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Coastal land subsidence in West Africa: an overlooked threat? The case of Lagos and the Volta Delta

Lagos and the Ghana's Volta Delta face significant downward vertical land motion, a phenomenon called land subsidence, compounding sea-level rise. Several stressors drive subsidence rates of several mm per year in both areas, exacerbating the prevalent coastal hazards. We therefore underscore the urgent need for integrated strategies—deploying ground control points networks for satellite data, community-based monitoring, and scaling effective and site-appropriate nature-based solutions—supported by regional data-sharing and open-data policies to protect vulnerable communities.

I. Introduction: The Growing Threat of Coastal Land Subsidence

Coastal land subsidence (see Box) is an overlooked threat in West Africa, compounding the risks of sea-level rise (SLR) and endangering millions of lives and livelihoods. While global attention focuses on SLR driven by climate change, land subsidence silently amplifies its impacts through relative sea-level rise (rSLR, the combined effect of SLR and subsidence), particularly in low-lying deltas and rapidly urbanizing coastal cities. When combined with SLR, subsidence intensifies flooding, coastal erosion, and saltwater intrusion, threatening critical infrastructure, ecosystems, and socioeconomic livelihoods (Appeaning Addo *et al.*, 2011; Avornyo *et al.*, 2023). Without effective intervention targeting the root causes of coastal land subsidence, the risks will continue to escalate. Integrated coastal management strategies are, therefore, essential to address both the causes and impacts of land subsidence, safeguarding vulnerable low-lying coastal communities in West Africa.

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What is land subsidence?

Land subsidence is defined as the gradual lowering of the land surface. It can be driven either by natural processes, human activities or both. Natural drivers include tectonic activity or the compaction of soft and unconsolidated sediments with increased loading, such as the accumulation of new sediments. This later phenomenon occurs notably in river deltas, which are young geological formations with thick layers of unconsolidated sediments and ongoing new inputs of fluvial sediments. Human activities include rapid urbanization – adding weight at the surface from buildings and infrastructure – or fluid extraction (water, oil or gas) in the subsurface. Indeed, the pressure decrease due to pumping leads to a reduction of porosity in the sediment layers, resulting in increased underground compaction and hence elevation loss at the surface. Groundwater over-extraction in particular is a well-known driver of the highest subsidence rates observed worldwide, for instance in the Mekong Delta or in Jakarta, where values of more than 5 cm/year and 10 cm/year respectively are recorded in some places. As silts and clays are more compressible than sand, the potential for land subsidence depends on the thickness and composition of the sediment layers.

In deltas and coastline in their natural state, new inputs of sediments used to compensate for natural subsidence. But nowadays, in many areas sediment starvation caused by upstream dams, river diversions, and coastal infrastructures, disrupts natural sediment deposition, preventing elevation recovery.

2. The Volta Delta and Lagos Megacity: two different environments affected by land subsidence

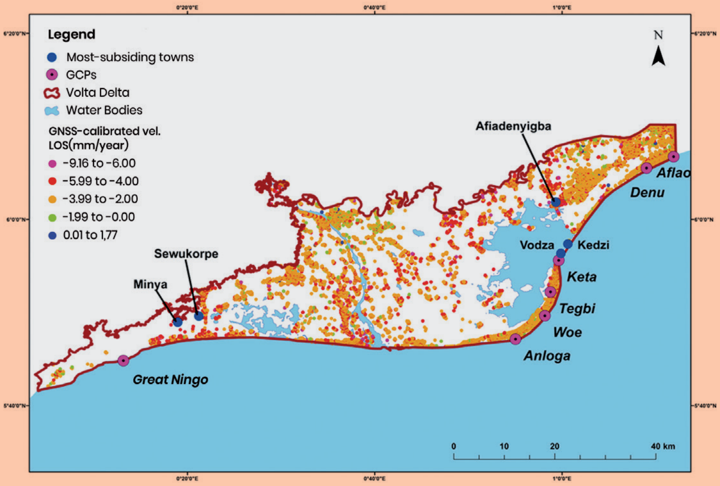
The low-lying West African coast, though understudied, has emerged as a critical region for understanding the compounding risks of coastal land subsidence and SLR. To highlight the urgency of addressing the hazard of coastal subsidence, we present research findings of two case studies: the Volta Delta (Ghana) (Avornyo *et al.*, 2024) and Lagos (Nigeria) (Ikuemonisan *et al.*, 2023). These cases underscore the irreversible consequences of continued business-as-usual and the need for integrated management strategies to protect vulnerable communities and ecosystems.

