Innovations

Flood Resistant Landscape in Nigeria: Green Infrastructure as a Landscaping Tool for Flood Resilience in Nigeria

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Abstract: *Fathered by Frederick Law Olmsted in 1994, the concept of green infrastructure was adopted to offer sustainable environmental landscaping solutions, with the aim of achieving ecological and social balance in the environment. Green Infrastructure features support for plant and animal growth, provide space for the protection of historic sites, bridge the gap between humans and nature, as well as provide conservation corridors, green belts, recreational corridorsscenic corridors, utilitarian corridors, trails, and reserves. They are also accountable for preserving ecological and cultural/historical sites. The aim of this research paper is to examine the role of green infrastructure in combatting urban floods in Nigeria. Using a case study of Lagos, green infrastructure is discussed as a foolproof solution for recurrent flood issues. It begins with a background reviewing the historical overview of Green Infrastructure, and it goes on to highlight the Aesthetic, Social, Health, Environmental, Ecological, Functional, and Economic benefits of green infrastructure. It further reviews the history of flooding in Nigeria, stating its causes and negative impact which lead to food shortage, loss of property, health hazard, economic distress, aesthetic malfunction, and land distress. The research assesss the present state of landscape in Lagos state, and concludes by suggesting the best green infrastructure practices and materials for ensuring environmental sustainability.*

Keywords*: Sustainable, Infrastructure,Green, Flood, Nigeria.*

1.0. Introduction

1.1. Historical Overview of Green Infrastructure

Green infrastructure is a concept riddled with diverse definitions depending on the context within which it is used (Seiwert and Rößler, 2020). Within the context of landscape, Green infrastructure, not to be mistaken with alternative drainage systems (Adesoji and Pearce, 2024), was pioneered by Olmsted and Howard and refers to sustainable environmental landscaping solutions used to achieve balance in the "ecosystem economic and social spheres". Citing the President's Council on Sustainable Development (1998:141), the concept of Green Infrastructure is believed to 'promote place-based approaches to conserve, protect, restore, and manage local

and regional networks of natural living, and environmental resources and amenities.'(Ian, 2008).

Though the concept appeared in different forms all through ancient civilization, a 1994 report by Buddy MacKay names Frederick Law Olmsted (an American landscape architect, journalist, social critic, and public administrator) as the father of green infrastructure (though it was called greenways, not green infrastructure) following his design of New York's Central Park and Brooklyn's Prospect Park as well as Boston's "Emerald Necklace". These projects paved the way for the "park and parkway" idea. In that report, Green Infrastructure features the following:

a) ''landscape linkages to support plant and animal growth, as well as provide space for the protection of historic sites'' and bridge the gap between humans and nature.

b) Conservation corridors

c) Green belts

d) Recreational corridors

c) Scenic corridors

d) Utilitarian corridors

e) Trails

f) Reserves and preserves

g) Ecological sites

h) Cultural/historical sites

i) Urban areas

Two famous applications of Green infrastructure in ancient civilizations were the use of natural elements(gardens, rocks, water bodies, bridges flowerbeds, lawns, and pavilions) in Chinese landscapes (Johansson, 2015), and the use of hanging gardens in the design of Babylon.

Green Infrastructure (GI) has since evolved and improved into more complex technological solutions that are being adopted due to their efficiency in combating global urban environmental concerns such as flooding, which is the focus of this paper.

1.2. Benefits of green infrastructure

1.2.1 Aesthetics benefits: Green Infrastructure manifests itself as green roofs and walls, scenic corridors, green belts, etc., all of which improve the visual taste and beauty of a landscape (Ayisha & Rexford & Alexander, 2018);

1.2.3. Social benefits: GI improves the built environment through the creation of green spaces like parks, trails, etc. These spaces host team and community gatherings that foster bonding, and physical activities that improve the health of their users (Uzonnah, IChukwu, and Ibem, 2023);

1.2.2. Health benefits: The use of GI solutions directly improves air quality and decreases pollution thus increasing the quality of life of the people (Kim, & Miller, 2019).

1.2.3. Environmental benefits: It offers protection and conservation of the ecosystem, ensures efficient management of natural resources through recycling, and promotes rejuvenation of environmental components (Shreyas, Dharmendra, & Shweta. 2023);

1.2.4. Ecological benefits: it offers resilient solutions that secure the ecosystem, increasing its adaptability to climate change (Ying, Zhang, Zhang & Bilan, 2022);
1.2.5. Improved functionality of landscape:It ensures the functionality and interconnectivity of landscape elements, increasing their usability and durability;
1.2.6. Economic benefits: GI solutions (such as trails, parks, and conserved natural heritage sites) serve as tourist attractions. Thus attracting investors, generating revenue from tourist activities, and creating job opportunities.

