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Research Article

EMPOWERING CLIMATE-RESILIENT COMMUNITIES THROUGH NATURE-BASED FLOOD ADAPTATION STRATEGIES IN SOUTHERN GUYANA: ADVANCING THE SDGS THROUGH INTEGRATED LOCAL ACTION

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ABSTRACT

This study introduces an integrated, community-empowered framework that combines nature-based solutions (NBS) with socially inclusive approaches to strengthen flood resilience in Lethem and Tabatinga, Guyana. Recognising the region's growing vulnerability to climate-induced flooding, exacerbated by poor urban planning, land use practices, and socio-economic inequities—the study expands on prior NBS initiatives by embedding Sustainable Development Goals (SDGs) 1 (No Poverty), 5 (Gender Equality), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), and 13 (Climate Action) into a holistic strategy for local adaptation. Using geospatial analysis, socio-economic surveys (via Statistical Package for the Social Sciences (SPSS)), and participatory engagement with local stakeholders, including women, elders, and persons with disabilities, the research identified systemic gaps and community-driven priorities. The findings emphasise that integrating flood conveyance and bioretention solutions with inclusive policy design and knowledge co-production significantly improves both ecological outcomes and social resilience. Additionally, the framework advocates for local capacity-building, inclusive decision-making, and the mainstreaming of traditional ecological knowledge to sustain long-term climate adaptation. This novel convergence of NBS and social equity offers a replicable model for climate-resilient development in flood-prone communities across the Global South.

1. Introduction

Flooding is among the most pervasive and damaging climate-related hazards affecting low-lying and riverine regions of the Global South (Agrawala et al. 2003; Baker, 2006; Shah et al., 2020; Becker et al., 2024; Hussainzad & Gou, 2024). In Guyana, flood risk is amplified by a combination of climatic, geomorphological, and socio-economic factors, including high rainfall variability, flat topography, limited drainage capacity, and dependence on climate-

sensitive livelihoods (Pelling, 1999; Strauss & Kulp, 2018; Dalrymple, 2006; Saleh, 2020; Stewart, 2022; Hamer et al., 2025). While much of the national discourse on flooding has focused on the coastal plain, recent extreme events have highlighted the growing vulnerability of inland and southern regions, particularly communities along the Upper Takatu River basin (Bovolo et al., 2012; Hickey & Weis, 2012; Pereira et al., 2014; Graça et al., 2025). Conventional flood management in Guyana has historically relied on grey infrastructure, including embankments, culverts, and drainage canals (Vaughn, 2012, 2022; Stewart et al., 2024). However, these measures are often costly to maintain, environmentally disruptive, and insufficient under increasing climate variability. In this context, nature-based solutions (NBS) have emerged as a promising alternative or complement, offering multifunctional benefits that enhance flood regulation, ecosystem services, and social resilience (Calliari et al., 2019; Seddon et al., 2020; Sowińska-Świerkosz & García, 2022). Recent peer-reviewed work has demonstrated the technical feasibility and early benefits of NBS interventions in Lethem and Tabatinga (Oyedotun et al., 2025). This paper builds on that foundation by expanding the analytical scope to address community empowerment and SDG alignment explicitly. The central argument advanced here is that climate-resilient communities are not achieved through infrastructure alone, but through integrated local action that combines science, participation, and policy coherence. By synthesising empirical evidence from Southern Guyana with broader theoretical and policy frameworks, this article contributes to the growing literature on locally led adaptation and the operationalisation of the SDGs at the community level.

This article, therefore, advances its central argument through an empirical case study of Lethem and Tabatinga, two flood-prone communities in the Upper Takatu region of Southern Guyana. By examining the design, implementation, and evaluation of locally tailored nature-based flood adaptation interventions in these settings, the paper demonstrates how integrated approaches—combining remote sensing, hydrological and hydraulic modelling, socio-economic diagnostics, and gender-inclusive participation—can translate global resilience agendas into practical community-level action. The experiences from Lethem and Tabatinga provide concrete evidence of how locally led nature-based solutions can reduce flood impacts, strengthen institutional and social capacity, and contribute directly to the achievement of the Sustainable Development Goals through context-specific adaptation pathways.

