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Research Article

LEAVING NO ONE BEHIND: GEOGRAPHIC INSIGHTS INTO INCLUSIVE DEVELOPMENT, A G-CAS EXAMPLE

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ABSTRACT

The accelerating impacts of climate change continue to expose inequalities in access to information, technology, and adaptive capacity, particularly in vulnerable coastal regions. This article is based on a keynote presentation given at Unique Conference Canada's Sustainable Development Goals 2025, and it explores how geographic insights and digital innovation can advance the principle of leaving no one behind through the example of the Guyana Coastal Analysis System (G-CAS) — a satellite-driven, web-based platform developed to monitor and analyse coastal dynamics in near real time. G-CAS integrates multi-source geospatial data to assess shoreline change, coastal squeeze, bathymetric shifts, and flood risks, offering actionable intelligence for policymakers, researchers, and communities. By providing open-access geospatial analytics, the system democratises data and enhances decision-making across multiple governance levels — from national disaster management to local community planning. This article discusses how the design and implementation of G-CAS embody inclusive development principles, blending science, technology, and community engagement. It highlights how the platform supports the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 11 (Sustainable Cities and Communities), while creating pathways for data equity, capacity building, and participatory adaptation planning. Ultimately, this article emphasises how geospatial science can bridge the gap between technological innovation and social inclusion — ensuring that small states and local communities not only access but actively shape the data ecosystems that influence their future resilience.

1. Introduction

Climate change has emerged as a defining challenge of contemporary development, reshaping patterns of risk, vulnerability, and inequality across spatial scales (Lankao & Qin, 2011; Venner, García-Lamarca, & Olazabal, 2024; Yadav et al., 2025). While its physical impacts—sea-level rise, coastal erosion, flooding, and extreme weather—are increasingly well documented (e.g., Griggs & Reguero, 2021; Gomez et al., 2025; Laino & Iglesias, 2025), the social distribution of these impacts remains deeply uneven. Vulnerable populations, particularly in low-lying coastal regions of developing states and Small Island and Developing States (SIDS), are often the least responsible for greenhouse gas emissions yet face the most severe consequences (van der Putte, 2021; Hernández-Delgado, 2024; Tandrayen-Ragoobur et al., 2024; Mansoor & Inam, 2025). Compounding this inequity is a persistent gap in access to environmental information, analytical capacity, and decision-support tools necessary for effective adaptation (Oyedotun & Burningham, 2021; Galaitsi et al., 2024; Shah & Kelman, 2025).

The United Nations' commitment to *Leaving No One Behind* (LNOB) under the 2030 Agenda represents a normative response to these disparities, emphasising inclusion, equity, and the prioritisation of the most vulnerable (UNGA, 2015; UNSDG, 2018; Mackie & Allwood, 2022). However, translating LNOB from principle into practice remains a significant challenge, particularly in climate-sensitive sectors such as coastal management (Breil et al., 2021; Siragusa et al. 2024). In many developing contexts, decision-making continues to rely on fragmented datasets, externally driven analyses, and technical systems that are inaccessible to local institutions and communities (Heeks & Shekhar, 2019; Oyedotun & Burningham, 2021; Cronemberger & Gil-Garcia, 2024). Geography and geospatial technologies occupy a critical position in this debate. Spatial data underpin climate risk assessment, land-use planning, disaster risk reduction, and ecosystem management (Rezvani et al., 2023; Chandel et al., 2025; Corrigan et al., 2025). Yet access to high-resolution satellite data, cloud-based analytics, and advanced modelling tools has historically been restricted by cost, infrastructure, and expertise (Wagemann et al., 2021; Andries et al., 2022; Franchi et al., 2023; Yasin et al., 2025). Recent advances in digital Earth platforms, open satellite archives, and cloud computing have begun to disrupt this landscape, creating opportunities for more inclusive forms of geographic knowledge production (Rejaur Rahman et al., 2025; Tabor et al., 2025).