1.3. Research question

What green infrastructure can be incorporated in the Landscape to combat flooding in Nigeria?

2.0. Literature Review

2.1. Flooding in Nigeria

Nigeria is a West African country with an estimated population of 226.2 million (Statistia, 2023). It is marked by two seasons: the rainy season and the dry season. The dry season spans from December to March, while the rainy season occurs between April to Septemberwith an annual rainfall that can reach up to about 1200 mm, exposing its inhabitants to the likelihood of flood, a is a natural disaster that results from both natural and man-made factors.

According to a 2023 National Bureau of Statistics report, flooding is named the most common natural disaster in Nigeria.It can occur at different scales, and its impact leaves a devastating effect on the economy, environment, agriculture, aesthetics, and ecology, all of which affect the health and well-being of her citizenry.

2.2. Impact of flood in Nigeria

Across the country, the horrible tales of the impact of flood are in their hundreds affecting homeowners and farmers, rich and poor alike, disrupting their daily activities.

Food shortages - Flood is directly linked to the food shortage crisis because diligent farmers in the fertile farmlands of Nigeria lose hectares of harvest-ready farm produce to flood annually(Adebayo, 2023). A 2022 National Bureau of Statistics report on the impact of flood in six Nigerian states links “disrupted agricultural activities, reduced crop yield, a hike in food prices, and scarcity of nutritious food” to flood.

Loss of property- floods occur when modifications are made to the environment mostly without consideration and adequate channels to manage runoff or stormwater. This leads to damage to properties and displacement of its users. Property loss due to flood is estimated to be worth billions of Naira with 1,400,000 people displaced from their homes across Nigeria. This leads to trauma which affects the mental and psychological health of the victims.

Health hazard -besides drowning and destruction of health infrastructure caused by flood, there is an increased chance of an outbreak of the disease in floods as floodwaters are believed to be vectors of hundreds of disease-causing pathogens, thus negatively impacting the health of Nigerians (Abdulrahim et al. 2022).

Economy - flooding in Nigeria destroys or renders streets, bridges, and marketplaces inaccessible. This stalls production and commercial activities. Also, the devastation of farmlands led to the loss of livelihood and all revenue that would have been generated from that source. All these staunch the growth and development of the economy of the nation as they discourage tourists and investors;
Aesthetics: flood water transports dirt which defaces the landscape. In addition, it destroys plants and hardscape elements, thus turning a well-landscaped Nigerian street into an eye sore;
Environmental distortion- floods cause erosion and landslides, destroy the natural habitat of organisms thus displacing biodiversity and causing an imbalance in the ecosystem.

2.3. Causes of flood in Nigeria

The causes of floods in Nigeria are divided into two (Ifiok, Oguike, Eteng, Moses & Etim, 2022)
a) Human causes - these include all man-made activities that evoke flood e.g. rapid urbanization, poor drainage of the cityscape, improper or inadequate management of solid waste, insufficient or un-enforcement of environmental protection policies, and deforestation;
b) Natural causes - this refers to all the activities beyond the control of man that lead to flooding. Such activities include excessive rainfall due to forces of climate change''(Mfon et al, 2022).

3.0. Gi Landscape as a Flooding Solution in Nigeria

3.1. Contextual Overview of GI Landscape

In cities like Lagos state, the slightest drizzle can constitute a flood. The same can be said of Port Harcourt, Warri, and many other cities which lack adequate planning forit'srapidly urbanizing cities. Hence the need to incorporate Green Infrastructure(GI) in landscape designsas a sustainable solution to combat the persistent occurrence of floods in Nigeria.
Green infrastructure (GI) can be defined as the design of natural systems to manage the challenging issue of storm water runoff thus achieving urban sustainability (Chini, Canning, Schreiber, Peschel, and Stillwell, 2017).
Green Infrastructure landscape includes all woodlands and reserves, hiking trails, recreational parks, open spaces, playing fields, street verdure, allotments, private gardens, green roofs and walls, and drainage systems that protect biodiversity, mitigate climate change, and increase environmental resilience.

