International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 10 Issue 5, Sep-Oct 2026 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Flood Management

Paul A. Adekunte[1], Matthew N. O. Sadiku[2], Janet O. Sadiku[3]

[1]International Institute of Professional Security, Lagos, Nigeria
[2]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Flooding as of recent has become the most frequent and devastating natural disaster in Nigeria, with increasing intensity due to climate change and urban governance. In 2021, flood displaced 2.1 million people with N2.6 trillion worth of damage, while that of 2022 affected 4.4 million, 603 deaths and 1.4 million displaced across 36 states, and with $6.7 billion economic loss. Despite ecological fund disbursement of over N1.4 trillion from 2012-2022, flooding has continued to persist due to systemic failures. Flooding is caused as a result of: (i) climate changed-induced heavy rainfall and sea level rise, (ii) poor urban planning where 68% of buildings in Lagos block waterways, (iii) deforestation and loss of wetlands – mangroves that reduce flood by 35% destroyed, (iv) dam-induced floods from Lagdo Dam Cameroon release and poor dam management, and (v) institutional corruption and lack of fear of God where ecological funds are diverted. This paper examines the causes, challenges, mitigation, and plausible solutions to flooding in order to avert the damaging effects to humans and the environment.

KEYWORDS: *Flood management, Integrated Flood Management (IFM), climate change, Nigeria, Ecological Fund, GIS, Fear of God, corruption, flood management cycle, flood-prone areas, natural hazards, population growth, environmental degradation/management, forecasting, emergency response.*

How to cite this paper: Paul A. Adekunte | Matthew N. O. Sadiku | Janet O. Sadiku "Flood Management" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-10 | Issue-5, October 2026, pp.1698-1707, URL: www.ijtsrd.com/papers/ijtsrd142280.pdf

IJTSRD142280

Copyright © 2026 by author (s) and International Journal of Trend in Scientific Research and Development Journal. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0) (http://creativecommons.org/licenses/by/4.0)

INTRODUCTION

Flooding is one of the most frequent and damaging natural hazards affecting communities around the world, as shown in Figure 1. This occurs when water exceeds the capacity of rivers, drainage systems, coastal areas, or land surfaces to contain or absorb it, resulting in the temporary inundation of normally dry areas. Floods can result in deaths, displacement of populations, destruction of houses and infrastructure, disruption of transportation and economic activities, agricultural losses, environmental degradation, and outbreaks of water-related diseases. Floods may arise from intense rainfall, river overflow, storm surges, coastal processes, dam or drainage-system failures, and combinations of these factors. Other causes also include rapid urbanization, inadequate drainage, poor land-use planning, environmental degradation, and climate-related changes can increase exposure and vulnerability to flooding.

Integrated Urban Flood Management (IUFM) is a shift from traditional resistance-based levee blocking to **hybrid layered approach** combining **Grey + Green + Blue + Non-structural** across catchment source-to-sea (same as Yu Gong chapter). Modern World Bank definition, says that since 2019, $4.4bn has been committed to 69 projects in 58 countries with hybrid approaches combining engineering grey, Nature-Based Solutions (NBS) green, and non-structural urban planning early warning [1, 2]. The World Meteorological Organization (WMO) identifies floods as among the world's most significant natural hazards, with increasing risks associated with population growth, development in flood-prone areas, environmental degradation and climate variability and change [3].

Flood management is the coordinated process of reducing human and socio-economic losses from flooding and improving floodplain benefits [4, 5]. Flood risk = Hazard x Exposure x Vulnerability [6]. Flooding in Nigeria has now become an annual disaster. In Nigeria, the 2022 flood affected 33 of 36

States, 4.4 million, 603 deaths, 2,400 injuries, 1.4 million displaced, 332,327 houses damaged, and 1.4 million farmlands destroyed [7, 8]. The World Bank PDNA estimated $6.7bn (N4.2trn) losses – equivalent to 0.8% GDP [9]. Contemporary approaches increasingly promote Integrated Flood Management (IFM), which seeks to reduce losses while making appropriate and sustainable use of floodplains and water resources [4].

HISTORY

Flood management is the organized effort to reduce the likelihood, severity, and consequences of flooding through engineering, land-use planning, environmental management, forecasting, preparedness, emergency response, and recovery, as shown in Figure 2. The history of flood management reflects a gradual movement from trying to control rivers physically toward managing flood risk and community vulnerability.

