Assessing Carbon Sequestration and Land Productivity Dynamics in Namibia Using Multi-Sensor EO Data and a GeoAI Framework

Ryan Theodore Benade and Oluibukun Gbenga Ajayi (Namibia)

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SUMMARY

Land degradation and climate variability constrain carbon sequestration in African drylands, yet national-scale, spatially explicit evidence to guide Land Degradation Neutrality (LDN) and climate reporting remains limited. This study applies a GeoAI-enabled monitoring framework to quantify carbon sequestration dynamics and attribute degradation drivers across Namibia from 2000 to 2024. Implemented entirely in Google Earth Engine, the workflow integrates MODIS annual net primary productivity (MOD17A3HGF, 500 m), MODIS vegetation indices (MOD13A1, NDVI composites) and CHIRPS precipitation (v2.0; ~5 km).

Temporal trends are quantified using pixel-wise linear regression, and carbon density is estimated via a simplified residence-time conversion of Net Primary Productivity (NPP). Land Productivity Dynamics (LPD) is operationalised through trajectory, state and performance components, with a complementary rule-based attribution separating climate-driven productivity decline (co-occurring rainfall decline) from anthropogenic signals (declining vegetation under stable/improving rainfall). Results reveal pronounced north–south gradients in carbon density consistent with rainfall controls: national mean carbon density is 2.1 ± 1.5 kg C/m², with northern, central and southern regions averaging 5.2, 3.6 and 1.2 kg C/m², respectively and peak stocks (5–7 kg C/m²) concentrated in the northeastern corridor. Positive carbon trends dominate ~81% of the country, but drought intensification (notably 2015, 2019 and 2023) exposes threshold vulnerability, particularly in Central Namibia.

Attribution mapping indicates 670,232 km² (81.3%) as stable or recovering, while climate-driven degradation affects 69,270 km² (8.4%) and anthropogenic degradation 84,419 km² (10.3%), with distinct spatial clustering that supports targeted intervention. The framework demonstrates a transparent, scalable approach for operational dryland carbon monitoring and restoration

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prioritisation, directly supporting Namibia's UNCCD LDN implementation and Paris Agreement mitigation planning.