansion, or monitoring water resource depletion with high fidelity (see Figure 3).

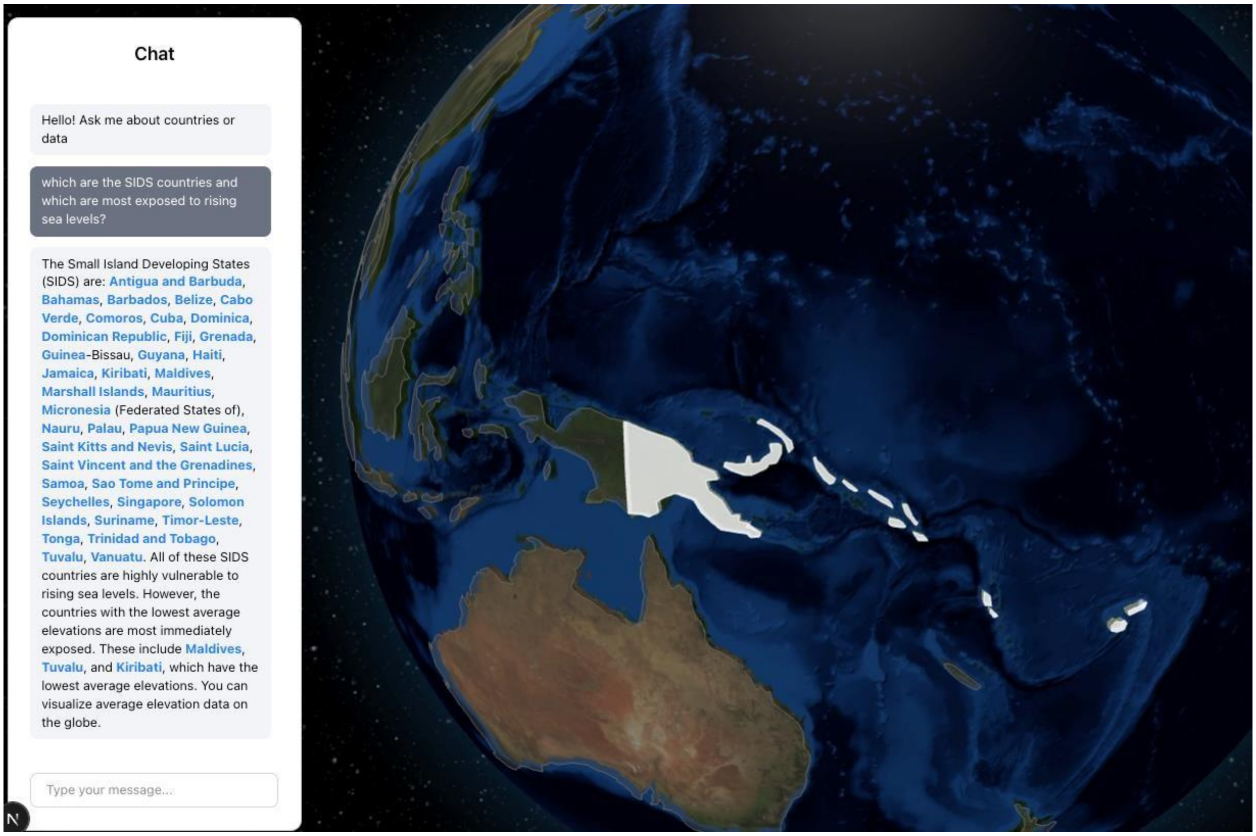
Figure 3: Feature extraction process for simplifying complex geospatial data



Source and credit: The State Key Lab, LIESMARS, Wuhan University, and Project Management Center, Marine Equipment Department.

Second, to make these complex datasets accessible to policymakers and non-technical stakeholders, interfaces that combine conversational AI with powerful data visualization can be developed. Such a system can leverage a Large Language Model (LLM) fine-tuned on geospatial and sustainable development terminology, allowing users to query the database using natural language. The AI can employ a Retrieval-Augmented Generation (RAG) framework to fetch the precise geospatial data required to answer a query, ensuring responses are grounded in empirical evidence. The retrieved information can then be rendered dynamically on an interactive WebGL globe, providing an intuitive visualization of trends, forecasts, and spatial patterns directly within a web browser (see Figure 4). This transforms the user experience from static data consumption to an interactive dialogue with the data itself.

Figure 4: An example conversational AI tool for interacting with geospatial data.