1. Ancient Period (3000 BC – 500 AD) – Living with Flood

Mesopotamia, Egypt, China, Nigeria

- **3100 BC Egypt:** First flood management – Nile flood measured by Nilometer, and with basins to store water (440 BC) documented.
- **3000 BC Mesopotamia:** Trigis-Eupharites levee, Code of Hammurabi (1750 BC) Law 53-58 punished farmers who failed to maintain dykes – first flood law.
- **China 2000 BC:** Yu the Great (Da Yu) – first flood engineer, and dredging. "Yu Gong" (also called Yu Kung) chapter documented how Da Yu after controlling flood for 13 years divided China into 9 provinces based on flood control and tribute.
- **Nigeria Ancient:** Kainji, Jebba, Igbo traditional – communities built on high grounds, mounds (Tell) [11, 12].

2. Medieval To Colonial Period (500-1900) Structural Control

- **1000 AD Netherlands**: Started windmills and dykes – "God created earth but Dutch created Holland" [13].
- **14th Century England**: Statute of sewers 1531 – first flood Act.
- **Japan Edo period (1603**-1868): Super levees – making use of continuous levee flood control [14, 15].
- **USA 1849**: Swamp Land Acts – federal gave land for levees. Mississippi Flood 1927 changed everything – 700,000 displaced.
- **Nigeria Colonial (1900-1960)**: Colonial government built Kainji Dam survey 1925, Lagos drainage 1910 by British. No national policy, only protection of colonial quarters [16].

The key shift was from living with flood to trying to control flood with concrete – "levee effect" was coined.

3. Modern Period (1930-1970) – Structural Era – Build Dams

- **USA 1936:** Flood Control Act 1936 – US Army Corps of Engineers built 1000+ dams.
- **1933 Tennessee Valley Authority (TVA) –** multipurpose dam.
- **Netherlands 1953:** North Sea Flood killed 1,836 – Delta Works project $5bn, world's largest.
- **Nigeria 1960-1970**: Post-independence: Kainji Dam 1968 first major dam – 760MW. Designed for hydropower + flood control [17-20].

According to White, "Floods are acts of God but flood losses are largely acts of man" – first to challenge structural only approach.

4. Neo-Structural Period (1970-1990) – Non-Structural Begins

- **1970 USA:** National Flood Insurance Program (NFIP) 1968, Flood Disaster Protection Act 1973 – Zoning, and floodplain mapping.
- **1975 UN:** First international flood conference.
- **Nigeria:** 1970s-1980s: More dams were constructed like – Jebba 1985, Shiroro 1990, Bakolori 1978 but collapsed in 1980 causing flood. The Federal Ministry of Water Resources was created in 1979.
- **UK 1980s:** Catchment management [21].

5. Integrated Era (1990-2010) – IFM & Sustainability

- **1992 Rio Earth Summit:** Agenda 21 links flood to sustainable development.
- **1990s Japan & Netherlands:** Shift from control to Room for River – give river space [13].
- **1997 UN:** ISDR established.
- **2000 EU:** Water Framework Directive, 2007 EU Floods Directive 2997/60/EC – requires flood mapping.
- **2002 WMO:** Associated Programme on Flood Management (APFM) – coined Integrated Flood Management (IFM) [20].
- **2004 Indian Ocean Isunami:** Changed disaster management globally.

In Nigeria:

- **1999:** NEMA Act 12 established NEMA**.**
- **2007:** NIHSA established – hydrological agency.
- **2010:** NiMET Act.
- **2012:** Worst flood in 40 years – 2.1m displaced – triggered review [9].
- **2012:** National Contingency Plan for Floods [4, 5, 22, 23]

Climate Change & Smart Era (2010-Date) – Current

- **2015 Sendai Framework 2015-2030:** UNDRR (2015) – priority is understanding risk, not just response [24].
- **2015 SDGs & Paris Agreement:** Flood linked to climate action SDG 13.
- **2018 IPCC:** SR1.5 – Floods increase by 50% with 2^{o}C warming.
- **2020-2023 Technology:** IoT sensors, AI flood forecast, and Sentinel satellite SAR mapping [25].
- **Nature-Based Solutions (NBS):** IUCN and the World Bank found out that wetlands are cheaper than concrete [26, 27].
- **Sponge City:** China 2015, adopted by Lagos state [28].

In Nigeria:

- **2015-2023:** Annual Flood Outlook started by NIHSA (2013 first).
- **2022:** Most devastating – 4.4m people were affected**,** $6.7bn loss [9].
- **2022:** Draft National Flood Management Policy [29], this is still a draft, not passed.
- **2023:** 178 LGAs predicted high risk [8].
- **Challenge:** Ecological Fund of N1.4trn 2012-2022 was diverted [30, 31], which is coupled or linked with the lack of fear of God [32, 33].