2. Study Area: Southern Guyana and the Upper Takatu Region

Southern Guyana is characterised by a tropical savanna climate with a pronounced wet season, during which intense rainfall events frequently trigger riverine and pluvial flooding (Junk, 1993; Hoogesteijn et al., 2019; Schöngart et al., 2024). The Upper Takatu region, including Lethem and surrounding settlements such as Tabatinga, lies within a low-gradient landscape where surface water accumulates rapidly during heavy rainfall (Lujan, 2009). The Takatu River, which forms part of the border between Guyana and Brazil, plays a central role in regional hydrology and cross-border socio-economic interactions. Flooding in this region disrupts transportation networks, damages housing, compromises water supply and sanitation systems, and restricts access to health and education services (Oyedotun et al., 2025). The impacts extend beyond immediate physical damage to include long-term livelihood losses, heightened food insecurity, and increased vulnerability among women, children, and elderly

populations. These characteristics make the Upper Takatu region an instructive case for examining how NBS can be tailored to local environmental and social contexts.

3. Conceptual Framework: Nature-Based Solutions, Community Empowerment, and the SDGs

Nature-based solutions are defined as actions that protect, sustainably manage, and restore natural or modified ecosystems to address societal challenges while providing benefits for human well-being and biodiversity (Albert et al., 2019; Cohen-Shacham et al., 2019; Liu et al., 2021; Sowińska-Świerkosz & García, 2022; de Oliveira, 2025). In flood management, NBS include interventions such as floodplain restoration, retention basins, bioretention systems, and vegetated channels that attenuate runoff, store excess water, and enhance infiltration (Hill et al., 2023; Griffiths et al., 2024; Molnar-Tanaka & Surminski, 2024). The study by Oyedotun et al. (2025) adopts a conceptual framework that positions NBS within a broader process of community empowerment and sustainable development. Here, in this study, community empowerment is understood as the capacity of local actors to participate meaningfully in decision-making, implementation, and maintenance of adaptation measures. When aligned with the SDGs, such locally driven actions contribute not only to climate adaptation (SDG 13) but also to poverty reduction (SDG 1), gender equality (SDG 5), resilient infrastructure (SDG 9), and sustainable settlements (SDG 11).

4. Baseline Conditions and Vulnerability Assessment

Baseline assessments revealed a high degree of exposure and sensitivity of critical infrastructure to flooding, including roads and bridges that serve as primary access routes, drainage systems with limited conveyance capacity, health facilities and schools located within low-lying zones, and power supply infrastructure vulnerable to prolonged inundation (Oyedotun et al., 2025). Disruption of these assets was shown to have cascading effects on mobility, service delivery, public health, and local economic activity. Socio-economic analysis further highlighted pronounced differential vulnerability, with female-headed households experiencing approximately 25–30% higher flood-related income losses than male-headed households (Oyedotun et al., 2025). This disparity reflects unequal access to financial resources, diversified livelihoods, and recovery support mechanisms, as well as the disproportionate burden of care and unpaid labour borne by women during flood events.

Rainfall analysis for the Upper Takatu region revealed a markedly skewed distribution characterised by relatively frequent moderate rainfall events and less frequent but high-intensity extremes with severe flood impacts (Oyedotun et al., 2025). Extreme value analysis indicated that while typical daily rainfall amounts are modest, episodic extreme precipitation events exert a dominant influence on flood generation. The cumulative density function showed a 50% probability of daily rainfall being 20 mm or less; however, the heavy upper tail of the distribution underscores substantial residual risk associated with extreme rainfall (Oyedotun et al., 2025). These findings emphasise that flood risk in Southern Guyana is driven not by average conditions, but by low-probability, high-impact events, reinforcing the need for adaptive flood management strategies capable of buffering extremes rather than relying solely on mean climate behaviour.

5. Nature-Based Flood Adaptation Interventions

5.1 Flood Conveyance Solutions in Tabatinga: - In Tabatinga, a flood conveyance solution was implemented along an existing canal identified as a flood hotspot. The intervention included channel widening and deepening (approximately 900 m long, 20 m wide, and 6 m deep), embankment construction, and the creation of detention and retention areas (Oyedotun et al., 2025). Modelling results demonstrated that the channel acted as an effective buffer during moderate rainfall events, reducing surface water accumulation and delaying peak flows.

5.2 Water Storage and Bioretention in Lethem: - In Lethem, a water storage and bioretention system was implemented at the Culvert City Housing Scheme. The design incorporated subsurface drainage pipes, storage basins, and vegetated bioretention areas. Post-implementation observations showed improved drainage performance, reduced inundation duration, and enhanced groundwater recharge potential (Oyedotun et al., 2025).