This article examines the Guyana Coastal Analysis System (G-CAS) as an applied example of how digital geography can operationalise LNOB in a climate-vulnerable coastal setting. Developed as an open-access, web-based platform using Google Earth Engine (GEE), Guyana Coastal Analysis System (G-CAS) provides near-real-time analysis of coastal dynamics without requiring specialised software or high-end computing infrastructure (Oyedotun et al., 2025a). By focusing on Guyana, a country where approximately 90% of the population and critical infrastructure are concentrated along a low-lying, flood-prone coast, the paper situates Guyana Coastal Analysis System (G-CAS) within an urgent development and climate adaptation context (Oyedotun et al., 2025a). The objectives of this article are threefold: (1) to situate inclusive geospatial systems within the LNOB and sustainable development discourse; (2) to document the conceptual design, analytical capabilities, and implementation of G-CAS; and (3) to assess its implications for inclusive governance, capacity building, and climate resilience. In doing so, the paper contributes to emerging scholarship on digital inclusion, climate justice, and the role of geography in shaping equitable adaptation pathways.

2. Leaving No One Behind and the Geography of Inclusion

2.1 Conceptualising Leaving No One Behind -The LNOB principle is both ethical and operational (Ubillús & Van Ongevalle, 2024). Ethically, it demands that development processes prioritise those most at risk of exclusion. Operationally, it requires mechanisms to identify, measure, and address spatial and social inequalities. Geography is central to this task, as vulnerability is inherently place-based, shaped by physical exposure, socio-economic conditions, governance structures, and historical patterns of development. In the context of climate change, LNOB extends beyond income or service provision to encompass access to information and decision-making power (Mackie & Allwood, 2022; de Jong et al., 2025). Communities that lack timely data on flooding, erosion, or environmental change are effectively excluded from adaptation processes. Thus, informational inequality becomes a form of structural vulnerability.

2.2 Geographic Inequalities in Data and Technology - Despite rapid advances in Earth observation, access to actionable geospatial intelligence remains uneven (Andries et al., 2022). Many developing states depend on externally produced analyses, often delivered in formats that are difficult to update, interrogate, or integrate into national workflows (Adewole et al., 2024). Proprietary software limited technical capacity, and inadequate computational infrastructure further constrain local ownership of data (Brodie, 2023; Bietti, 2025; Bokolo, 2025). These constraints are particularly pronounced in coastal zones, where dynamic processes operate across land–sea interfaces and require frequent monitoring. Without inclusive geospatial systems, policy responses risk being reactive, fragmented, or misaligned with local realities.

2.3 Digital Geography as an Inclusion Enabler - Digital geography, characterised by cloud computing, open data, and web-based analytical tools, offers a pathway to address these inequalities (Graham et al., 2014; Vysotskyi & Vysotskyi, 2023). Platforms such as Google Earth Engine democratise access to petabyte-scale satellite archives and parallel computing, reducing barriers to entry for resource-constrained institutions (Wagemann, 2022; Sigler et al., 2025). When embedded within locally relevant frameworks, such technologies can shift the focus of knowledge production from external consultants to national agencies, universities, and communities.

3. Coastal Vulnerability and Inclusive Development in Guyana

3.1 The Coastal Context - Guyana's coastal zone presents a textbook case of compounded climate vulnerability. Much of the coast lies below mean sea level and is protected by an ageing system of sea defences, drainage canals, and conservancies (Hickey & Weis, 2012; Oyedotun & Burningham, 2021; Zephyrin, 2021; Stewart et al., 2024; Trotz, 2024). Sea-level rise, increased rainfall intensity, and storm surges amplify risks of flooding and erosion, with direct implications for housing, agriculture, transportation, and public health. Approximately 90% of the population and the majority of economic activity are concentrated along this narrow coastal plain (Oyedotun & Burningham, 2021; Stewart et al., 2024; Trotz, 2024). This spatial concentration magnifies the social consequences of coastal hazards, particularly for low-income and marginalized communities living in flood-prone areas.

3.2 Data Gaps and Institutional Challenges - Historically, coastal monitoring in Guyana has relied on sporadic surveys, isolated studies, and externally funded projects (Oyedotun and Burningham, 2021). Data fragmentation limited temporal coverage, and delays in analysis have constrained proactive planning. Moreover, access to geospatial tools has been uneven across institutions, reinforcing silos between science, policy, and community engagement. These challenges underscore the need for an inclusive, integrated system capable of providing timely, accessible, and policy-relevant coastal intelligence (Oyedotun and Burningham, 2021).