TYPES OF FLOODS IN NIGERIA

Some of the types of floods in Nigeria are [8, 16, 23]:

1. River flood – caused by the overflow of Niger and Benue Rivers.
2. Urban/Flash flood – caused by blocked dams and poor planning.
3. Coastal flood – caused by sea level rise and storm surge.
4. Dam failure/Release flood – caused by Lagdo Dam in Cameroon.
5. Pluvial flood – caused by extreme rainfall.

NEMA OFFICIAL CLASSIFICATION 2022

NEMA classifies Nigerian floods as follows [7]:

1. Riverine/Fluvial flooding – This happens in Lokoja (Niger-Benue confluence), Makurdi, Jigawa (Hadejia), Ogun, and Anambra. This is caused by river overflow when discharge is > channel capacity, and dam release.
2. Coastal flooding – It happens in Lagos, Delta, Bayelsa, Cross River, Ogun, Rivers and Ondo States - Atlantic coast. Caused by sea level rise, tidal surge, storm, and low elevation (2m).
3. Flash/Pluvial flooding – It occurs in Lagos, Ibadan, Kano. It is a sudden occurrence in urban areas, which is caused by intense rainfall > 30mm/hr, exceeds infiltration, and blocked drains.
4. Urban flooding – Occurs in Lagos Metropolis due to 70% built-up. It is caused by unplanned urbanization, where concrete replaces absorptive soil, and waste block drains/drainage failure.
5. Dam failure/Dam release flooding – This happens in Lagdo Cameroon, Benue, Shiroro, Kainji, and Jebba. Caused by dam releasing water e.g., Lagdo discharge at 21.6m, causing Nigerian dams to overflow.
6. Groundwater/Water Table flooding – This happens in Sokoto and Borno States with high water table areas. It leads to rise in water table, low infiltration, with soil saturated.

HIHSA added "**Combination flooding" –** 2022 was a combination of all the first five above (i. e., 1-5) at once – which was described as the reason for the worst in a decade [8].

CAUSES OF FLOOD IN NIGERIA

According to Aderogba, there are 3 schools of thought about the causes of flood:

"There are three schools of thought about the preponderance of floods all over the globe especially in the tropics. The first is of the opinion that there is **global warming and climate change** that is directly and or indirectly increasing the amount of rain and ice melting that is increasing the amount of runoff… The second school has it that **poor management of wastes, inadequate drains** for the built up areas and others… The third school has it that it is the **combination of both global warming and climate change**, **and the abuses of man on the environment** that are the causes of prolonged and torrential showers of rains and the resultant runoff."

Aderogba's position is in support of the **third school** of thought i.e., **combination.**

Substantive Causes: According to Aderogba, some of the substantive causes of flood (South Western Nigeria) are due to:

1. **Heavy and prolonged rainfall**
2. **Global warming and climate change**
3. **Poor management of wastes** – refuse dumping in drainages
4. **Inadequate drains** for built-up areas
5. **Abuses of man on environment** – deforestation, concretization
6. **Low-lying topography** – Lagos average gradient is <1: 100:000 – low land
7. **Urbanization** – replacing absorptive soil with concrete
8. **Living habits of urban dwellers** – wastewater from homes, hospitals, maternity homes, markets, schools, and manufacturing industries contribute as base water.

Governments therefore should not allow global warming to compound the challenges already posed by floods in the metropolis, which can be achieved via:

- Sustainable developments of cities and towns
- Proper waste management
- Adequate drainage, and
- Strict enforcement

Some of the causes of flood in Nigeria include:

NATURAL CAUSES

1. Climate change

- Warmer air holds more moisture – Clausius-Clapeyron relation.
- Flood damage will increase from $20bn (2021) to $32.2bn (2051) due to climate change [27].
- Risk Rating of 2.0 introduced because flood frequency changed [33].

2. Heavy Rainfall/Intense precipitation

A. West Africa rainfall intensity increased 2.1% per decade, and sea level rise 3.6mm/year [34, 35]. Heavy rainfall/intense precipitation, where excessive rainfall exceeds infiltration capacity. Climate change has caused increased rainfall intensity by 7% per 1^{o}C warming [25, 34-36].

B. NiMET in 2023 predicted above-normal rainfall [36].

3. Human (or Anthropogenic) causes – Most important to Nigeria

A. Poor urban planning: 68% of Lagos buildings are on floodplains [16], while Town Planning Law is not enforced due to unplanned urbanization/building on floodplains [37]. This is the biggest cause in Lagos and Lokoja. 45% of buildings in Lokoja violate 30m buffer – classified as highly vulnerable zone [25].

B. Lagos: 70% of floodplain encroached in Ogun River Basin [16]. Furthermore, building on wetlands blocks natural flow [38, 39].