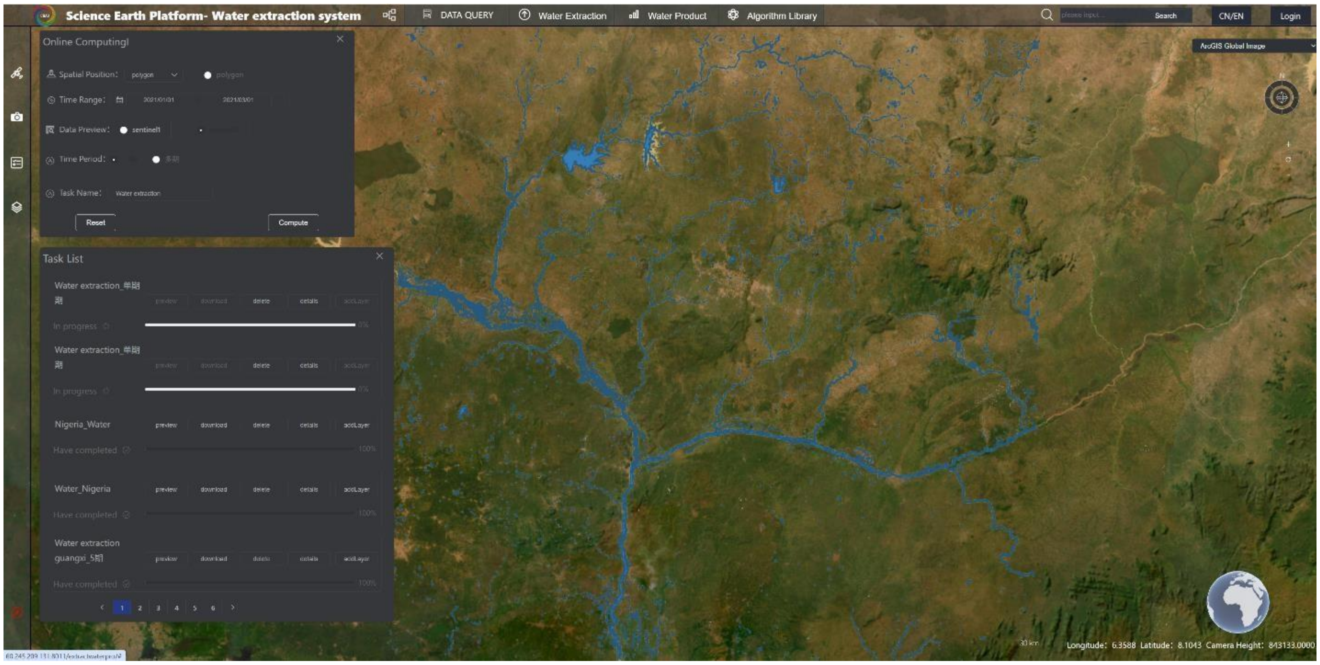


Source and credit: Gregory Mcgann, DIPDG, DESA.

However, the effective utilization of this geographic spatial data and forward-looking analysis fundamentally relies on combining cross-disciplinary technical skills with creativity. By enabling startups, researchers, and innovators to tap into real-time datasets, such platforms provide the foundation to transform raw data into tangible problem solutions – the core driving force for bridging technological gaps.

For example, Figure 5 demonstrates the application of AI to a critical resource challenge. It shows how machine learning models, trained on remote sensing imagery, can accurately map and monitor water extraction patterns. This capability is vital for sustainable groundwater management (SDG 6), allowing policymakers to identify over-exploited aquifers and inform policies for water security.