3.2. Goal of Incorporating Green Infrastructure (GI) in Nigerian Landscapes

The goal of GI is to recycle and regenerate runoff water to combat the negative impact of floods on landscape and human activities (Wyk, 2014).

3.3. Benefits of Incorporating Green Infrastructure (GI) in Nigerian Landscapes

The effectiveness & potential of GI Landscape are as follows:
3.3.1 Climate Change: GI landscapes combat climate change by promoting Carbon sequestration. Carbon sequestration is the process where toxic Carbon is safely cap-

tured and stored in landscape greenery (Rattan, 2007) like forest reserves, street lawns, woodlands, etc. Thus reducing the carbon footprint;

3.3.2. Property value:Flood-prone areas in Nigeria affect livability and discourage occupancy of both commercial and residential buildings. Incorporating GI landscapes to eliminate the likelihood of flood will serve as a unique selling point, increase the property value of these buildings, and increase the livability and ease of doing business in these areas;

3.3.3. Health:Flooding in Nigeria deteriorates both the physical and mental health and well-being of its victims. Incorporating GI landscape in the design and planning of flood-prone areas will improve the health and wellbeing of its inhabitants.

3.3.4. Environmental resilience:GI landscape improves environmental resilience by adequately managing storm and runoff water, promoting biodiversity, providing habitats for necessary ecosystems to thrive, reducing erosion, and minimizing pollution caused by flood;

3.3.5. Economy:The GI landscape impacts the economy positively by making the environment conducive to investors, as well as creating job opportunities for GI service/product providers, & staff of GI spaces like parks & reserves.

3.4. GI Landscape Elements

3.4.1. Perméable Pavements

Permeable Pavements are sustainable drainage systems that effectively minimize storm water pollutants, volumes and rates, and temperature (Hemanth & Saicharan, 2014).Commonly used in parking lots, low-traffic roads, sidewalks, and driveways, this system can be designed using total, partial, or zero infiltration with "open granulometry materials" containing little or no amount of fines to allow the passage of runoff water through their porous surfaces. This improves the quality of storm water, and renders them reusable for certain potable and nonpotable purposes by reducing heavy metal by up to 74%, retaining solids at a rate of 87%, and intercepting hydrocarbons at a 90% rate (Antunes, Ghisi, and Thives, 2018).

Available permeable pavement options include:

a) Plastic Reinforcement Grid Pavers
b) Permeable interlocking concrete pavement (PICP)
c) Concrete grid pavers
d) Permeable concrete
e) Permeable asphalt

3.4.2. Downspout Disconnection:

Downspout Disconnection is a simple, inexpensive, effective, stormwater control measure employed to harvest rainwater by using a down-pipe connected to the fringes of eaves and/or roof gutters of buildings to channel stormwater to lawns and other pervious surfaces where they are treated and temporarily stored (Vinicius, Erin & William, 2018).

3.4.3. Rain Gardens

Rain Gardens or bioretention systems are acknowledged as the most recommended stormwater management systems. Developed in 1990 by Dick Brinker, rain gardens

are hollow planted areas designed to temporarily collect runoff water from impervious surfaces, and purify it, before allowing it to soak back into the ground (Malaviya, Sharma, and Sharma). A cross-section of this system would reveal the base level filled with stones to serve as a temporary pouch for the storage of water.

3.4.4. Planter Boxes

Rapid urbanization accounts for congested spaces leaving little or no provisions for greenery. In such cases, the adoption of planter boxes is highly recommended. Known to positively influence the productivity of users (Tonia, 2018), Planter Boxes are artificially constructed gardens designed with nonpermeable materials like concrete, to support the growth of greenery, while also capturing the stormwater runoff and for settlement of sediments and pollutants (Matina, 2017).

3.4.5. Bioswales

Similar to rain gardens but offering more retention capacity, Bioswales are stormwater management systems ideally specified to capture and partially improve a minimum of 11cm of stormwater quality in 24 hours. Other design specifications of bioswales include:

1. Minimum space area - less than 4 hectares
2. Slopes - less than 5%
3. Total surface area - 1% of the area from which it is receiving stormwater

In addition to their usefulness in managing stormwater, they improve the aesthetics of the host environment and serve as a habitat for biodiversity (Brankovic, Mitković, Bogdanovic, Ivana, Milica, & Jelena, 2019).