C. Blocked drainage & waste: According to LAWMA 13,000 tonnes of wastes are dumped in Lagos drains daily.

D. Deforestation/Loss of vegetation cover & Wetland loss: Nigeria lost 60% wetlands in 1990-2020, and while mangroves reduce flood by 35%. When there are no trees, there would be no infiltration, and while runoff increases five times (5x) [14, 40, 41].

E. Dam release river overflow management: There are no buffer dams in Nigeria to contain Lagdo Dam release + Kainji, Jebba, and Shiroro dams since the failure of 1982 agreement [42].

F. Corruption/Lack of fear of God/Lack of Enforcement: Ecological Fund of N1.4trn shared in 2012-2022 [30, 31], but no project to show for it, as shown in Figure 3. This was linked to lack of fear of God [32].

4. Topography/Low elevation

- Lokoja at confluence Niger-Benue 45m above sea level – naturally collects water.
- Lagos coastal city 2m above sea – vulnerable to sea level rise + tidal surge [25, 43].

5. Sea level rise/Storm surge

- Lagos lost 10m shoreline per year.
- 76km trapezoidal drainage built but sea overtops.

6. Poor drainage infrastructure/Inadequate maintenance

- Lagos has 57 LGAs but having only 19 high capacity equipment in 2022.
- Office of Drainage Services awarded contracts to companies registered in 2020 for N147m, and N132m – but no capacity.
- Ecological Fund diverted – as N40bn was disbursed in 2022-2023 but floods still ravaged states [30].

Flood Management Cycle

This is based on Jha et al. (2012), World Bank and WMO (2009):

1. Stage 1: Prevention/Mitigation (Before)

- Structural Measures:
- Dams, levees, dykes – Netherlands model [13].
- Drainage: Lagos needs 22,000km but has 6,000km only [41].

- Retention ponds.

Non-structural Measures:

- Land-use zoning, building codes [29].
- Floodplain mapping: NIHSA mapped 178 LGAs as high risk in 2023.
- Reforestation & Nature-Based Solutions [26, 38].

Stage 2: Preparedness

- Early Warning System**:** NIHSA Flood Forecast + NiMET + NEMA, but information dissemination poor, only by radio.
- Community Early Warning**:** ActAid by sirens, town criers in Anambra.
- Emergency plans, evacuation routes.
- Geographic Information System (GIS) & Remote Sensing: The use of Sentinel-1 SAR for Lokoja flood mapping [25].

Stage 3: Response (During)

- NEMA Act 1999 established NEMA, SEMA, LEMA.
- Activities: Search/rescue, IDP camps, relief materials, health (WHO, 2023).
- 2022 Response: NEMA + Army, Navy deployed, 2,400 IDP camps.

Stage 4: Recovery

- Post Disaster Needs Assessment (PDNA): Global methodology developed by EU, UNDP, World Bank; Global Facility for Disaster Reduction and Recovery (GFDRR) produced Guidance Notes for Conducting Post Disaster Needs Assessment [9].
- Reconstruction, compensation: Release of N3bn by the Federal Government [42].
- Build Back Better [33].

7. Modern Integrated Strategies

A. Integrated Flood Management (IFM), as shown in Figure 4.
B. Nature–Based Solutions (NBS)
C. Sponge City
D. Flood Insurance
E. Smart Technology

9. Flood Management Institutions in Nigeria are:

- NiHSA – for Hydrological data
- NiMET – for weather forecast
- NEMA – for emergency
- Federal Ministry of Environment – for policy
- Federal Ministry of Water Resources – for dams
- State Ministries of Environment
- NESREA

The problem is that there is no coordination but duplication [29].

ROLE OF AI IN FLOOD MANAGEMENT

The role of artificial intelligence (AI) is now central to flood management, as shown in Figures 5 and 6. The following 8 roles of AI in flood management have been identified:

1. AI Flood Mapping – Sentinel-1 SAR + Machine Learning
2. AI Flood Susceptibility Mapping – AHP + Weighted Overlay + Machine Learning
3. AI Early Warning – NIHSA + NiMET + Machine Learning
4. AI Rainfall Prediction – NiMET + Deep Learning
5. AI Waste Detection – Solving 75% blockage
6. AI Dam Management – Lagdo + Alau Dam Preventing 2022 & 2024 Floods
7. AI Nature-Based Solutions (NBS) Optimization – 50% cheaper
8. AI for Old Citizens Vulnerability Mapping
9. Some of the AI techniques used include:
   - Threshold Classification ML - This classifies water vs non-water SAR
   - Random Forest/AHP – It is used for weighted overlay vulnerability
   - LSTM Neural Network – This is for time series river prediction
   - YOLO Computer Vision – It detects waste in drains from drones
   - Reinforcement Learning – It optimizes dam release
   - ConvLSTM – Is for rainfall prediction.

