

The Causes of Flooding in the City of Kinshasa Province

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Abstract: Kinshasa, the capital of the Democratic Republic of the Congo, is located in the west of the country, on the southern bank of the Congo River, at the western end of the Malebo Pool. The increased frequency and intensity of precipitation, linked to climate change, envisaged by some experts, could further increase this risk in future on certain parts of the capital. Although it is a city, it has the administrative status of a province. A flood refers to the temporary submersion, whether natural or artificial, of an area by water. On average, floods affected more than 1 million people between 2019 and 2025, and the city of Kinshasa suffered severe flooding several times, due to problems with urbanization, waste and gutters that were poorly built to standards and very badly maintained.

Keywords: Causes of Flooding, City Kinshasa Waterproofed Surface, Urban Runoff,

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I. INTRODUCTION

Kinshasa is located in the west, on the south bank of the Congo River, at the western edge of the Malebo Pool. Although it is considered a city, it has the administrative status of a province. Kinshasa developed between the Gombe promontory, which closes the Malebo Pool, and Ngaliema Bay, located before Livingstone Falls, as well as the hills to the south. A flood can be defined as the temporary immersion of an area by water, either from runoff or river waters. This term is often used to describe flooding, which represents one of the major natural hazards in the world, being the most destructive natural disaster. Between 1996 and 2005, approximately 80% of natural disasters worldwide were meteorological or hydrological in origin. Flooding frequently occurs when the water volume of a river or stream exceeds its capacity. Flooding can also occur along lakes and coastal areas when the water level rises above the surrounding land level. Various factors affect flood risk and impact a river's flow. Among the most significant factors that lead to flooding are the amount and type of precipitation, the nature and condition of the watershed, and climatic

conditions. The city of Kinshasa has faced serious flooding on numerous occasions due to urbanization problems, waste, and poorly constructed and maintained gutters. Since 2004, the city-province of Kinshasa has experienced a significant population increase, mainly due to the influx of people from different provinces. The urban authority's task is to regulate environmental issues. Some mountainous regions, such as Gombe and Bandalungwa, are crossed by rivers that meander across the plain. South of this same boulevard lies the working-class part of the city, characterized by a checkerboard structure typical of modern cities, until the hills disrupt this organization. This region is cut by a vast undeveloped area that delimits the extension of the new neighborhoods of the 1940s (Kalamu, Kasa-Vubu). It is also home to several of the capital's main infrastructures, stretching from west to east: Kokolo Camp, Kamanyola Stadium, as well as Ndolo Airport. The province of Kinshasa, which covers an area of 9,965 km², includes a region larger than the city itself. , Nsele and Maluku, are largely rural, with Maluku alone occupying 79% of the provincial territory.



Fig 1 The City Province of Kinshasa, The City Center.

- Runoff flooding occurs in steeply sloped areas, particularly in some municipalities of Kinshasa, where informal markets have been established. Vendors there dump their waste in gutters and on the roadway because the water cannot infiltrate the ground, causing runoff. This type of flooding is often very localized and can occur far from rivers. Runoff erodes valleys. It is important to distinguish runoff flooding, which occurs outside the river system, from flooding caused by overflowing rivers, even if this overflow results from heavy rains that have flowed over a watershed.

Runoff flooding is thus associated with intense and localized rainfall, without overflowing permanent rivers. When it rains in a region, some of the water infiltrates, some evaporates, and the rest flows across the surface.

The distribution of these three outcomes for rainwater varies depending on the municipality and the nature of the rainfall (duration, intensity).



Fig 2 Urban Runoff in The City of Kinshasa

- Urban runoff is one of the causes of flooding. This phenomenon results from rainfall exceeding the capacity of drainage systems, such as storm sewers. It is often caused by flash floods, storm surges, overflows or

snowmelt, and manifests itself in recurring, costly and systemic impacts on communities. Tropical areas tend to experience higher volumes of runoff.