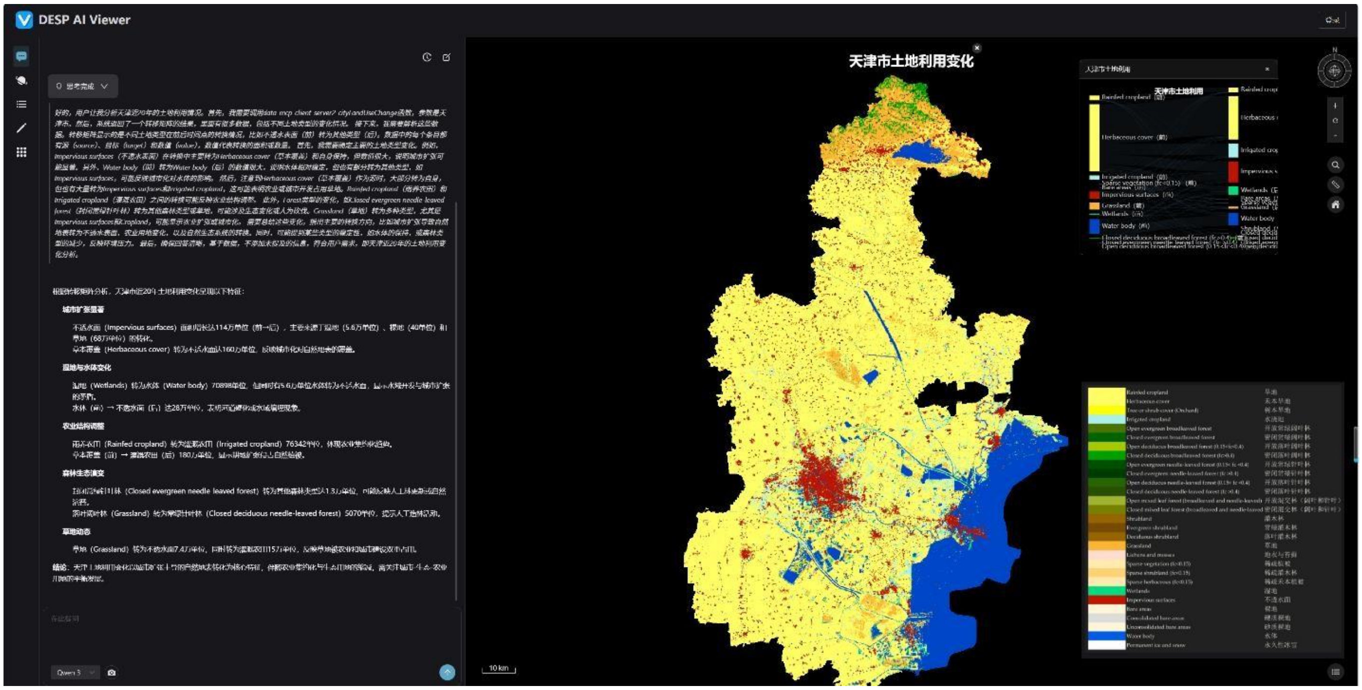
Figure 5 Water extraction based on AI model and remote sensing images



Source and credit: Zhongchang Sun, CBAS.

Figure 6 illustrates an integrated AI system designed for sustainable development planning. The AI4DESP (AI for Sustainable Development Planning) system exemplifies how AI can synthesize diverse geospatial data to model complex systems, optimize resource allocation, and predict the outcomes of policy interventions. Such tools are critical for creating data-driven, cross-sectoral STI roadmaps that can navigate trade-offs between goals like energy production, water use, and agricultural output.

Figure 6 AI4DESP system



Source and credit: Zhongchang Sun, CBAS.

The UNITAR UNOSAT Database illustrates how layered datasets can be visualized and selected for specific analyses, while the Vision Zero initiative in Louisville shows how GIS can integrate traffic, roadway, crash, and community data into prioritization models for safety. Interactive dashboards and StoryMaps improved transparency and helped the city secure significant federal funding for transport safety.

Such examples demonstrate how open-data platforms, when combined with innovative analytical tools, accelerate the development of practical, interdisciplinary applications— from AI-enhanced flood forecasting systems to optimized crop planning models.

4.4. Policy Levers to Enhance STI Alignment to the SDGs

A. Sandbox Piloting

Create policy "sandboxes" that allow the fast-track testing of geospatial-driven technologies, such as satellite, aerial and drone-based reforestation monitoring, under controlled but flexible frameworks. Develop national strategies for the enhancement of STI foresight and geospatial information capacity.

B. Challenge Funds

Launch competitive grant schemes targeting priority technology gaps, for example, AIpowered systems for early detection and prediction of desert locust outbreaks, enabling rapid scaling of effective solutions. Resource permits, consider funds that enhance directly national STI and geospatial capacities across themes of the SDGs - towards a more integrated approach and investments.

C. Skills Development

Invest in the training of GIS analysts, remote sensing experts, data and AI scientists as well as the user community for geospatial data to ensure geospatial trend analyses are effectively interpreted and integrated into policy and innovation planning. This can include use of geospatial data to identify early signals of change that can inform multi-disciplinary foresight exercises. Crucially, this expertise enables the integration of individual technologies into the broader landscape engineering ecosystem, unlocking their full value. Trained professionals are key to transforming isolated technologies into scene-driven engineering packages and transitioning catalytic innovations from laboratory validation to large-scale deployment.

A useful reference in this regard is a capacity-building workshop developed by UNOSAT, which covers geospatial data analysis skills, data visualization, and the operation of GIS tools (UNOSAT Knowledge Hub, Introduction to GIS and Remote Sensing). Similar training models could inspire the design of future workshops tailored for the user community in SIDS and other developing contexts.