Challenges of AI in Nigeria flood management - These include:

1. Data: Lack of historical flood data
2. Cloud: Optical Landsat blocked, now resolved by use of SAR
3. Corruption: Ecological Fund of N40bn diverted. AI needs governance/fear of God.
4. Power: SAR processing needs cloud computing – Google Earth Engine free [43, 53-59].

SOLUTIONS

Flooding cannot be completely prevented, but its frequency, severity, and impacts can be significantly reduced through a combination of structural measures, environmental management, river engineering, effective land-use planning, early warning systems, community preparedness, and strong government institutions, as shown in Figure 7. Nigeria makes use of Integrated Flood Management (IFM) which is a combination of both structural (engineering) and non-structural (policy and social) measures.

1. Improve drainage systems

Governments are to construct, expand, and regularly maintain storm-water drains, culverts, channels and drainage networks. All existing drains should be desilted and cleared of vegetation and solid waste before the rainy season. Properly designed drainage systems help move excess water away from homes, roads and other infrastructure.

2. Stop dumping waste in drainage channels

The indiscriminate disposal of refuse is a major contributor to urban flooding because waste blocks drainage channels and reduces their capacity. Governments should enforce environmental regulations while providing adequate waste-collection facilities. There is also need for public education to discourage residents from using waterways and drains as dumping grounds.

3. Strengthen flood early-warning systems

Meteorological and hydrological agencies should improve rainfall, river-level and flood forecasting. Early warning should be communicated rapidly through radio, television, mobile phones, social media, sirens and community networks. Early warning is most effective when it is linked to clear evacuation and emergency-response plans. The Meteorological Organization emphasizes early warning as an important tool for reducing disaster losses.

4. Improve land-use planning and zoning

Construction should be restricted in floodplains, wetlands, natural drainage corridors and other high-risk areas. Flood-risk maps should guide decisions about where residential buildings, industries, schools, hospitals and critical infrastructure are located. Planning authorities should enforce building regulations rather than allowing uncontrolled development in vulnerable areas.

5. Protect and restore wetlands

Wetlands, floodplains, forests and other natural ecosystems can store excess water and reduce the speed and volume of runoff. Protecting these areas can therefore complement engineered flood-control measures. The United Nations Environment Programme recognizes ecosystem-based approaches as an important component of climate and disaster risk management.

6. Construct appropriate flood-control infrastructure

Depending on local conditions, structural measures may include:

- Flood-control channels
- Levees and embankments
- Retention and detention ponds
- Dams and reservoirs
- Flood barriers
- Improved culverts
- Pumping stations, and
- Urban storm-water storage systems.

Such infrastructure should be based on proper hydrological studies and should be regularly inspected and maintained.

7. Promote sustainable urban development

Cities should increase permeable surfaces through parks, green spaces, rain gardens, permeable pavements and urban forests. All of these measures allow rainfall to infiltrate into the soil instead of rapidly flowing into already overloaded drainage systems. This approach is often described as **green infrastructure** or **nature-based flood management**.

8. Improve river-basin management

Flood management should not focus only individual communities. Governments should manage entire river basins because activities upstream can affect downstream flooding. Measures to adopt would include reforestation, erosion control, watershed protection, appropriate reservoir management and restoration of natural flood-storage areas.

9. Relocate people from extremely high-risk areas

Where communities are repeatedly exposed to severe flooding and adequate protection is impracticable, then voluntary relocation or resettlement may be necessary. Governments should provide suitable housing, infrastructure and livelihood opportunities so that relocation does not create additional social and economic hardship.

10. Strengthen community preparedness

Communities should be trained in flood preparedness, evacuation, first aid, emergency communication and rescue procedures. Local emergency committees can identify vulnerable households, evacuation routes and safe locations before disasters occur.

11. Enforce building standards

Flood-resistant designs should be enforced in buildings in flood-prone areas, such as raised foundations, elevated electrical equipment, appropriate drainage around buildings and water-resistant construction materials. Building approvals should require consideration of flood risk.

12. Improve emergency response

Emergency-management agencies should maintain adequate equipment, rescue boats, temporary shelters, medical supplies, food and clean water. Need for adequate coordination among government agencies, emergency services, NGOs and communities is essential for effective response.

13. Develop flood-risk insurance and financial protection

Insurance and disaster-risk financing can help households, farmers and businesses recover after floods. Governments can also establish emergency funds and social-protection programmes for vulnerable populations.

14. Address climate change

Climate change can increase the risk of extreme rainfall and other flood-related hazards in many regions. For this reason, flood management should be integrated with climate adaptation. Reducing greenhouse-gas emissions, protecting ecosystems and strengthening climate-resilient infrastructure can reduce long-term risks.