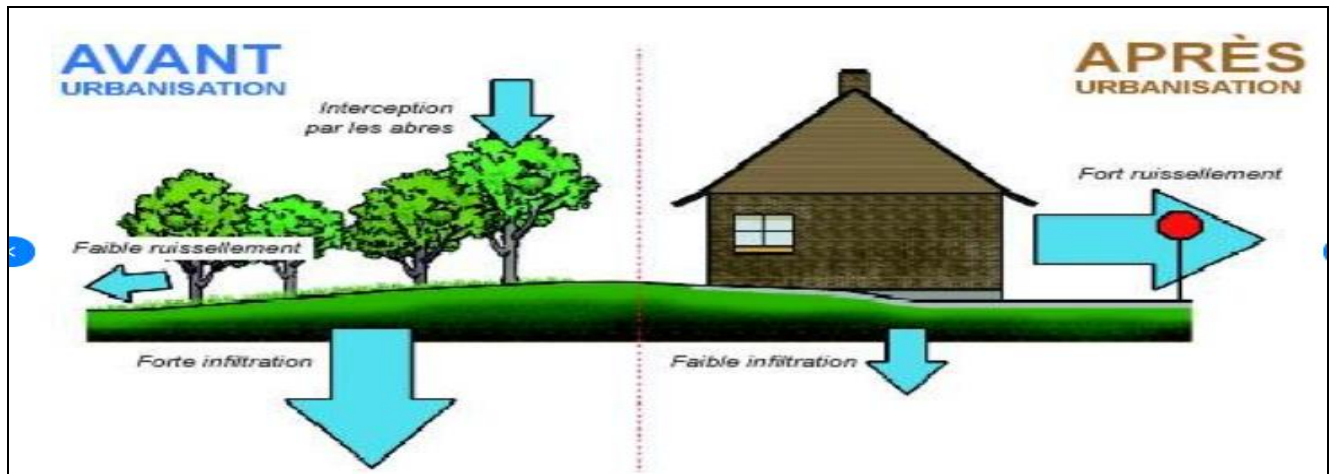


Fig 3 The Effect of Urbanization On Stormwater Runoff

Figure 3 illustrates the importance of increasing the number of trees in our environment to promote better infiltration and reduce runoff.

The runoff coefficient is defined by the ratio between the amount of water that has flowed over a specific surface

area, called "net rainfall," and the total amount of water that fell, called "gross rainfall."

This runoff coefficient formula is subject to significant variation depending on the surface's impermeability, its slope, and whether it is open or partitioned. (Ecovégétal)



Fig 4 Runoff Coefficient

➤ *The 4 Types of Runoff:*

Schematic diagram showing four types of surface runoff generation mechanisms:

(A) DIRECT SURFACE RUNOFF (DO); (B) SATURATED SURFACE RUNOFF (SO); (C) SATURATED MIXED SURFACE RUNOFF (MS); AND (D) SATURATED EXPULSIVE SURFACE RUNOFF (ES). FIGURE 5 ILLUSTRATES THE DIFFERENT TYPES OF RUNOFF.