3.4.6. Green Streets and Alleys

Green streets and alleys are public roads that feature GI Landscapes (such as Rain gardens and bioswales) installed in their right of way to manage stormwater runoff (Joowon, 2019).

3.4.7. Green Parking

Asphalt is the most common construction material in conventional parking spaces. This material is a huge conductor of heat leading to thermal discomfort for its users and residents in neighboring properties. It also constitutes a source of pollution for stormwater in urban areas. Green parking offers alternatives to Asphalt, and encourages the use of canopy trees, permeable pavements, and other GI landscaping features to combat this problem;

3.4.8. Green Roofs

Green roofs are partial or fully vegetated roofing systems installed to minimize the impact (volume and intensity) of stormwater on the drainage, thus reducing the likelihood of floods. They also purifythe water, rendering it fit for environmental and certain domestic use (World Green Infrastructure Network).

3.4.9. Urban Tree Canopy

Planting trees with large canopies in streets, parking lots, recreational parks, bus stops, streets, gardens, and other public spaces significantly intercepts, absorbs,

and reduces stormwater runoff from impervious surfaces (Pataki, Alberti, Cadenasso, Felson, McDonnell, Pincetl, Pouyat, Setälä, Whitlow, 2021).

4.0. Recommendation

Flooding is not peculiar to Nigerians alone, it is a natural disaster that has affected both developed and developing countries alike. In Nigeria, it is experienced in different degrees in both the rural and urban areas, and within the urban areas, it is experienced by both the elite and urban poor. Flooding must be treated as an emergency. To handle this emergency, it is imperative to explore a mixture of available GI Landscape systems to mitigate the possibility of a flood.

The following recommendations should be adhered to in the adoption of GI Systems within the Nigerian context.

4.1. Best practices: In the use of GI systems to combat floods in Nigeria, best practices and due process must be adhered to. It is recommended hence that only building professionals should be employed to ensure that standard design requirements are met, and design specifications for green roofs, rain gardens, and all the other GI solutions are adhered to avoid malfunctions that may stem from improper installations or maintenance of these GI systems as this could yield to disasters equivalent to that of flood;

4.2. Education: the curriculum for the education of Landscapers in Nigeria should be designed to encourage production and innovation, not just to rely on the consumption of imported GI solutions. Also, emphasis and priority should be placed on the use of locally sourced materials for these innovations. Finally, investments should be made available to designers and researchers to foster the development of local, budget-friendly, innovative green infrastructure solutions to reduce reliance on foreign, often costlier alternatives;

4.3. Awareness: many citizens are ignorant of the extent of damage, the dangers, and the cost implication currently being accumulated from neglecting the environment, and the benefits and role of Green Infrastructure Landscape in solving this. It is important that the citizenry be educated about GI systems, as well as enlightened through both conventional and non-conventional media. They should also be empowered with the knowledge and skill needed to apply GI Systems in their lifestyle;

4.4. Research: supporters and collaborations should be made with private and public stakeholders to invest in research and innovations geared towards the development of more innovative GI solutions to flooding in Nigeria;

4.5. Accountability: it is popular to witness property owners and road users engage in practices that degrade the environment and lead to flooding. Such practices include littering, illegal dumping of refuse in drainages, and the vandalization of landscape elements installed to check flood. This can be stopped through the imposition of strict punishment and fines for property owners and building users apprehended for violating the environment.

4.6. Policy reforms.

Policies that mandate landscape designers, Architects, and all other allied professionals in the built environment to specify green infrastructure methods, techniques, and components as a minimum requirement for acquiring building approvals should be enforced. These policies should encourage environmental management at the grassroots and the local government level, as well as create an enabling environments for investors to inject capital towards green infrastructure construction.

Conclusion

History has taught us that nature opposes designs that disrespect nature, hence the need for GI systems - an organic solution that joins the built environment and nature features in a marriage that both serves the users and preserves the environment. This paper highlights the various Green Infrastructure Landscape options aimed at designing flood-resistant Landscapes in Nigeria. While these systems offer positive possibilities for the Nigerian Landscape, and improves the interaction of citizens with the natural environment, they also offer sustainable solutions to combating flood by temporarily capturing runoff and stormwater, cleansing this water from impurities and pollutants, and efficiently releasing them either back into our homes for consumption, our gardens for irrigation, or to the atmosphere through evaporation. This paper also recommends a set of guiding principles for the adoption of this GI Landscape solution within the Nigerian context to avoid any negative impact on life, property, or the environment.

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