15. Strengthening government institutions and coordination

Effective flood management requires cooperation among meteorological agencies, water-resource authorities, environmental agencies, urban-planning departments, local governments and emergency-management organizations. Clear responsibilities, adequate funding, reliable data and enforcement of regulations are essential.

16. Use integrated flood-risk management

The most effective approach is not to depend on one solution. Governments should combine **"grey" infrastructure** such as drainage and levees with **"green infrastructure** such as wetlands, and vegetation, together with land-use planning, early warning, preparedness and emergency response. The IPCC and UNDRR emphasize integrated disaster-risk reduction and climate adaptation as important approaches to reducing disaster losses.

Flooding is a complex environmental and development problem that requires **prevention, mitigation, preparedness, response and recovery.** In countries such as Nigeria, priority should be given to maintaining drainage systems, controlling waste disposal, protecting wetlands and floodplains, improving urban planning, strengthening early-warning systems and enforcing environmental and building regulations. A combination of engineering solutions and nature-based approaches, supported by community participation and effective government institutions, will provide a more sustainable strategy than relying on flood-control structures alone [24, 46-52].

CONCLUSION

Flood management is essential for reducing the loss of lives, property, infrastructure, and livelihoods caused by flooding. An effective management will require a combination of proper drainage, land-use planning, early-warning systems, environmental protection, community preparedness, and strong government intervention. It is recommended that: i. Federal government should adopt scientific allocation and Sentinel-1 SAR methodology or technology for Nigeria, ii. Lagos State 2022 model can be replicated in all the States, iii. LGAs, waste collection/proper management and drainage clearing, iv. Public enlightenment, whistleblower, integrate flood ethics into school curriculum, and fear of God sensitization, and v. Protection of old citizens in cheap flood prone lands. Sustainable flood management should combine structural measures with nature-based solutions and public participation. Overall, effective planning, prevention, preparedness, and timely response are key to reducing flood risks and building resilient communities. More information on flood management can be obtained in books in [60-67] and the following related journals:

Journal of Spatial Information Sciences
Journal of Human Ecology
Academic Research International
Journal of Environmental Issues
Nigerian Journal of Environmental Sciences
ISPRS Journal of Photogrammetry & Remote Sensing
Remote Sensing of Environment
Geocarto International
Journal of African Earth Sciences
Earth Science Informatics
Habitat International
Cities
Urban Climate
Waste Management
Journal of Environmental Management
International Journal of Water Resources Development
Water Policy
Journal of Hydrologic Engineering
Disasters
International Journal of Disaster Risk Science
Corruption & Development Journal
ICPC Reports
Journal of Flood Risk Management
Natural Hazards
Water Resources Management
Natural Hazards and Earth System Sciences
International Journal of Environmental Studies
Water Resources Research
Hydrological Processes

Journal of Hydrology

International Journal of Disaster Risk Reduction

Environmental Hazards

Mitigation and Adaptation Strategies for Global Change

REFERENCES

[1] Technical Deep Dive (TDD) on urban flood management – *Implementing integrated approaches for sustainable urban flood resilience*, https://www.worldbank.org

[2] World Bank Group (January 27, 2026), *Strengthening flood resilience in rapidly growing cities*, https://www.worldbank.org

[3] World Meteorological Organization (WMO) (2020), *Floods.* World Meteorological Organization.

[4] World Meteorological Organization (WMO) & Global Water Partnership (GWP) (2009), *Integrated Flood Management Concept Paper*. Associated Programme on Flood Management.

[5] A. K. Jha, R. Bloch & J. Lamond (2012), *Cities and flooding*. World Bank.

[6] United Nations Office for Disaster Risk Reduction (UNDRR) (2022), *Global Assessment Report on Disaster Risk Reduction (DRR).*

[7] National Emergency Management Agency (NEMA) (2022), *2022 Flood Impact Report*.

[8] Nigeria Hydrological Services Agency (NIHSA) (2023), *Annual Flood Outlook – Lagdo Dam, Lokoja levels.*

[9] United Nations Development Programme (UNDP) (2023, December 7), *Nigeria Flood Impact, Recovery and Mitigation Assessment Report 2022-2023.*

[10] K. Wittfogel (1957), *Oriental despotism.*

[11] B. Floyd, (1969), *Eastern Nigeria.* Macmillan.

[12] J. Needham (1971), *Science and civilization,* vol. 4, In: R. M. Adams (1981), *Heartland of cities.* University Chicago Press.

[13] F. Klijn et al. (2018), "Room for the River," *Journal of Flood Risk Management,* vol. 11.