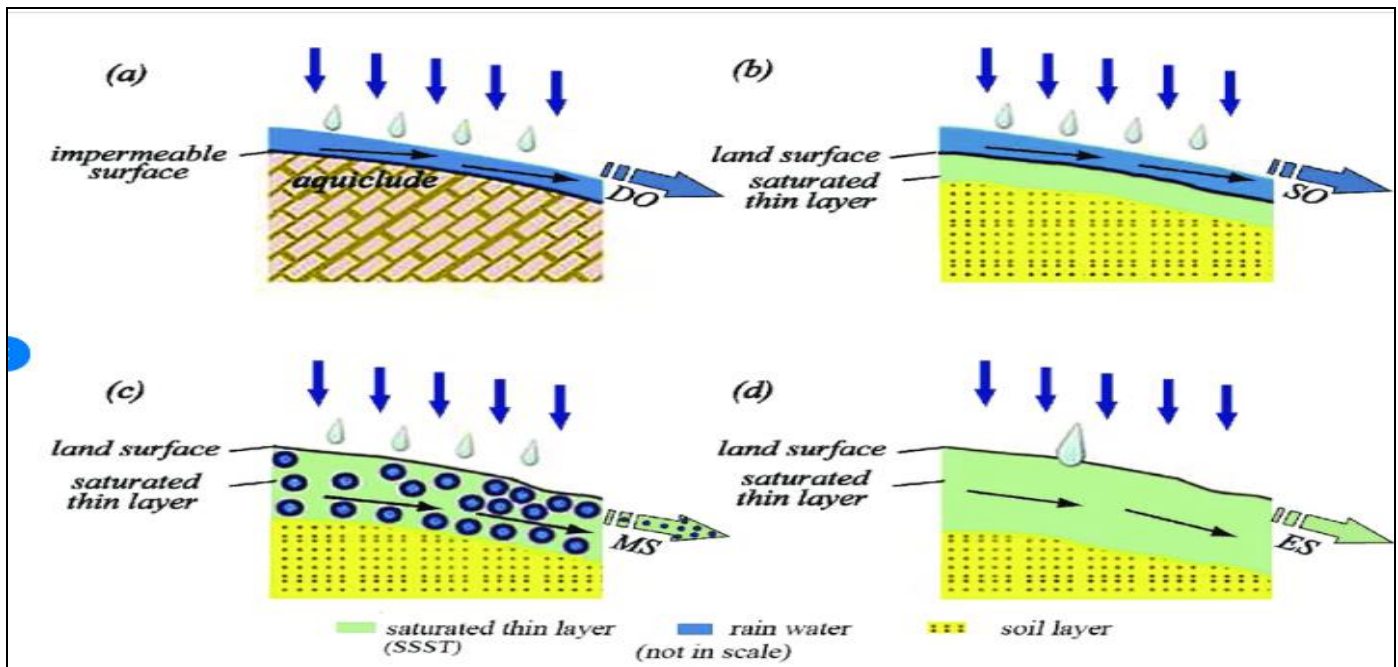


Fig 5 Types of Runoff

Field runoff measurement is usually carried out using current meters and calibrated or nominal channel sections, standardized flumes or weirs, and water level readings, often taken by automatic recorders, to give a continuous record of height which can be correlated with discharge.

➤ Precipitation:

Encompass different forms of water, which come from the atmosphere. They are distinguished by three main parameters: volume, intensity and frequency, which vary according to region and period (days, months or years). The frequency and type of precipitation in a specific region are essential elements of its climate. They play a crucial role in

the fertility and habitability of temperate or tropical zones, while in polar regions they contribute to the maintenance of ice caps. Liquid precipitation is measured in equivalent water depth over a given period (for example: mm per year, per month, per day). On the other hand, solid precipitation, such as snow, is evaluated in centimeters (cm). For water droplets to form and give rise to a cloud and then precipitation, a mechanism is necessary to saturate the air. Unless the air is cooled by cold air advection or radiative transfer, as is the case during fog formation, this phenomenon usually occurs by uplift. When hydrometeors become too heavy to be supported by vertical motion, they fall toward the ground.