4. The Genesis and Philosophy of G-CAS

4.1 From Concept to Platform: The Guyana Coastal Analysis System (G-CAS) emerged from recognition of the limitations of conventional coastal monitoring approaches and the potential of cloud-based geospatial technologies (Oyedotun et al., 2025, a, b). Building on earlier initiatives such as the Guyana Coastal Database (Oyedotun et al., 2022), G-CAS was conceived as a next-generation system that would integrate satellite data, automated analysis, and user-friendly interfaces (Oyedotun et al., 2025, a, b). Developed through collaboration between the University of Guyana, the Spatial Informatics Group and the University College London, G-CAS reflects a partnership model that combines local contextual knowledge with international technical expertise.

4.2 Design Principles for Inclusion: Inclusion is embedded in G-CAS (https://gcas.gy/) through several design choices: **Open access:** The platform is freely accessible via a web browser, eliminating licensing barriers; **No local installation:** All heavy computation occurs in the cloud, reducing hardware requirements; **Transparency:** Analytical workflows are explicit and reproducible; **Policy relevance:** Outputs are aligned with national coastal management and climate adaptation needs. These principles align directly with the LNOB agenda by broadening who can access and use coastal data.

5. Data Architecture and Analytical Framework

5.1 Satellite Data Integration: G-CAS integrates multi-sensor satellite datasets, including optical and radar imagery, to support comprehensive coastal analysis (Oyedotun et al., 2025a). The use of long-term archives enables both historical trend analysis and near-real-time monitoring, critical for understanding morphodynamic change.

5.2 Cloud-Based Processing: By utilising Google Earth Engine, G-CAS performs computationally intensive tasks, such as image compositing, classification, and statistical analysis, on a parallel cloud infrastructure. Users interact with results through a lightweight browser interface, ensuring accessibility even in low-bandwidth environments.

6. Core G-CAS Modules and Tools (Figure 1)

To enhance the visual understanding of the platform, Figure 1 provides a more detailed representation of the core design and user interface of the Guyana Coastal Analysis System (G-CAS). The figure illustrates the main analytical modules and tools that constitute the platform

(Figure 1a), highlighting its integrated approach to shoreline monitoring, flood detection, coastal squeeze assessment, and other resilience-focused applications. The landing page of the operational web-based system, accessible at https://gcas.gy/, is shown in Figure 1b, demonstrating the open-access nature of the platform and its browser-based functionality. In addition, the module selection interface (Figure 1c) displays the interactive environment through which users can choose and execute specific coastal analyses (https://gcas.gy/main/selection). Together, these visual components clarify how G-CAS translates advanced Earth observation analytics into an accessible decision-support system for inclusive coastal governance and climate adaptation.