[14] F. Nakamura et al. (2019), "Environmentally friendly flood management since 16th century," *Sustainability Science.*

[15] F. Nakamura & K. Oki (2008), "Coexistence of river and human," *Journal of Disaster Research.*

[16] B. O. Odufuwa et al. (2022), "Urban planning and flood," *Journal of Urban Management.*

[17] B. F. Sule & O. Alabi (2023), "Lagdo Dam," *Nigerian Journal of Hydrological Science.*

[18] G. F. White (1945), *Human adjustment to floods.* University of Chicago.

[19] D. J. Parker (2000), *Floods. Routledge.*

[20] World Meteorological Organization (WMO) (2009), *History of flood management.*

[21] I. Burton, R. Kates & G. F. White (1978), *Environment as hazard.* Oxford University Press.

[22] European Parliament and Council (2007), "Directive 2007/60/EC of 23 October 2007 on the assessment and management of flood risk," *Official Journal of the European Union L288, pp. 27-34. Brussels.*

[23] National Emergency Management Agency (NEMA) (2012, 2022), *Flood Reports,*

[24] United Nations Office for Disaster Risk Reduction (UNDRR) (2015), *Sendai Framework for Disaster Risk Reduction 2015-2030.* United Nations.

[25] K. C. Onyelowe et al. (2022), "Application of geospatial techniques in flood risk and vulnerability mapping for disaster management at Lokoja, Kogi State, Nigeria," *Journal of Environmental and Earth Science (EES), IISTE.*

[26] International Union for Conservation of Nature and Natural Resources (IUCN) (2020), *Global Standard for Nature-Based Solutions* (1st ed.). Gland. Validated 2022.

[27] World Bank Group (2021), *The economic case for nature-based solutions.* World Bank.

[28] Lagos State (2020), *Lagos Resilience Strategy.*

[29] Federal Ministry of Environment (2022), *National Flood Management Policy Draft.*

[30] Independent Corrupt Practices and Other Related Offences Commission (ICPC) (2023), *Ecological Fund probe, N40bn diversion zero conviction.*

[31] Nigeria Extractive Industries Transparency Initiative (NEITI) (2023), *Ecological fund audit.*

[32] S. B. Oluwole & K. N. Okoro (2021), "Lack of fear of God," *Filosofia Theoretica,* vol. 10, no. 2.

[33] FEMA (2021), *National Flood Insurance Program – Risk Rating 2.0 Fact Sheet.* October 1, 2021 implementation for new policies, April 1, 2022 for renewals.

[34] IPCC (2021), *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group l to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge & New York.

[35] IPCC (2023), *Climate Change 2023: Synthesis Report*. Contribution of Working Groups l, ll and lll to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.

[36] Nigerian Meteorological Agency (NiMET) (2023), *Seasonal Climate Prediction*.

[37] N. O. Adeoye (2022), *Building on floodplains in Nigeria*.

[38] K. A. Aderogba (2012a), "Substantive causes and effects of floods in South Western Nigeria and sustainable development of the cities and towns," *Journal of Human Ecology,* vol. 40, no. 2, pp. 147-154.

[39] K. A. Aderogba (2012b), "Global warming and challenges of floods in Lagos Metropolis, Nigeria," *Academic Research International,* vol. 2, no. 1, pp. 448-468.

[40] Food and Agriculture (FAO) (2020), *Mangroves unique role in climate emergency*.

[41] O. Adekola & J. Lamond (2018), "Flood risk in Lagos," *International Journal of Disaster Risk Reduction* (IJDRR), vol. 28, pp. 714-725.

[42] B. F. Sule & O. Alabi (2023), "Lagdo Dam and Benue floods," *Nigerian Journal of Hydrological Sciences.*

[43] A. A. Adeshina et al. (2025), "Urban flood mapping using Sentinel-1 SAR Data and Machine Learning: A case of Maiduguri, Nigeria," *Journal of Spatial Information Sciences,* vol. 2, no. 3, pp. 89-106.

[44] Lagos State Ministry of Environment and Water resources (2022), *Office of drainage services report 19 equipment inauguration February 23, 2022.* Oregun.

[45] Punch Newspapers (2018, September 15), *Flood: EU supports states with N400m, as FG assists victims with N3bn.*

[46] Intergovernmental Panel on Climate Change (IPCC) (2022), *Climate change 2022: Impacts, adaptation and vulnerability.* Cambridge University Press.

[47] World Meteorological Organization (WMO) (2023), *Global status of multi-hazard early warning systems 2023.* WMO.

[48] World Bank (2012), *Cities and flooding: A guide to integrated urban flood risk management for the 21st Century.* World Bank.

[49] A. K. Jha, R. Bloch & J. Lamond (2012), *Cities and flooding: A guide to integrated urban flood risk management for the 21st Century.* World Bank.

[50] United Nations Environment Programme (UNEP) (2022), *Nature-based solutions: Opportunities and challenges for scaling up.* United Nations.