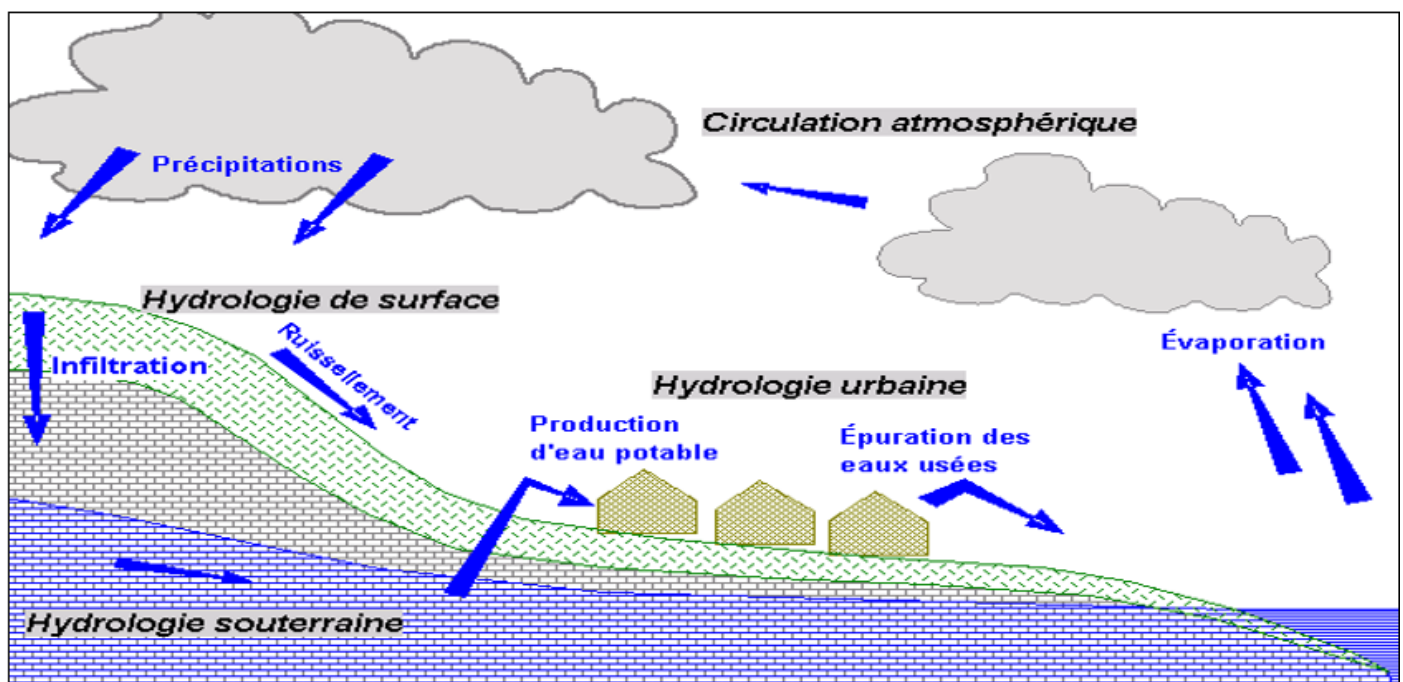


Fig 6 Precipitation Formation Mechanisms

II. MATERIALS AND METHODS

In our research, we applied both an analytical and an inductive approach, drawing on data collected by the Meteorological and Remote Sensing Satellite Agency (Mettelsat). The tools used included a rain gauge and a radiosonde system. The objective of this secondary data was to better understand the causes of flooding in the city of Kinshasa.

➤ *Causes of Floods:*

It is possible that the drainage and infiltration capacities of an area are not adequate to evacuate the water received, thus leading to its accumulation. This phenomenon is amplified by the sealing of soils (urbanization) without the establishment of an appropriate drainage network.

• *The Main Causes of Flooding:*

Flooding frequently results from natural phenomena that vary in frequency and intensity. Some of the most common natural causes include: torrential rains, which are intense precipitation events over a short period of time,

likely saturating soils and drainage systems, causing flooding; non-compliance with standards during the construction of gutters; and indirect overflow of a water reserve, whether surface or underground, due to rising water tables or water flowing through pipes.

The accumulation of runoff resulting from heavy rainfall. A region's drainage and infiltration systems may not be adequate to manage incoming water, leading to its accumulation. This phenomenon is exacerbated by soil sealing, a consequence of urbanization.

✓ *Urbanization and Soil Waterproofing :*

The construction of roads, pirate markets, buildings, and other infrastructure prevents water from seeping into the ground. This leads to increased surface runoff, overloads drainage systems, and exacerbates urban flooding. Kinshasa has experienced flooding intensified by its rapid urbanization, and the failure to comply with standards during infrastructure construction, as well as the dumping of garbage in gutters by the population, prevents the absorption of rainwater.



Fig 7 Overflow of the Ndjili River

In Kinshasa, more than 70% of riverbeds are invaded by waste and illegal construction, increasing the risk of flooding. These constructions, located in the main or middle reaches of rivers, result from a lack of suitable housing and irrational land use. The consequences include material and human damage during floods, as well as an increase in waterborne diseases.

✓ *Deforestation:*

Cutting down trees reduces the soil's capacity to retain water, increasing erosion and the risk of flooding. In the Amazon, large-scale deforestation has led to a significant increase in flooding, as degraded soils can no longer effectively retain water, accelerating its flow into rivers. Inadequate water management: Poorly maintained or poorly designed dams and canals can lead to overflows and levee

failures. Weather events, such as intense rainfall and storms, are becoming increasingly common due to rising temperatures.

✓ *Urban Areas: A Risk Amplified by Urbanization:*

Urbanization in Kinshasa plays a crucial role in increasing flooding. Impervious surfaces, such as roads and buildings, block the infiltration of rainwater into the ground, causing significant runoff. The city, like Kinshasa, is surrounded by marshy areas. These wetlands frequently result from the accumulation of rainwater and inefficient river drainage. Urban flooding regularly occurs following severe storms, significantly disrupting residents' daily lives.

✓ *Changes in Precipitation Patterns :*

Climate change is also altering precipitation patterns. Some regions are experiencing a significant increase in annual rainfall, while others experience prolonged periods of drought followed by intense rains.