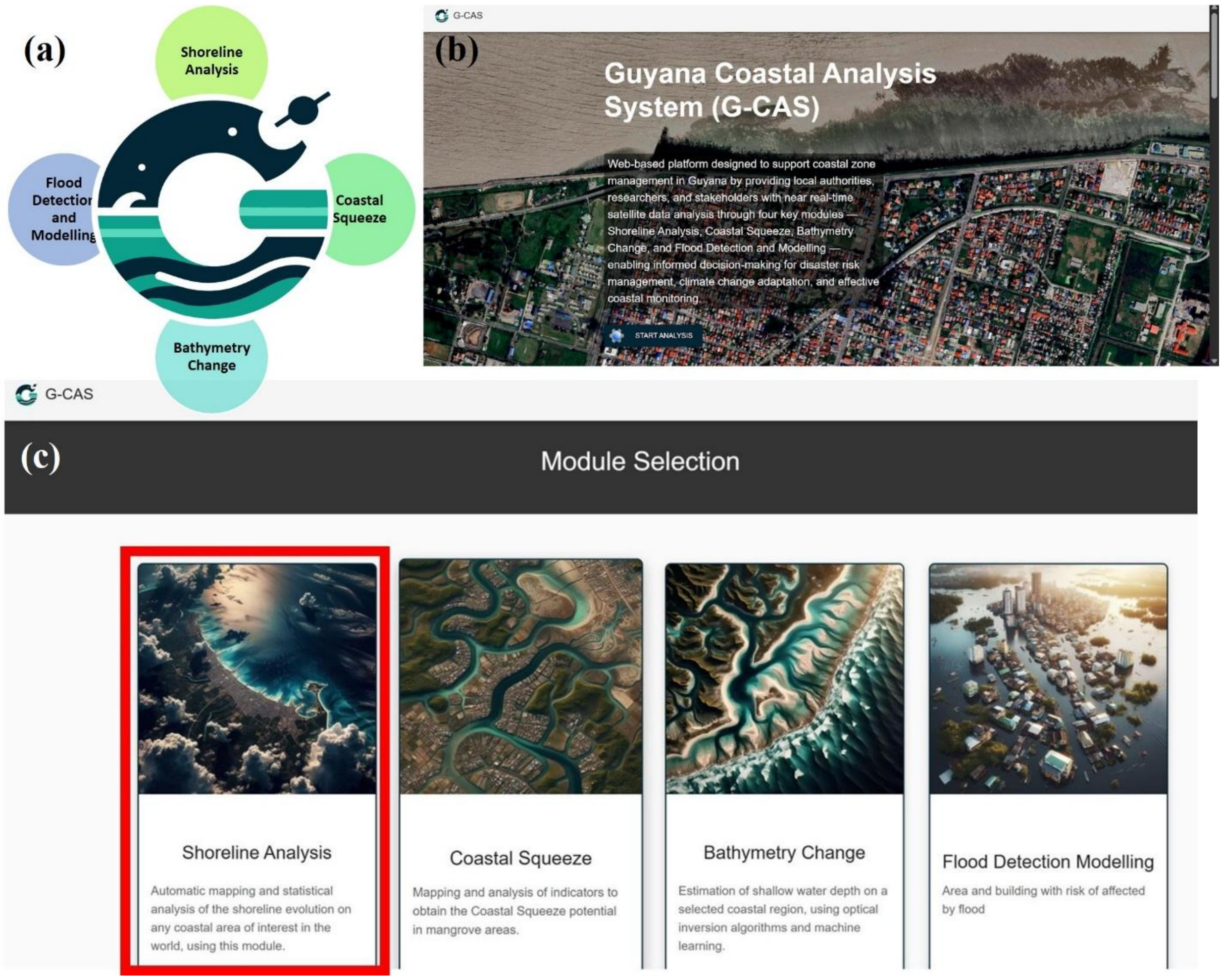

Figure 1 Core G-CAS Module and Tools (a), the landing page of the G-CAS platform at https://gcas.gy/ (b) and the module selection page where various analyses could be selected and executed - https://gcas.gy/main/selection (c)

6.1 Shoreline Monitoring and Change Analysis: The shoreline analysis module provides automated extraction and analysis of shoreline positions over time (Oyedotun et al., 2025a). Advancing beyond traditional desktop-based tools, it generates multiple statistical indicators—including Net Shoreline Movement, End Point Rate, Linear Regression Rate, and Shoreline Change Envelope—without requiring proprietary GIS software.

6.2 Coastal Squeeze Assessment: Based on established Coastal Squeeze Index methodologies (Oyedotun et al., 2025a, b), this module evaluates the interaction between sea-level rise, land-use constraints, and habitat migration. Its application supports sustainable land-use planning and ecosystem conservation in constrained coastal settings.

6.3 Bathymetry Change Detection: Using satellite-derived bathymetry techniques, G-CAS enables analysis of nearshore depth changes, supporting sediment management and navigation planning.

6.4 Flood Detection and Modelling: The flood module integrates historical inundation frequency with terrain attributes derived from digital elevation models to identify flood-prone areas. This spatial intelligence is critical for early warning, infrastructure planning, and community preparedness.

7. Capacity Building and Stakeholder Engagement

A defining feature of G-CAS is its emphasis on human and institutional capacity. Training programmes delivered to national agencies, including environmental and hydrometeorological authorities, have enabled direct use of the platform in operational contexts. Undergraduate and postgraduate students at the University of Guyana increasingly employ G-CAS in research and theses, embedding the system within national knowledge production pathways.

8. Discussion: Inclusive Development, Societal Impact and Visibility

G-CAS has demonstrated tangible societal impact by transforming how coastal and flood-related information is generated, accessed, and applied across the Guyana coastal environment. Through sustained engagement with national agencies, academic institutions, and the media, the platform has gained visibility as a credible and practical tool for investigating and responding to flood and erosion events. Its open-access, web-based design has enabled a wide range of users, from government technical officers to students, researchers, and informed community members, to independently explore coastal dynamics and hazard patterns without reliance on proprietary software or external consultants. This broad uptake has strengthened evidence-based governance by supporting more timely, transparent, and defensible decision-making in coastal risk management. Importantly, by making near-real-time coastal intelligence publicly available, G-CAS reduces information asymmetries between experts, policymakers, and affected communities, thereby enhancing public trust and participation in climate adaptation processes. Media coverage and public dissemination have further amplified its reach, positioning G-CAS not only as a scientific platform but as a socially embedded instrument for resilience building, early awareness, and inclusive climate action in line with the *Leaving No One Behind* principle.

