

LANDSCAPE AS CONSERVATIONAL INFRASTRUCTURE: A NATURE-BASED APPROACH TO MITIGATING GULLY EROSION IN EDO STATE, NIGERIA

Arc. Augustine Edegba

Senior Architect, Edo State Public Building and Maintenance Agency (EDPUBMA), Nigeria

ARTICLE INFO

Article No.: 0627

Accepted Date: 02/09/2026

Published Date: 09/10/2026

Type: Research

ABSTRACT

This paper examines the potential of landscape as conservational infrastructure for mitigating gully erosion in Edo State, Nigeria. Rather than treating vegetation and open space as decorative components added after engineering works, the paper conceptualises landscape as an active environmental infrastructure capable of intercepting rainfall, reducing surface-runoff velocity, increasing infiltration, stabilising exposed soil and protecting drainage corridors. The study adopts a qualitative case-study and secondary-data approach. A targeted review of twelve sources published between 2013 and 2025 was undertaken, comprising nine Edo State-focused studies, one Edo-NEWMAP project document and two broader reviews of nature-based solutions and stormwater management; sources were selected for their relevance to gully causes, erosion progression, control measures and landscape-based hydrological processes. Existing evidence identifies high-intensity rainfall, steep slopes, soil characteristics, concentrated runoff, vegetation loss and inadequate drainage as important contributors to gully development. Previous studies also report that biological measures such as tree planting can complement structural interventions. Based on a synthesis of these findings and principles of green infrastructure, the paper develops a landscape-based erosion-control framework comprising catchment protection, vegetated drainage, slope stabilisation, riparian buffers, strategic tree and ground-cover planting, and maintenance-based monitoring. The paper argues that effective erosion management in Edo State requires integration of landscape planning with civil engineering, hydrology, geotechnical assessment and spatial planning. The proposed framework provides a basis for site-specific implementation and future field validation rather than claiming measured performance from an unexecuted intervention.

Keywords: landscape infrastructure; gully erosion; green infrastructure; nature-based solutions; Edo State; runoff; soil conservation; landscape architecture.

1. Introduction

Gully erosion is a major land-degradation problem in humid tropical environments because concentrated surface runoff can progressively remove soil, enlarge channels and threaten roads, buildings, agricultural land and community infrastructure (Afegbua et al., 2016; Kayode-Ojo et al., 2019). In Edo State, Nigeria, the problem has been documented across different geographical zones and urban and rural settings. Research in selected Edo State locations identified Ekehuan, Auchi and Ewu among affected areas and associated erosion susceptibility with rainfall intensity, slope, soil properties and runoff concentration (Kayode-Ojo et al., 2019). Research in Auchi using remote sensing and field-based assessment also documented continuing gully progression and vulnerability over the period examined (Okeke et al., 2016).

The scale of the problem makes it necessary to reconsider erosion control as more than a narrow drainage or concrete-engineering exercise. Conventional measures such as channels, check structures, retaining systems, culverts and concrete protection can be essential where flow energy is high, while biological and landscape measures can complement mechanical interventions (Osayande et al., 2019). Broader evidence on nature-based solutions indicates that vegetation and other landscape interventions can influence runoff, infiltration and flow attenuation, although performance depends on location, design and environmental conditions (Lalonde et al., 2024).

This paper therefore investigates the proposition that landscape can function as conservational infrastructure. The term is used here to describe a deliberately planned network of vegetation, soil, landform, drainage corridors and open spaces whose environmental performance contributes to erosion prevention and catchment management. The central argument is not that landscape can replace engineering, but that landscape and engineering should be planned as one integrated erosion-management system.

2. Problem Statement

Erosion-control interventions in many developing urban environments are often initiated after gullies have become severe. In Edo State, documented studies have associated gully development with inadequate drainage, land-use practices, vegetation loss, steep slopes, soil characteristics and high-intensity rainfall (Kayode-Ojo et al., 2019; Afegbua et al., 2016). Evidence of gully-head advancement and the effectiveness of different control measures further indicates the need to consider both preventive and remedial responses (Osayande & Yari Mallo, 2017; Osayande et al., 2019).

A further planning problem is the separation between built infrastructure and landscape. Roads, buildings, drains and land subdivisions influence how rainfall is collected and discharged, while landscape is often treated as an aesthetic afterthought. Evidence from nature-based stormwater research shows that vegetation, soil and site characteristics can materially affect runoff mitigation and water movement (Liu et al., 2022). This paper addresses the resulting planning gap by asking how landscape planning can be deliberately incorporated into erosion-control infrastructure in Edo State.

3. Aim and Objectives

The aim of this study is to develop a landscape-based framework for using conservational landscape infrastructure to mitigate gully erosion in Edo State.