6. Results: Performance and Outcomes of Interventions

6.1 Hydrological Performance: - From the findings in the study (Oyedotun et al., 2025), the model simulations conducted as part of the post-implementation assessment revealed that the suite of nature-based interventions materially altered the hydrological response of the Lethem and Tabatinga catchments under a range of plausible rainfall scenarios. By embedding channels, detention basins, and vegetated water storage features into the existing landscape, runoff generated during moderate to high rainfall events was more effectively conveyed and redistributed across the floodplain, resulting in observable contraction in both the lateral spread of inundated areas and the peak water depths recorded. These outcomes were supported by comparisons between pre- and post-intervention hydraulic outputs that indicated reduced surface saturation extents and attenuated flow peaks, particularly in zones where bioretention elements and conveyance channels had been introduced. The modelling framework thus demonstrated the capacity of integrated nature-based solutions to modulate flow dynamics by enhancing storage and conveyance pathways, effectively smoothing hydrographs and reducing inundation pressure on the built environment.

Despite these improvements for a broad range of rainfall intensities, simulation results also clearly indicate that extremely intense precipitation, characteristic of threshold climate extremes, can still generate rapid rises in water levels that exceed the design capacities of current interventions. Under such extreme conditions, the hydrological regime remains dominated by high velocity and volume flows that propagate quickly through the system, producing pronounced spikes in channel discharge and transient backwater effects. However, even in these scenarios, the presence of interim upstream storage and expanded conveyance capacity reduced the duration of inundation and constrained the spatial footprint of flooding relative to a baseline without NBS. This effect suggests that while NBS alone may not fully prevent flooding under the most extreme climate events, they meaningfully enhance overall system resilience by reducing flood persistence and facilitating recovery. The findings underscore the importance of integrating ecological infrastructure with broader watershed planning and emergency preparedness to manage both frequent and extreme hydrological perturbations effectively.

6.2 Socio-Economic and Gender Outcomes - Post-implementation socio-economic evaluation revealed that residents in both Lethem and Tabatinga expressed noticeably higher levels of satisfaction with how flood risks were managed compared with baseline perceptions (Oyedotun et al., 2025). Survey respondents cited not only tangible reductions in flood-related damage but also increased predictability of water levels and fewer interruptions to daily economic activities such as market access, agricultural work, and transport. This translated into improved feelings of safety and well-being, especially among households previously burdened by repeated flood losses. In addition to material benefits, community members reported that the collaborative planning and implementation process contributed to a stronger sense of collective agency. Local leaders and participants described how repeated dialogues, community workshops, and joint monitoring activities fostered a shared understanding of flood dynamics and strengthened the legitimacy of locally led adaptation processes.

Gender-focused analysis uncovered that women's engagement went beyond attendance in meetings to active participation in decision-making and maintenance activities, reinforcing shifts in traditional roles and widening civic inclusion. Female respondents highlighted that their enhanced involvement was not merely symbolic but contributed to practical decisions about the siting of flood interventions, prioritising access to essential services, and equitable distribution of resources during flood events. This increase in confidence and agency was associated with higher levels of social cohesion and mutual support networks, which proved important in mitigating socioeconomic stresses following heavy rainfall events. The strengthening of trust in local institutions, particularly municipal councils and community committees, was frequently linked with their perceived responsiveness to concerns raised by women and other underrepresented groups. Collectively, these socio-economic and gender outcomes suggest that investing in inclusive adaptation processes can yield broader social dividends, fostering resilience not just through physical infrastructure but through enhanced community capacity and social capital.

6.3 Capacity Building and Knowledge Transfer - In addition to tangible infrastructure improvements, the project placed strong emphasis on strengthening local capacity to sustain and adapt nature-based solutions over the long term. A series of targeted workshops and hands-on training sessions was facilitated for officials and field technicians from governmental agencies, focusing on the principles of Flood Modelling, NBS design, routine maintenance practices, and systematic monitoring protocols. These capacity-building efforts were co-developed with local stakeholders to ensure relevance to existing knowledge, institutional roles, and resource constraints. Participants engaged in participatory exercises that demystified technical concepts such as hydrological dynamics, sediment management, and adaptive maintenance planning, which in turn fostered a deeper sense of ownership over the interventions. The formal handover of a tailored training manual to the Lethem Town Council marked a symbolic and practical milestone in this process, providing a locally appropriate reference tool for future planning and upkeep. This convergence of formal training, documentation, and stakeholder engagement helped embed NBS competencies within municipal structures, enhancing the prospects for sustainable management, iterative learning, and scaling of nature-based flood adaptation beyond the initial project sites.