Case Study 1: The Volta Delta, Ghana – Quantifying the Impact of Relative Sea-Level Rise (rSLR)

The Volta Delta, a vital agricultural and ecological hub in Ghana, faces existential threats from subsidence and SLR. Satellite data (PS-InSAR[1], a technique for measuring ground deformation using radar images of the surface) and Global Navigation Satellite System (GNSS, which provides geopositioning) data used to identify subsidence hotspots reveal rates of up to ~9 mm/year (Figure 1), i.e. values of the same order or higher than current global mean sea level rise (~3.7 mm/year). By integrating local vertical land motion projections—assuming current subsidence rates will remain constant—with SLR projections and elevation data, the study projects that up to 45% of the delta could be permanently inundated by 2100, of which nearly 10% of this loss would be attributed to subsidence. Depending on the SLR scenario, land subsidence could increase the deltaic area at risk by 4.31% (96.27 km^2) to 10.18% (227.64 km^2). The drivers of subsidence in the delta include the natural compaction of compressible alluvial deposits, groundwater over-extraction, soil oxidation, and sediment starvation caused by coastal interventions and the regulated flow of the Volta River. Additionally, salt pan dykes and land modifications have disrupted sediment distribution, exacerbating the problem.

Figure 1: Map of the Volta Delta showing the average soil movements obtained through satellite (PS-InSAR, measures in line-of-sight) over 2016-2020.

Negative values suggest downward vertical land displacement, i.e. land subsidence. The positions of the ground control points (GCPs) are locations where GNSS-monitored benchmark data are available.



Source : Avornyo *et al.* (2024)

The impacts of rSLR are already evident in the increasing frequency and intensity of coastal hazards. Flooding, erosion, and saltwater intrusion have escalated in recent years, with over 30% of households sampled across 9 districts reporting these impacts. Over 60% of the coastline experience erosion, mainly because of disturbed sediment dynamics and sediment starvation, but rSLR compounds this pressure. Communities such as Fuveme, Adina, and Keta have seen significant losses of residential and public infrastructure, farmlands, and fishing grounds. Saltwater intrusion into freshwater sources, both groundwater and surface water, has also been reported in several coastal communities, severely affecting irrigation-dependent agriculture and reducing farm yields. These changes have displaced locals and threatened socio-economic livelihoods. The Volta Delta serves as a warning for other West African deltas, where similar drivers of subsidence and rSLR are at play. Without mitigation action to reduce land subsidence and consequent elevation loss, the region's exposure to rSLR will continue to grow, underscoring the need for integrated coastal management strategies.

[1] Persistent Scatterer Interferometric Synthetic Aperture Radar.

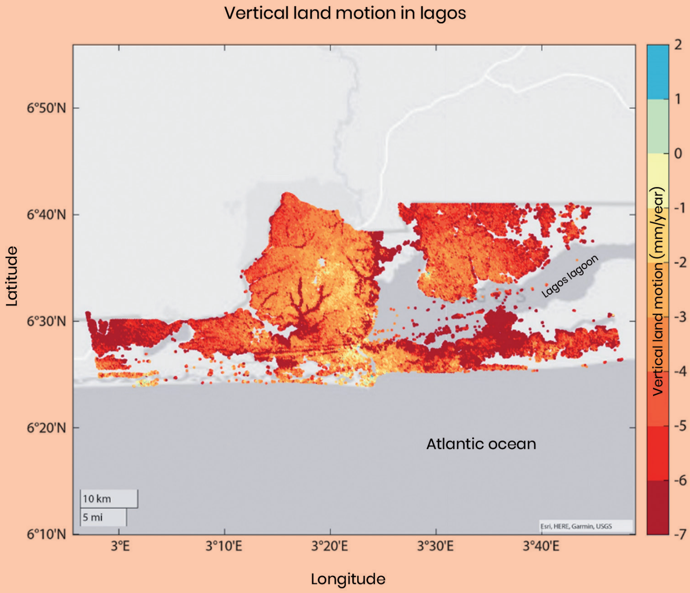
Case Study 2: Lagos – Urbanization and Groundwater Extraction as Drivers of Subsidence

With about 24 million inhabitants, Lagos is the largest coastal city in West Africa and a major economic hub. Many parts of the city are less than 2 meters above local sea level, mainly on the edges of its central lagoon, and hence exposed to rSLR and coastal flooding. Although limited studies have investigated land subsidence in Lagos, existing research show that parts of the city are significantly affected (Figure 2), with varying rates, spatial patterns, and associated risks, emphasizing the need for further scientific investigations. Radar satellite data over 2018-2021 show subsidence rates exceeding 4 mm/year, with hotspots surpassing 6 mm/year in Lekki, southwestern Lagos, and floodplains (Ohenhen & Shirzaei, 2022). While current subsidence rates may appear relatively small, they are already leading to significant damages in parts of the city, with several building collapses observed in subsidence hotspots. Within the next 10 to 75 years, up to 81 km² and 4,050 buildings could be at high risk. Another study based on geodetic data (2004-2019) suggests that subsidence rates may in places be significantly higher, up to ~87 mm/year in some parts of the city (Ikuemonisan & Ozebo, 2020). The phenomenon is attributed to groundwater over-extraction and urbanization.

