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Maximizing the role of trees in flood control and creating resilient landscapes in Sokoto State, Nigeria: A review

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ABSTRACT

As the planet warms, rainfall patterns shift, and extreme events such as drought, floods, and forest fires become more frequent resulting in poor and unpredictable yields, thereby making farmers more vulnerable, particularly in Africa. Similarly, several studies reported that the consequences of climate change coupled with human activities resulting in flooding incidences, adversely affect land productivity and destroy infrastructural facilities in Nigeria. Despite several efforts, flooding incidences persist, and losses incurred due to such phenomenon are escalating. Given this, a biological approach involving tree planting at strategic places as a flood control measure is currently receiving attention worldwide. Though trees have limitations with regard to flood mitigation especially in the urban setting, their role in slowing surface runoff and provision of ecosystem services cannot be overemphasized. However, the current paper reviewed the potential of trees in flood regulation and creating a resilient landscape in Sokoto State, Nigeria. This is to provide information for policymakers, forestry practitioners, and environmental stakeholders in curtailing the impact of flooding and developing a landscape that persists or supports biodiversity after perturbation.

Keywords: Resilient; landscape; trees; flooding; climate change

INTRODUCTION

Theoretical models and observations have been used by scientists for years in order to study past and future trends in climate (Townsend, 2014). In view of this, evidence emerged regarding future climate change, hence more rainfall and storms are expected (Andrew, 2016). Despite various efforts to avert the effects of climate change, natural events such as flooding, higher temperatures, and heavy wind persist, and losses recorded in lieu of such events are ever-increasing. Similarly, changes in land use practices seldom seriously affect the landscape and overall biodiversity (Kusimi, 2015). For decades, people in their quest to maximize agricultural productivity and infrastructural development altered landscape naturalness both in the upland areas, river valleys, and on the surrounding hill slopes (John, 2015). These activities have fuelled the risk of flooding globally due to

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increased run-off speed from upland areas and along the river channels towards downstream communities (McGovern, *et al.*, 2013).

The damaging impact of flooding on a landscape varies with the scale, intensity, and duration of water flow from the upland to the lowland areas (John, 2015; Pedro and Santiago, 2013). Whilst the consequences of flooding are universally acknowledged, engineering and natural measures are emphasized to regulate the inflow of water into the water bodies (like Rivers and streams.) which may otherwise lead to flooding (Hugh, 2016). Despite this, flooding occurrences are recorded annually in different parts of the world.

Nevertheless, evidence has shown that the diverse structural arrangement of trees on the landscape has a direct relationship with infiltration and surface water run-off (Gareth, 2016). Therefore, it is imperative to maintain a tree cover sufficiently enough to mitigate the impact of flooding and provide numerous ecosystem services.

However, in Sokoto State, deforestation occurs at an upsetting rate of 3.49 % per annum (194.88 ha) (Maniyunda and Ya'u, 2019). Deforestation and degradation in this area usually stem from human activities in rural areas, such as bush burning, uncontrolled mining activities, overgrazing, and poverty (NESREA, 2023), while urbanization and poor management practices threatening the growth and development of green infrastructures in the metropolitan areas of the state (Dangulla, *et al*, 2020). Despite the efforts by government and donor agencies, flooding incidences persist in the State. Given this, the current review was made in order to provide baseline information on flooding incidences, causes, consequences, and control measures that will guarantee resilient ecosystems in the State. The objective is to establish the significance of the tree plantation establishment and management as a panacea to flooding and the provision of ecosystem services.

What is a Resilient Landscape?

A resilient landscape can adapt to changing environmental conditions and maintain its ecological functions and services (Hugh, 2016; Gareth, 2016**).** It is characterized by supporting biodiversity, human well-being, and sustainable development amidst relatively natural or anthropogenic intrusions. Resilient landscapes can cope with disturbances such as climate change, natural disasters, land degradation, urbanization, and conflicts, and recover from such unforeseen events without losing their essential characteristics (Townsend, 2014; Gareth, 2016).

Why Resilient landscapes?

Resilient landscapes are not only desirable but necessary, given the pressing environmental challenges and uncertainties in the 21st century (Gareth 2016). Insecurity, war, climate change, and rebelliousness to environmental laws and regulations resulted in degradation and poverty, especially in rural areas where sources of livelihoods are climate-dependent (Gareth, 2016; CSGN, 2013). However, resilient landscapes can provide multiple benefits for people and nature, such as food security, water availability, biodiversity conservation, carbon sequestration, disaster risk reduction, and cultural heritage. It can also foster social cohesion, empowerment, and innovation among the communities that depend on them.