4.5. Case Example: The Water–Energy–Food (WEF) Nexus

Combine datasets on cropland water-use efficiency (SDG 6), evapotranspiration, and energy access to identify regions where scene-driven intervention packages can have the greatest impact.[19] This integrated analysis exemplifies how catalytic technologies, when packaged for specific WEF nexus challenges, can be deployed at scale. The corresponding STI milestones involve developing policy frameworks and governance models that incentivize the bundling of technologies (e.g., precision irrigation sensors, renewable energy microgrids, drought-resistant crop variants) into replicable solutions for identified priority regions.

STI Roadmap Actions

Research: Advance low-energy drip irrigation technologies tailored to local conditions.

Innovation: Pilot solar-powered water pumping systems in high-potential croplands to improve agricultural productivity.

Policy: Offer targeted subsidies for water-efficient technologies adopted by smallholder farmers, ensuring equitable access and uptake.

This integrated WEF nexus analysis exemplifies how catalytic technologies, when packaged for specific challenges, can be deployed at scale. To further strengthen this process, future work will

[19] For example, see One UN Geospatial Situation Room, concept developed by the UN geospatial Network, a coalition of 42 entities of the UN system.

include developing practical, multi-level tutorials. These will range from technical Jupyter notebooks for data scientists — demonstrating how to download and fuse geospatial with socio-economic data — to policy simulation exercises that show how these evidence-based insights, alongside their inherent uncertainties and competing stakeholder values, are negotiated to reach a final investment or policy decision.

4.6. First Steps for SIDS: Building Data-Driven Foresight and Roadmap Capacity

Small Island Developing States (SIDS) have limited technical capacity to conduct foresight or geospatial analyses independently and will need to rely on partnerships and external support frameworks to make progress. It is important to map out these potential resources and supports, and to establish initial contacts. Crucially, this must be paired with efforts to build strong governance frameworks that ensure these external partnerships translate into sustained local capacity and nationally owned outcomes.

For ministries in SIDS, integrating data-driven foresight into policymaking is a necessity, enabling government officials to anticipate and respond effectively to climate, economic and social challenges. This approach reflects the Antigua and Barbuda Agenda for SIDS (ABAS), which emphasize resilience, sustainable development, and evidence-based decision-making.

For SIDS, the path to implementing this approach is fraught with challenges that must be proactively managed. Key hurdles include:

- Data Acquisition: Access to high-resolution, frequently updated satellite data often requires subscriptions or partnerships, presenting a financial barrier.
- Funding: Significant investment is needed not only for technology but for the entire innovation lifecycle—from R&D and piloting to scaling successful solutions.
- Government Capacity Gap: A critical shortage exists in local expertise for advanced geospatial analysis, data science, strategic foresight facilitation, and STI policy design.
- Technical Infrastructure: Limited bandwidth in remote areas and a lack of computing power for processing large geospatial datasets can be significant constraints.

The following steps are designed to systematically overcome these challenges.

Key initial steps include:

Assess existing capacities: Conduct a systematic review or mapping of skills, infrastructure, and institutional arrangements in geospatial information system (GIS), data science, and policy analysis across government and academia. This provides a baseline for prioritizing technical assistance and targeted training, which could lead to setting up national or provincial STI foresight committees/unit to align priorities across sectors.

Leverage open data and open-source tools: Utilize global and regional open-data portal (e.g. CBAS, UNOSAT, NASA Earthdata) and open-source GIS software (e.g., QGIS) to reduce initial costs, foster early adoption, and strengthen local proficiency in foresight-informed analysis.

Establish strategic partnerships: Collaborate with international organizations (e.g., GEO, the International Science Council (ISC) and its associated offices), regional research institutions, and peer SIDS governments to access expertise, co-develop tools, and share best practices. Regional universities and training centers can anchor sustained capacity building.[20]

Implement pilot projects: Focus on a high-priority issue (e.g., coastal erosion, disaster risk mapping, or water security) to demonstrate the practical value of geospatially foresight. Lessons learned can inform and support scaling across sectors.

By sequencing these measures, SIDS can progressively embed foresight practices into governance, transitioning from reactive crisis management to anticipatory, resilience oriented policymaking. These steps support the principles of ABAS, promoting innovation, resilience, and evidence-based policy in small island contexts and beyond.