More than 80% of Lagos' growing population do not have access to clean water through a public water network and most of inhabitants rely on wells and boreholes. Developing water access is therefore one of the key challenges of the city. However, a strategy based on increased groundwater pumping for instance could significantly increased subsidence rates and exposure to rSLR, depending on pumping rates and the type of geological setting.

While variations in methodology and spatial focus contribute to disparities in reported subsidence rates, the research collectively affirms that land subsidence is an ongoing issue in Lagos: increased flooding risk, structural instability leading to building collapses, and economic strain due to property damage and displacement. However, given the limited number of studies, existing uncertainties and the paucity of ground-truth data, further scientific investigations using long-term, high-resolution datasets and multidisciplinary approaches are essential for accurately assessing subsidence trends, developing effective mitigation strategies and avoid creating a new "Jakarta case".

Figure 2: Map of vertical land motion (mm/year) in Lagos over 2018-2021, derived from satellite Sentinel-1 data (referenced to IGS14 global reference frame).



Credit: Oluwaseyi Dasho, Virginia Tech.

3. Bridging the Gap: Challenges in Monitoring and Data Collection

Coastal land subsidence in the West African Coast remains poorly quantified due to critical gaps in monitoring infrastructure and governance. The sparse coverage of ground control points and permanent GNSS stations limit InSAR validation and hinder high-precision measurements of land movement, particularly in vulnerable and dynamic coastal areas where subsidence rates spatially vary even over short distances. Additionally, reliance on outdated global Digital Elevation Models (DEMs), often with low spatial resolution, further obscures subtle elevation changes and the assessment of areas at risk of flooding. In general, there are challenges in (post-)processing, managing and interpreting scientific data, especially when translating InSAR-observed vertical land motion to relative sea-level rise projections. These challenges create additional uncertainties in current studies and call for a rigorous and uniform approach. Compounding these technical limitations are institutional gaps, including overlapping mandates and interagency rivalries that stall coordinated action. Fragmented governance structures in West Africa, particularly weak enforcement of groundwater extraction policies, enable unregulated practices like over-extraction that accelerate subsidence. Furthermore, the lack of regional frameworks for data sharing and collaboration hinders the development of a unified approach to subsidence monitoring. Finally, the hydrogeological data needed to assess the subsidence potential are scarce and scattered in different public institutions or private companies and not easily accessible for the scientific community. Without coordinated efforts, individual countries struggle to pool resources, share expertise, or implement standardized monitoring protocols, leaving the region ill-prepared to address this boundary-transcending issue.

4. Pathways to Resilience: Data-Driven Solutions for Coastal West Africa

West Africa's coastal subsidence issues demand an integrated strategy combining geospatial innovation, regional cooperation, and participatory governance. Critical first steps include deploying permanent GNSS stations that provide open-access data to ground-truth InSAR satellite data in high-risk zones like Lagos and the Volta Delta, complemented by piezometric networks and field surveys to refine subsurface, hydrogeological understanding and land subsidence assessments. Regional bodies like Economic Community of West African States (ECOWAS) must spearhead standardized monitoring protocols and shared data infrastructure to address transboundary drivers like groundwater extraction, while community-based initiatives can expand observational coverage through low-cost tools and local knowledge integration. Concurrently, legally binding policies, particularly integrated coastal zone management plans, should regulate groundwater use and land zoning to curb anthropogenic contributions to subsidence, paired with nature-based solutions like mangrove restoration to stabilize sediments and mitigate erosion. These efforts must prioritize open-access data platforms to enable real-time monitoring and interdisciplinary research, ensuring alignment with global climate commitments under the Paris Agreement and Sendai Framework. By synthesizing technical rigor, ecological stewardship, and participatory governance, West Africa can forge a scalable model for coastal resilience amid escalating climatic and anthropogenic pressures.

5. Conclusion and Call to Action

To mitigate the risks posed by land subsidence in the low-lying West Africa sub-region, the concerned authorities and policy-makers must prioritize four fronts:

1. **Accurate Monitoring:** Deploy a network of low-cost GNSS stations and ground-truthed InSAR data to map subsidence hotspots, ensuring that decisions are backed by real-time, high-resolution data.

2. **Regional Collaboration:** Establish shared frameworks for transboundary data sharing, resource pooling, and joint research to address the drivers.

3. **Free-Data Policy:** All data collected pertaining to land subsidence, hydrogeological settings, groundwater use, aquifer pressure, and aquifer properties must be made freely available for non-commercial purposes.

4. **Adaptive Governance:** Integrate subsidence mitigation into national climate policies, enforce land-use regulations, restore mangroves or wetlands for natural resilience, and empower communities through participatory monitoring to foster ownership of adaptation strategies.

The path forward requires an urgent collaboration among governments, researchers, civil society, and international partners. By aligning advanced geospatial monitoring, ecological stewardship, and collaborative governance frameworks, West Africa can protect its coastal communities, ecosystems, and long-term sustainability. Immediate action is imperative to prevent irreversible consequences from rising sea levels and land subsidence.

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