In Kinshasa, almost all rivers flood urban areas in the lowlands during the heavy rains due to inadequate management (lack of cleaning, garbage dumping, etc.). Records from the Riverways Authority reveal that the water level reached a maximum of 6.23 m on December 17, 1961. The maximum difference between the highest and lowest water levels recorded is approximately 6 m. Data on water levels in the port of Kinshasa show that 100-year floods can exceed 5.55 m, 50-year floods 4.71 m, and 100-year floods 4.9 m. Kinshasa has two main flood-prone areas:

- Areas located in the Congo River floodplain and on the lower terrace of the Kingabwa and Ndolo districts, with Kingabwa being the most exposed due to frequent rises in the water table, depending on the hydrology of the Congo River;
- as well as those located along the rivers, notably the districts of Abattoir, des Marais, Ndanu, Salongo, Pompage, Debonhomme, etc.

• *The Various Floods Observed in Kinshasa:*

✓ *Flooding Due to River Surges:*

These floods are caused by a lack of maintenance of the rivers that flow through the capital. Residents dump waste and solid garbage (plastic bottles, trash, vehicle wrecks, tree trunks, etc.) in them due to the absence of several public landfills. During rains, these rivers become blocked, causing flooding.

✓ *Flooding Due to Rapid River Rise:*

These floods are caused by rivers blocked by sediment from erosion and garbage left behind by the population. Following rainfall, riverside areas are systematically flooded.

- The Funa River frequently floods due to overflowing, the flow of which is increased by rapid urbanization in the hilly area, without adequate drainage capacity.
- The Bumbu River is also prone to flooding, as the volume of soil washed into its bed by erosion from the Selembao Drève (700,000 m³) hinders water flow. For its

part, the Mbinza River faces the influx of soil from erosion at Mataba 2 in Ngaliema (1,852,000 tons), leading to irregularities and flooding.

- The Lukunga River, for its part, is affected by sedimentation and the influx of soil (6,151,000 tons) resulting from erosion at Masikita in Ngaliema. Finally,
- The Kalamu River is flooded due to the obstruction of its infrastructure by solid waste such as garbage and vehicle wrecks, which causes a significant rise in the water level and diverts it from its banks during heavy rains.
- In addition to erosion, which brings sand and obstructs the rivers, the population living along the rivers represents a real obstacle to the peaceful flow of Kinshasa's rivers. With this waste management method, it is normal to observe that the rivers quickly overflow their banks during rains, flooding the surrounding neighborhoods.

➤ *Solutions:*

Various measures have been proposed to combat flooding around Kinshasa. These include strengthening the resilience of urban areas, improving drainage and sanitation systems, reducing land take, preserving flood-prone areas, and raising public awareness.

• *Optimizing Drainage and Sanitation:*

- ✓ Cleaning pipes and remediating flood-prone areas are essential actions to mitigate flooding and minimize damage.

✓ *Public Awareness and Education:*

It is imperative to educate the public about flood hazards, appropriate behaviors, and the importance of responsible water and waste management.

• *Watershed Development:*

This requires managing stormwater at the source, reducing runoff and promoting infiltration.

• *Urban Development:*

This involves establishing green spaces, planting green roofs, and using permeable materials to reduce runoff.

The provincial government must integrate waste management.

- ✓ Establishing an efficient collection system:
- ✓ Organize a regular and extensive solid waste collection system across the city, providing the necessary infrastructure (dumpsters, trucks, etc.).
- ✓ Waste recovery: Explore waste recovery solutions (composting, energy production) to reduce the amount of waste to be disposed of.
- ✓ Watershed management and river protection:
- ✓ Reforestation and erosion control: Carry out reforestation campaigns in areas upstream of rivers to mitigate runoff and erosion, while stabilizing the soil.
- ✓ Establish systems to monitor river water levels and establish an early warning system to inform the population in the event of a flood risk.

III. CONCLUSIONS

Flood management caused by runoff has evolved significantly in recent decades, and this issue will continue to gain importance. With the constant increase in impervious surfaces and evolving agricultural methods, this problem affects and will continue to affect a growing number of cities, regardless of their size. An area's drainage and infiltration capacity may not be adequate to evacuate the water it receives, causing it to accumulate. The city of Kinshasa is surrounded by marshy communities. These marshy areas are often the result of stagnant rainwater and poorly drained rivers. They regularly experience urban flooding following violent storms, causing major disruptions to residents' daily lives. To combat flooding around Kinshasa, the provincial government must implement plans to prevent future flooding in the city-province of Kinshasa.

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