- to examine documented causes and spatial characteristics of gully erosion in selected areas of Edo State;
- to identify landscape processes capable of reducing runoff generation, flow velocity and soil exposure;

- to synthesise landscape and engineering measures into an integrated erosion-control framework; and
- to propose planning and design principles that can be tested through future site-based field studies.

4. Research Questions

- What recurring environmental and human conditions are reported across documented Edo State gully-erosion studies?
- Through what landscape processes can runoff generation, flow velocity and soil exposure be influenced?
- Under what site conditions can landscape measures complement, rather than substitute for, conventional engineering interventions?
- What integrated landscape framework can guide site-specific erosion planning in Edo State?

5. Methodology

This study adopts a qualitative case-study synthesis based on secondary research. For this revised synthesis, a targeted literature search was undertaken using combinations of the terms “gully erosion,” “Edo State,” “Auchi,” “Ekehuan,” “Ewu,” “Ikpoba-Okha,” “Etsako West,” “erosion control,” “vegetation,” “tree planting,” “drainage,” and “nature-based solutions” across Google Scholar, African Journals Online (AJOL), journal websites and institutional/project repositories. The evidence base comprised twelve sources published between 2013 and 2025: nine Edo State-focused research studies, one Edo-NEWMAP project document, and two broader reviews of nature-based solutions and stormwater management. Sources were selected where they directly addressed gully occurrence or progression, erosion drivers, control measures, or the hydrological functions relevant to landscape-based intervention. The study does not present new field measurements or claim performance data from a constructed landscape intervention.

The selected evidence was organised under four themes: (1) rainfall and runoff; (2) terrain and soil; (3) land use and vegetation; and (4) erosion-control responses. Published evidence was then interpreted through a landscape-infrastructure framework. The framework considers the catchment as a connected system rather than treating each gully as an isolated defect. At the upper catchment, the priority is runoff interception and infiltration; along slopes, the priority is soil protection and flow deceleration; at drainage corridors, the priority is conveyance without destructive concentration; and at gully heads and active channels, landscape measures are combined with appropriate structural stabilisation.

For future empirical validation, the framework recommends field surveys using GPS/GNSS, drone or satellite imagery, digital elevation models, soil sampling, rainfall data, drainage mapping, cross-sectional gully measurements and vegetation inventories. These data would permit comparison of pre-intervention and post-intervention erosion indicators.

6. Results

6.1 Evidence of the erosion problem in Edo State

Existing studies demonstrate that gully erosion is not confined to one locality in Edo State. Research has documented erosion in Auchi, Ekehuan, Ewu, Ikpoba-Okha and other parts of the state (Kayode-Ojo et al., 2019). A study of selected gully sites reported conditions associated with erosion susceptibility, including intense rainfall, steep slopes, substantial runoff and soils with relatively low organic content and shear strength (Kayode-Ojo et al., 2019). The study also reported different gully cross-sectional forms, illustrating the importance of site-specific hydrological and geomorphological assessment (Kayode-Ojo et al., 2019).

In Auchi, remote-sensing and field-based research found continuing gully progression and vulnerability over the period examined (Okeke et al., 2016). Research on Ikpoba-Okha quantified substantial sediment loss at selected gully sites, demonstrating that erosion can represent not only a landscape problem but also a loss of productive land and a threat to settlements and infrastructure (Eremen et al., 2025). Geotechnical investigation at the University of Benin also examined soil susceptibility to gully erosion, reinforcing the importance of local soil conditions in site assessment (Ojeaga & Afolabi, 2022).

6.2 Landscape factors affecting erosion

Vegetation is particularly important because it modifies the relationship between rainfall, soil and runoff. Canopy interception, ground cover and root systems can influence rainfall delivery to the soil surface, soil protection and runoff behaviour; the magnitude of these effects depends on vegetation, soil and site characteristics (Liu et al., 2022; Lalonde et al., 2024). Edo State studies also document biological measures, including tree and crop planting, as components of erosion-control responses used alongside mechanical measures (Osayande et al., 2019).

Landform is another landscape variable. Steep terrain can concentrate runoff and increase erosion susceptibility, while appropriately designed terraces, contour planting, level spreaders, vegetated swales and infiltration areas can be considered where site conditions permit (Kayode-Ojo et al., 2019; Lalonde et al., 2024). The appropriateness of each measure depends on slope, soil, rainfall, catchment size and expected discharge, so the framework does not prescribe universal dimensions or plant specifications.

6.3 Literature-Derived Landscape Functions

The literature supports five interconnected functions relevant to a landscape-infrastructure approach: rainfall interception, infiltration, flow attenuation, soil reinforcement and ecological buffering (Osayande et al., 2019; Liu et al., 2022; Lalonde et al., 2024). These functions provide the evidence base from which the author develops the proposed six-zone framework in Section 8. The zone-by-zone arrangement itself is an authorial synthesis and is therefore not presented as a direct finding of any single source.