The G-CAS experience illustrates how digital geography can meaningfully operationalise the *Leaving No One Behind* (LNOB) principle by directly addressing informational inequities that underpin climate vulnerability and uneven development outcomes. Rather than treating access to geospatial data as a purely technical concern, G-CAS demonstrates that inclusion emerges from the deliberate integration of open digital infrastructure with institutional ownership, human capacity development, and policy relevance. By embedding advanced Earth observation analytics within an accessible, web-based platform, G-CAS redistributes analytical capability from a narrow group of specialists to national agencies, academic institutions, and, indirectly, affected communities. This shift challenges traditional top-down models of environmental management that rely on externally produced analyses and episodic consultancy-driven interventions. Instead, G-CAS supports a more decentralised and participatory approach to coastal governance, where local actors can interrogate data, interpret spatial patterns, and contribute to evidence-informed decision-making. In doing so, the system reinforces transparency, accountability, and trust while strengthening the institutional foundations necessary for sustained climate adaptation. Ultimately, G-CAS highlights that inclusive development in climate-vulnerable contexts is not achieved through technology alone, but through the co-evolution of digital tools, governance structures, and social learning processes that ensure geographic intelligence serves the needs of those most at risk.

9. Transferability and Regional Implications

Although G-CAS is firmly grounded in the environmental, institutional, and socio-economic context of Guyana, its underlying framework is intentionally designed for transferability to other Small Island and Developing States (SIDS) and climate-exposed coastal regions facing comparable challenges. Many SIDS share common characteristics, including low-lying coastal zones, high population concentration along the shoreline, limited technical capacity, and constrained access to proprietary geospatial tools. The open architecture and modular design of G-CAS allow core analytical components, such as shoreline change detection, flood mapping, coastal squeeze assessment, and bathymetric analysis, to be adapted to different geomorphological settings and policy needs with minimal restructuring. By utilising globally available satellite datasets and cloud-based processing, the system avoids dependence on country-specific infrastructure, making it particularly suitable for regional scaling. This flexibility supports the longer-term vision of a Caribbean Coastal Analysis Network, where harmonised methodologies, shared data standards, and collaborative capacity building can strengthen collective coastal resilience. Such a network would not only enhance technical efficiency but also foster regional knowledge exchange and solidarity, reinforcing inclusive development and climate adaptation efforts across SIDS in alignment with the *Leaving No One Behind* agenda.

10. Critical Reflections and Limitations of G-CAS

While the Guyana Coastal Analysis System (G-CAS) represents a significant advancement in inclusive digital geography and open-access coastal intelligence, it is important to acknowledge that its effectiveness is shaped by several practical and structural limitations. First, as a cloud-based platform operating through Google Earth Engine, G-CAS depends on reliable internet connectivity, which remains uneven across Guyana and particularly constrained in remote hinterland and rural coastal communities. This digital infrastructure gap can limit the reach of the platform to those most vulnerable, thereby reinforcing the very informational inequalities it seeks to address. Second, the accessibility of G-CAS is not solely determined by openness, but also by users' levels of digital literacy and technical confidence.

Without sustained training, user support, and institutional capacity building, there is a risk that advanced analytical tools may remain underutilised or misinterpreted, especially outside specialist agencies. Third, questions of long-term sustainability must be considered, including the need for continuous funding, platform maintenance, software updates, and institutional ownership to prevent dependency on short-term project cycles or external partnerships. Finally, as with many automated geospatial systems, there are methodological uncertainties linked to satellite resolution, algorithm assumptions, and the interpretation of outputs in complex coastal environments. Recognising these constraints does not diminish the value of G-CAS; rather, it highlights that inclusive geospatial innovation is an evolving process requiring ongoing investment in infrastructure, human capacity, governance integration, and sustainability planning to fully realise the *Leaving No One Behind* principle.

11. Conclusion

This article has presented G-CAS as a practical example of how inclusive geospatial systems can advance the LNOB agenda in climate-vulnerable coastal settings. By integrating open data, cloud computing, and local capacity building, G-CAS transforms geographic information from an elite resource into a shared public good. As climate risks intensify, investing in geographic inclusivity is not optional; it is foundational to resilient and equitable development.

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