[51] E. J. Plate (2002), "Flood risk and flood management," *Journal of Hydrology,* vol. 267, nos. 1-2, pp. 2-11.

[52] Z. W. Kundzewicz (1999), "Flood protection-sustainability issues," *Hydrological Sciences Journal,* vol. 44, no. 4, pp. 559-571.

[53] D. M. Omar et al. (2025), "Landslide susceptibility Lokoja GIS multicriteria," *Journal of Spatial Information Sciences* (JSIS), vol. 2, no. 3, pp. 180-198 – same authors AI.

[54] K. C. Onyelowe et al. (2022), *Geospatial flood Lokoja AHP weighted overlay – precursor to ML.*

[55] S. Nevo et al. (2022), *Flood forecasting with ML – Google – Nature – 90% accuracy India*.

[56] First Street Foundation (2021), *Flood risk AI Risk Rating 2.0* – FEMA.

[57] S. Thota et al. (2023), *AI waste detection drains YOLO computer vision*.

[58] HelpAge (2022), *Old citizens vulnerability – AI mapping*.

[59] Food and Agriculture (FAO) (2020), *Wetlands 60% lost – AI restoration site*.

[60] K. Smith & R. Ward (1998), *Floods: Physical processes and human impacts.* Wiley.

[61] H. Wheater & E. Evans (2009), *Land use, water management and future flood risk.* Land Use Policy / related flood-risk literature.

[62] B. Buchele et al. (2011), *Flood risk management: Research and practice.* CRC Press.

[63] D. L. T. Hegger et al. (2016), *Flood risk management strategies: Building resilience in a changing climate.* Routledge.

[64] J. W. Hall & D. P. Solomatine (2010), *A framework for flood risk management.*

[65] B. Wisner et al. (2004), *At risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London: Routledge.

[66] K. C. Wu (1982), *The Chinese heritage.* Crown Publishers – Yu Gong 9 provinces.

[67] K. Maier (2000), *This house has fallen: Midnight in Nigeria.* PublicAffairs – contrast house fallen vs Yu Gong house fixed.



Figure 1. Natural disasters in Nigeria
Source:
https://en.wikipedia.org/wiki/Natural_disasters_in_Nigeria

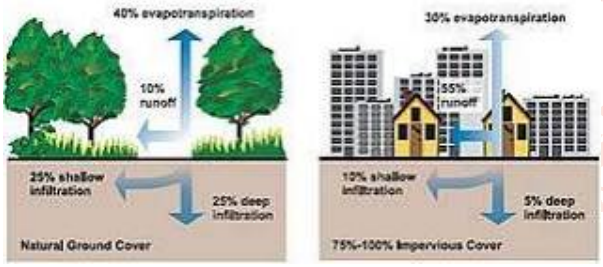


Figure 2. Flood management
https://en.wikipedia.org/wiki/Flood_management



Figure 3. Flood control projects scandal in the Philippines
Source:
https://en.wikipedia.org/wiki/Flood_control_projects_scandal_in_the_Philippines

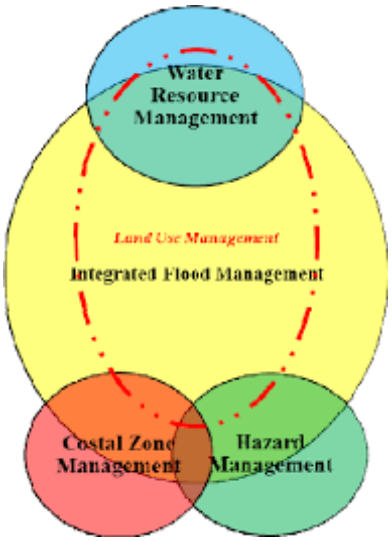


Figure 4. Integrated flood management model Adapted from WMO

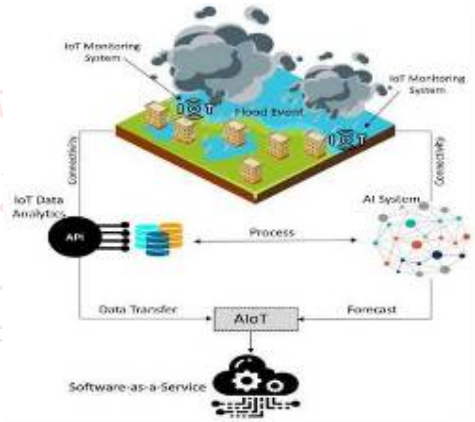


Figure 5. The convergence of AI, IoT and Big Data for advancing flood analytics research



Figure 6. AI for instant flood detection



Figure 7. Room for the River – Dutch flood control