7. Discussion

The evidence indicates that erosion in Edo State is produced by interacting hydrological, topographic, soil and land-use conditions (Kayode-Ojo et al., 2019; Ojeaga & Afolabi, 2022). Consequently, a single intervention is unlikely to be appropriate for every site. This has direct implications for landscape planning: landscape planning should begin at the catchment scale, where the quantity and speed of water entering a vulnerable slope can be influenced, rather than beginning only at the visible gully. This is consistent with broader nature-based-solutions research, which emphasises that intervention effectiveness depends on location, design and environmental context (Lalonde et al., 2024).

An integrated landscape-engineering approach can therefore be represented as a sequence: retain where rainfall falls, infiltrate where soil permits, slow water as it moves downslope, safely convey unavoidable excess flow, stabilise vulnerable soil and protect receiving environments. Where discharge exceeds the capacity of a vegetated system, structural measures remain necessary. The role of landscape is therefore complementary and strategic rather than a substitute for engineering.

This approach is consistent with evidence from Edo State showing that biological control methods, including tree and crop planting, have been used alongside mechanical measures (Osayande et al., 2019). Recent work in Etsako West found soil texture and slope

degree to be important gully-susceptibility factors and recommended good drainage channels and tree planting in settlements at risk (Okoeke et al., 2025). A 2025 study of Iwogban in Ikpoba-Okha also recommended re-channelisation, partial gully-head reclamation, vegetative cover and afforestation (Eremen et al., 2025). These findings support the principle that drainage and vegetation should be considered together rather than as competing approaches.

8. Proposed Landscape Conservational Infrastructure Framework

Landscape zone	Primary function	Possible measures
Upper catchment	Reduce runoff generation	Tree belts; ground cover; infiltration areas; contour planting
Slope zone	Protect soil and reduce flow velocity	Terraces; contour vegetation; check structures; mulching
Road/drainage interface	Manage concentrated runoff	Vegetated swales; grassed channels; inlet protection; level spreaders
Gully head	Prevent headward retreat	Vegetated buffers plus engineered head stabilisation
Gully/channel	Protect banks and convey flow	Riparian planting; bioengineering; bank protection; appropriate structures
Downstream zone	Reduce sediment and protect receiving waters	Buffer strips; sediment traps; wetland/retention areas

8.1 Catchment protection

Development control should prevent unnecessary clearing and uncontrolled concentration of runoff. Existing vegetation should be retained where possible, while new development should incorporate infiltration and controlled discharge. This subsection is a design proposal derived from the evidence base; it is not a tested intervention.

8.2 Vegetated drainage

Open drainage systems can incorporate stable grassed or planted sections where hydraulic conditions permit. Where velocities are too high, vegetated systems should transition to engineered channels or energy-dissipation structures. The choice should be based on hydraulic assessment rather than assumed vegetation performance.

8.3 Slope stabilisation

Slopes should be assessed for gradient, soil strength and drainage. Ground covers, deep-rooted vegetation, contour planting and bioengineering can be combined with structural reinforcement where necessary. Site-specific design and field validation are required before dimensions or species are specified.

8.4 Gully-head management

Gully heads should be treated as part of the upstream drainage system. Preventing additional runoff from entering the head and stabilising the head with appropriate engineering and vegetation can reduce continued retreat. The specific intervention should follow hydrological and geotechnical assessment.

8.5 Riparian and buffer landscapes

Vegetated buffers can reduce sediment movement and protect waterways. Their width and planting design should be determined by hydrology, channel characteristics, land ownership and maintenance requirements.

8.6 Downstream sediment and receiving-water protection

Downstream zones should incorporate buffer strips, sediment traps, wetlands or retention areas where appropriate to reduce sediment delivery and protect receiving waters. These measures should be sized and located according to catchment behaviour, land availability and maintenance capacity.

8.7 Maintenance and monitoring as a cross-framework requirement

Maintenance should be treated as a continuous component across all six landscape zones. Vegetation establishment, drainage clearance, sediment removal, inspection of erosion-prone points and repair of damaged protective measures should be incorporated into implementation and monitoring plans. The frequency and scope of maintenance should be determined by site conditions, seasonal rainfall, sediment loads and available institutional capacity.

9. Implications for Architecture, Planning and Public Infrastructure

For architects and planners, the key implication is that landscape should be considered at the beginning of site planning. Building orientation, road alignment, plot subdivision, parking areas, roof drainage and surface paving all influence runoff. A development can therefore either increase or reduce erosion risk depending on how these elements are coordinated.