Building a Resilient Landscape

Resilient landscapes can be achieved through integrated planning, management, and restoration of natural and human-modified ecosystems (Steve, 2016). Although Nisbet and Thomas (2006) argued that, due to landscape variations as induced by climatic conditions, land use practices, and human activities, there are no single universally agreed-upon criteria for building a resilient landscape. Still, some general principles and practices can guide the achievement of a landscape that can prevail despite natural or anthropogenic disturbances.

1. Adopting a holistic and integrated approach that considers the interactions and trade-offs among different landscape components and stakeholders.
2. Promoting diversity and redundancy of species, habitats, functions, and livelihoods within and across landscapes
3. Enhancing connectivity and mobility of organisms, resources, and information within and across landscapes
4. Supporting adaptive management and learning that enables experimentation, monitoring, evaluation, and feedback
5. Engaging in participatory and inclusive processes that involve multiple actors and perspectives in decision-making and governance
6. Building on local knowledge and practices that reflect the history, culture, and values of the landscape inhabitants
7. Aligning policies and incentives at different scales that support the vision and objectives of the landscape stakeholders

However, building and managing resilient landscapes is not an easy task (Hugh, 2016). It requires collaboration, coordination, and compromise among multiple actors with diverse interests and values. It also requires long-term commitment, flexibility, and resilience from the landscape stakeholders themselves. However, the rewards are worth the effort. Resilient landscapes can offer us a more sustainable and fulfilling way of living on this planet (Steve, 2016).

RELATIONSHIP BETWEEN LAND USE AND FLOODING

Land use and flooding are closely related (Andrew, 2016). Urban development, for instance, can have a significant impact on flooding. According to Andrew (2016), changes in land use associated with urban development can increase the volume and frequency of floods in nearby streams. This is because deforestation and grading of land surface coupled with constructing drainage networks increase runoff to streams from rainfall and snowmelt.

Land use is one of the most important drivers of environmental changes, it involves the purposes and activities through which people interact with natural ecosystems. According to the FAO (2022) global forest report, forests cover 31% of the global land mass and only half of the forested ecosystems are intact. At the local scale, about 78% of land in Nigeria is used for agricultural activities and only 9.5% is covered by forest (Sasu, 2022). Given the rapid increase in human population, the demand for infrastructure increases exponentially, resulting in excessive deforestation and land degradation. In view of this, environmental problems such as erosion, land degradation, pollution, and flooding incidences persist.

Flooding is a phenomenon that damages landscapes and associated infrastructures (Hugh, 2016; John, 2015). It is aggravated by climate change, human activities, poor agricultural land use practices, and deforestation among others (Hugh, 2016; Pedro and

Santiago, 2013). These factors, however, expose soil surface, promote land use changes, and increase the speed of surface run-off which leads to flooding.

According to Bello and Ogedegbe (2015), the most common natural disaster in both developed and developing countries is flooding. In Nigeria, ninety-three (93) local government areas experienced flooding in 2012 and the number of deaths recorded in such events was 148. Heavy rainfall, deforestation, and inadequate drainages resulted in flooding incidences that claimed lives and properties worth millions in Sokoto State. According to SEMA, about 36 people have died while 470 others were displaced from their homes following floods recorded in 2023 in various parts of Sokoto state. Also, about 302, 500 hectares of farmlands were submerged and about 120 animals were killed due to flooding experienced across the state. Similarly, 19 out of 23 local government areas in Sokoto state have been affected by devastating flooding since the start of the rains in the year 2020 (SEMA, 2023).

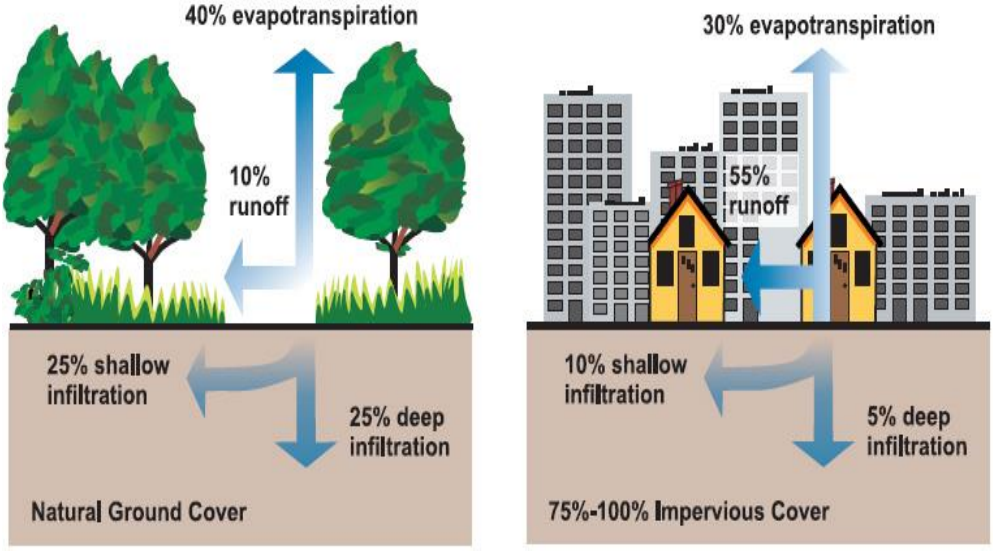

Figure 1: The impact of trees or vegetation on the landscape with respect to infiltration and evapotranspiration rates and surface run-off. (EPA, 2003)