5. Conclusion and Future Work

This working paper provides a solid, practical framework for integrating strategic foresight and technology assessment with geospatial data for STI roadmapping. Anchoring STI roadmaps in STI foresight and technology assessment transforms raw geospatial data into targeted, scalable innovations. By clearly framing the transition from diagnostic analysis ("what is") to anticipatory foresight ("what could be"), the paper provides a useful model for policymakers.

Furthermore, by combining inclusive capacity-building, effective policy levers, robust governance structures, and cross-sectoral coordination, aligned with Pact for the Future's whole-of-society approach and FfD4's call for STI governance support, countries can bridge technology access gaps and ensure that innovation serves as a driver of equity and resilience, rather than a source of inequality. Recent literature further strengthens this conclusion. For instance, Tan et al. (2025) demonstrate how Earth observations and geospatial approaches are critical to anticipating environmental change and embedding sustainability into long-term

[20] High-Level Group on the Integrated Geospatial Information Framework (HLG-IGIF) https://ggim.un.org/UNGGIM-HLG-IGIF/ and the Expert Group on the Integration of Statistical and Geospatial Framework (EG-ISGI) https://ggim.un.org/UNGGIM-Expert-Group-ISGI/ could support with peer-to-peer learning and sharing of positive national experiences of Framework implementation for development of geospatial capacity towards STI foresight.

planning.[21] In addition, Chen et al. (2024) introduce the FuXi-S25 machine learning model, which significantly outperforms the European Centre for Medium-Range Weather Forecasts' subseasonal-to-seasonal system in predicting precipitation and extreme events.[22] This advancement underscores the transformative role of AI in strengthening foresight exercises and enhancing STI roadmaps.

The transformative potential of these approaches is being accelerated by emerging technologies, as seen in advances in AI for climate prediction and Earth observation for anticipating environmental change. However, as noted in discussions on sensitive data, ensuring transparency and access remains a critical challenge for robust foresight. By connecting national efforts to global communities of practice like GEO and the ISC, SIDS and other developing countries can leverage these innovations, share lessons, and ensure their roadmaps are not only evidence-based and future-oriented but also inclusive and grounded in local realities.

Above all, this working paper proposes an operational framework. The next critical phase involves operationalizing it through applied research, pilot projects, and robust capacity-building initiatives. Future work could focus on:

Quantifying SDG Impact: Developing a methodology to quantitatively model the potential contribution of specific geospatial-STI interventions to individual SDG targets and indicators within the SIDS context.

Developing Implementation Toolkits: Creating practical, step-by-step guides and toolkits that detail the resources required—including data sources, cost frameworks, and governance models—for executing the eight-step process outlined in this paper.

Documenting Concrete Case Studies: Actively curating and publishing a repository of detailed case studies from pilot cities and countries, highlighting both successes and lessons learned from implementation.

To this end, broad and inclusive strategic partnerships will be crucial for translating this framework into tangible action on the ground. Collaboration with a diverse range of stakeholders—including UN agencies, other international organizations, regional bodies, government agencies, the private sector, and academia—will provide the necessary expertise, resources, and local grounding.

---

[21] Tan, X., Peng, Z., Cheng, Y., Wang, Y., Chao, Q., Yan, H., & Chen, D. (2025). Leveraging artificial intelligence for research and action on climate change: opportunities, challenges, and future directions. Science Bulletin, 70, 2886–2893. https://doi.org/10.1016/j.scib.2025.06.035

[22] Chen, L., Zhong, X., Li, H., Wu, J., Lu, B., Chen, D., ... Qi, Y. (2024). A machine learning model that outperforms conventional global subseasonal forecast models. Nature Communications, 15, 6425. https://doi.org/10.1038/s41467-024-50714-1

Academic institutions, in particular, play a vital role in this ecosystem. Their strength in fundamental and applied research, coupled with deep technical expertise and commitment to education, makes them ideal partners for advancing this agenda. For example, Tsinghua University offers a compelling model of such a partnership. Its interdisciplinary work on SDGs, spanning Earth system science, climate change and public policy, and economics, aligns closely with the needs of this initiative.

Potential areas for collaboration could include jointly refining foresight methodologies, co-designing pilot studies, and—importantly—developing and delivering the capacity-building programs and training workshops essential for empowering SIDS and other developing countries' officials. This collaborative spirit, engaging the full range of stakeholders, is key to ensuring these plans are not only visionary but also viable and sustainably implemented.

Contact: Wei Liu, Division for Sustainable Development Goals (DSDG), UN DESA liuw@un.org; Azeema Adam, Division for Public Institutions and Digital Government (DPIDG), UN DESA azeema.adam@un.org