At the municipal scale, erosion management should be incorporated into development plans, road projects, drainage masterplans and public open-space systems. Landscape corridors can become multifunctional infrastructure: they can manage stormwater, provide shade, support biodiversity, improve public space and protect vulnerable land. This is particularly relevant where resources for repeated reconstruction of failed drainage infrastructure are limited.

10. Limitations

The principal limitation of this paper is that it is a secondary-data and conceptual synthesis rather than a primary field experiment. No new erosion-rate measurements, soil tests, hydraulic simulations or intervention-performance measurements are claimed. The proposed framework therefore requires field validation before site-specific dimensions, plant species, drainage capacities or structural details are specified. Future studies should test the framework at selected Edo State sites using baseline and post-intervention measurements.

11. Conclusion

Gully erosion in Edo State is a multidimensional environmental and infrastructure problem involving rainfall, runoff, terrain, soil, vegetation and land-use practices. The evidence reviewed in this paper indicates that landscape can perform meaningful conservational functions when it is designed as infrastructure rather than treated as decoration. The proposed approach integrates catchment protection, vegetated drainage, slope stabilisation, gully-head treatment, riparian buffers and long-term maintenance with conventional engineering.

References

- Adediji, A., & Iyamu, F. (2013). Risk assessment analysis of accelerated gully erosion in Ikpoba Okha Local Government Area of Edo State, Nigeria. *Environment and Natural Resources Research*, 3(1), 68–76. <https://doi.org/10.5539/enrr.v3n1p68>
- Afegbua, U. K., Uwazuruonye, J., & Jafaru, B. (2016). Investigating the causes and impacts of gully erosion in Auchi, Nigeria. *Journal of Geography, Environment and Earth Science International*, 4(4), 1–13. <https://doi.org/10.9734/JGEESI/2016/22582>
- Eremen, P. E., Badru, G. S., Akoso, T. M., & Odunuga, S. (2025). Estimation of the volume of soil loss due to gully erosion in Iwogban urban catchment area in Ikpoba-Okha Local Government in Benin City, Edo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 29(4), 1333–1342. <https://doi.org/10.4314/jasem.v29i4.36>
- Kayode-Ojo, N., Ikhide, A. O., & Ehiorobo, J. O. (2019). Gully erosion problems in selected areas of Edo State: Factors and control. *Nigerian Journal of Environmental Sciences and Technology*, 3(1), 161–173. <https://doi.org/10.36263/nijest.2019.01.0104>
- Lalonde, M., Drenkhan, F., Rau, P., Baiker, J. R., & Buytaert, W. (2024). Scientific evidence of the hydrological impacts of nature-based solutions at the catchment scale. *WIREs Water*, 11(5), e1744. <https://doi.org/10.1002/wat2.1744>
- Orta Ortiz, M. S., & Geneletti, D. (2022). What variables matter when designing nature-based solutions for stormwater management? A review of impacts on ecosystem services. *Environmental Impact Assessment Review*, 95, 106802. <https://doi.org/10.1016/j.eiar.2022.106802>
- Ojeaga, K., & Afolabi, S. (2022). Geotechnical characterization of soil susceptibility to gully erosion, Capitol, University of Benin, Benin City, Edo State, Nigeria. *NIPES Journal of Science and Technology Research*, 4(2). <https://doi.org/10.37933/nipes/4.2.2022.31>
- Okeke, U. H., Alaga, A. T., & Eguaroje, O. E. (2016). An assessment of gully erosion progression and vulnerability in Auchi area in Edo State. *Journal of Geography, Environment and Earth Science International*, 7(2), 1–14. <https://doi.org/10.9734/JGEESI/2016/26459>
- Okoeaka, G. E., Oladosu, S. O., & Alademomi, A. S. (2025). Geospatial mapping of gully erosion susceptibility in Etsako West Local Government Area, Edo State, Nigeria. *Dutse Journal of Pure and Applied Sciences*, 11(2a), 399–415. <https://doi.org/10.4314/dujopas.v11i2a.34>
- Osayande, A., Edobor, W. W., & Kato, S. (2019). Effectiveness of gully erosion control measures in Edo State, Nigeria. *Open Access Library Journal*, 6, e5018.
- Osayande, A., & Yari Mallo, I. I. (2017). Mean rate of gully head advancement in Edo State, Nigeria. *International Annals of Science*, 3(1), 13–18. <https://doi.org/10.21467/ias.3.1.13-18>

World Bank/EDO-NEWMAP. (2015). Resettlement Action Plan: Auchu Erosion Gully Site in Etsako West, Edo State, under the Nigerian Erosion and Watershed Management Project (NEWMAP). Edo State World Bank Assisted Nigeria Erosion & Watershed Management Project.