7. Discussion

7.1 Comparison with Nature-Based Flood Adaptation Experiences in Latin America and the Caribbean - The outcomes observed in Lethem and Tabatinga are broadly consistent with evidence from other nature-based flood adaptation initiatives across Latin America and the Caribbean, while also highlighting important contextual distinctions. In Brazil, Colombia, and Peru, floodplain restoration, retention basins, and vegetated drainage corridors have demonstrated the capacity to attenuate peak flows, reduce inundation duration, and deliver co-benefits for biodiversity and livelihoods (Tellman et al., 2018; Alpízar et al., 2020; Marsters et al., 2021). Similarly, Caribbean small island states have increasingly adopted hybrid green–grey approaches, combining engineered drainage with wetlands restoration and bioretention systems to address urban and peri-urban flooding (e.g., Granderson & Leotaud, 2021; Suedel et al., 2023; Hernández-Delgado, 2024).

Compared with these cases, the Southern Guyana interventions are notable for their strong integration of remote sensing–based flood diagnostics, hydraulic modelling, and participatory decision-making at the municipal level (Oyedotun et al., 2025). While many Latin American NBS projects emphasise ecosystem restoration at larger watershed scales, the Upper Takatu experience demonstrates the effectiveness of targeted, community-scale interventions in low-gradient savanna–river systems. The explicit incorporation of gender analysis also distinguishes this work, addressing a gap frequently noted in regional adaptation practice.

7.2 Community Empowerment and Gender-Responsive Adaptation - The results (in Oyedotun et al., 2025) reinforce the argument that technical performance alone is insufficient to ensure long-term resilience. Community empowerment, expressed through participation in site selection, design, implementation, and maintenance, proved central to the acceptability and sustainability of the interventions (Sanoff, 1999; Haldane et al., 2019). Women's active involvement not only addressed differential vulnerability but also enhanced social learning and local stewardship. These findings align with broader adaptation literature emphasising that gender-responsive approaches improve both equity and effectiveness of climate interventions (Götzmann & Bainton, 2021; Awiti, 2022; Adhikari & Ghimire, 2025).

7.3 Nature-Based Solutions as Complementary Infrastructure - The study (Oyedotun et al., 2025) confirms that nature-based solutions should not be viewed as replacements for conventional grey infrastructure, but as complementary systems that enhance flexibility and robustness under climate uncertainty (Scott et al., 2016; Petsinaris et al., 2020). In Southern Guyana, flood conveyance channels, detention basins, and bioretention systems functioned as adaptive buffers, particularly during moderate to high rainfall events (Oyedotun et al., 2025). However, extreme events still generated harmful flow spikes, underscoring the need for integrated planning that combines NBS with early warning systems, land-use controls, and emergency preparedness.

7.4 Policy Implications for Guyana - The findings carry direct implications for national and local policy frameworks in Guyana. First, the evidence supports stronger integration of nature-based solutions within Guyana's National Adaptation Plan (NAP), particularly for inland and

hinterland regions that have historically received less attention than the coastal plain. The methodological approach demonstrated in the study, combining remote sensing, modelling, and participatory assessment, offers a practical template for scaling NBS within the NAP process. Second, the results align closely with the objectives of Guyana's Low Carbon Development Strategy (LCDS) 2030, which emphasises climate resilience, ecosystem services, and inclusive development. By delivering flood risk reduction alongside social and gender benefits, the Upper Takatu interventions illustrate how local adaptation actions can operationalise the LCDS at the community level. Finally, at the level of local government, the study highlights the importance of institutional capacity, training, and sustained financing. Municipal authorities such as the Lethem Town Council play a pivotal role in maintaining NBS infrastructure, coordinating community participation, and integrating adaptation into local development planning. Strengthening these capacities is essential for long-term resilience and for advancing the principle of leaving no one behind.

8. Conclusions

This study demonstrates that empowering climate-resilient communities through nature-based flood adaptation strategies is both feasible and effective in Southern Guyana. By combining scientific analysis with inclusive local action, NBS can reduce flood risk, enhance livelihoods, and advance progress towards the SDGs. The Upper Takatu experience underscores the importance of locally led gender-responsive adaptation as a cornerstone of sustainable development in climate-vulnerable regions.

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