Similarly, Yusuf and Igene, (2014) reported that 378.7 km^2 in Goronyo Local government, Sokoto State, has been lost between 1987 and 2010 due to the conversion of vegetation cover into rainfed agriculture. These increases in agricultural land and bare surfaces are at the expense of the vegetation cover which has led to environmental and ecological problems such as land degradation and gullies resulting from flood waters. However, despite efforts by the state government, incidences of flooding persist, this is partly due to poor land use practices and failure to adopt natural measures that will enhance the resilience of urban ecosystems in the state.

Given the risk and devastating nature of floods, information on rainfall patterns, drainage systems, and deforested ecosystems became crucial to achieving sustainable development goals. However, while excessive pavement and ditching of farmland, deforestation, and soil compaction caused by trampling animals increase run-off speed (Nisbet and Thomas 2006 and John, 2015.), evidence showed that changes in land use practices with a priority to increase in tree cover reduces run-off, prevent erosion, soil movement, and flooding (Hugh, 2016; Townsend, 2014;).

Moreover, excessive land clearing to pave the way for infrastructural constructions without giving due consideration to the urban green spaces promotes surface runoffs, reduces infiltrations, and evapotranspiration rates, and promotes likely incidences of flooding on natural landscapes (Figure 1).

Land use is one of the major factors significantly affecting the flooding process, and it is inextricably tied to the ecological risk of floods. Hence, flood risk estimates based on land use are essential for flood control and land use planning. Also, to regulate flooding and extreme temperatures, it is not only essential but necessary to promote environmental laws, regulate land use practices, and promote green infrastructures, especially in the urban setting. The conversion of natural ecosystems to man-made structures greatly impacts the supporting services provided by soils (Grebner *et al*, 2013) and disrupts the resilience of natural ecosystems. Hence the need for urban forests in order to tackle the effects of anthropogenic disturbance on natural ecosystems. Urban forests are an important component of urban ecosystems, providing numerous benefits such as flood regulation, air quality improvement, carbon sequestration, and temperature regulation (Ordonez *et al*, 2020). Despite the numerous benefits provided by urban green infrastructures, in Sokoto metropolis, lines of street trees and green spaces are cut down to pave the way for shopping malls and business centres (Figure, 2).

Figure 2: Interrupted street trees replaced with plazas and shopping malls (Al-sudais Road, Sokoto).

Mechanism of Flood-Attenuation by Trees

Landscape resiliency 'is not about a single ideal ecological state, but an ever-changing system of disturbance and recovery' (Banfield, 2009). Therefore, to enhance the resilience of a landscape, it is desirable to maintain (on a landscape) features with higher adaptation, tolerance, and regeneration potential. However, evidence has shown that trees; as a renewable natural resource, have the potential to withstand adverse environmental stress, recover after disturbance, enhance landscape resilience, and provide numerous ecosystem services (Kerlin, 2022).

For example, Trees using their canopy reduce raindrop impact on the soil surface and also trap rainwater, which is then subsequently evaporated into the atmosphere (Nisbet and Thomas 2006; John, 2015; CSGN, 2013), although under extremely low temperatures the trapped water constitutes a load to the tree canopy which may result in breakage or snapping of tree stems following a slight wind blow (Gareth, 2016). Nonetheless, Kerlin (2022) uncovered that forests with low tree densities can be more resilient to wildfire, drought, and other environmental hazards while maintaining sustainable ecosystem services provisioning.

The roots of trees prevent soil movement, enhance infiltration, and absorb water from the ground (John, 2015; McGovern, *et al.,* 2013) making it available for growing vegetation. Shelterbelt establishment and plantation of hedges on farms increase water infiltration and reduce runoffs on farmlands and nearby landscapes (Figure, 2). According to the UK Woodland Trust (2020), water infiltration rates can be 40 times higher in shelterbelts than in adjoining farmlands. Similarly, trees prevent siltation, and eutrophication, and protect aquatic habitats against other forms of pollution (Riva and Granger, 2012; Woodland Trust, 2015).

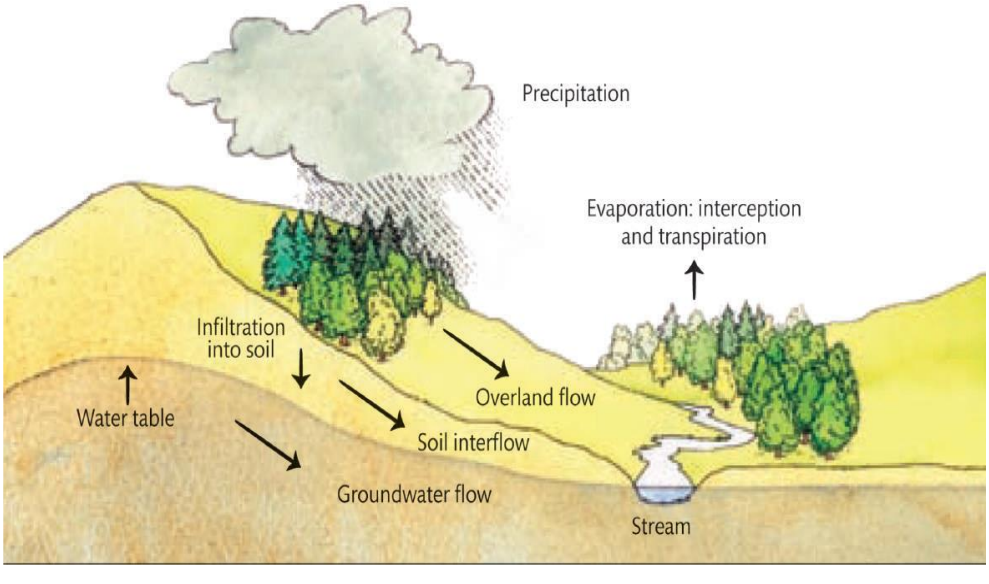

Figure 3: Trees control run-off via transpiration, enhanced infiltration, and reduced overflow (Andrew, 2016)

According to the NEWMAP (The Nigeria Erosion and Watershed Management Project) 2019 report, erosion and recurrent flooding incidences resulted in the collapse of agricultural activities which exacerbates hunger and poverty in Wurno Local government of Sokoto State. However, to address the menace, in addition to dam rehabilitation, tree planting with native species in the upland areas proved to be effective in slowing run-offs and mitigating the effects of erosion in the area.

Limitations of Flood Attenuation by Trees

According to Pedro and Santiago (2013), tree growth, yield, and fruit quality are affected by abiotic stress such as flooding. However, some species have the potential to make the landscape resilient to flooding due to adaptation or the ability to persist in a frequently flooded area. Given this, changing land use practices to create a resilient landscape involving a mixture of hygrophytic tree species is widely endorsed (Riva and Granger, 2012). Unfortunately, pests and diseases such as ash dieback and phytophthora have become a threat in various parts of the UK (Steve, 2016), while in Africa stem/shoot borer, Silkmoth, Root rot, canker, and foliar diseases threaten the growth and development of African forests (Graziosi, 2019), these and other pest and diseases of forest trees necessitates the destruction of the affected species and mapping of related stocks (Philip, 2016).

In Sokoto State, mistletoe has been threatening the growth and development of green infrastructures in the urban areas (Muhammad, *et al*, 2020). In view of this, the State Ministry of Environment conducts an annual pruning exercise to suppress the growth of mistletoes and improve the growth and development of forest ecosystems in the state. However, improved management prescriptions for felling and restocking of the affected sites, appropriate planting spacing as well as the breeding of resistant species are effective in promoting sustainable productivity on the natural landscapes (Kerlin, 2022; Philip, 2016 and Steve, 2016).

CONCLUSION

Land degradation and biodiversity loss in Nigeria and indeed all over the world resulted from natural disturbances and mismanagement of natural landscapes. Given this, several communities, floodplain, croplands, downstream farms, and their related infrastructures have been concurrently affected by flooding in various parts of the globe. As a result of losses recorded in the past, and the desire to tackle the menace, efforts by the government, stakeholders, NGOs, and farmers were intensified to provide a long-lasting solution to the menace. This has led to the modelling of best management practices in correlating past problems and guaranteeing environmental safety.

Sokoto is one of the Nigerian states in the north-western region threatened by land degradation, desertification, and prolonged droughts. Also, human population growth and demand for agricultural land resulted in excessive land clearing in rural areas. Also, insecurity and poverty promoted urbanization in the state, which in turn aggravated the destruction of municipal forest resources to pave the way for infrastructural development in the state. Given this, flooding incidences are recorded annually in the state especially in the urban and peri-urban areas, while the remediations fall short of the pace and magnitude required to address the menace.

However, evidence has shown that trees have the potential to mitigate the impact of flooding while simultaneously providing numerous ecosystem services. This can be viewed through the impact of trees in mitigating the consequences of natural and anthropogenic disturbances threatening natural landscapes. Consequently, regardless of the constraints and opportunities presented by the natural or built environment, it is essential to maintain tree cover adequately to mitigate the impact of flooding and increase landscape resiliency.

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