

A Review: Types of Floods Causes and Their Impact in Khartoum, Sudan

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Highlights

- Outlining the types of floods in Sudan in general and Khartoum to be specific.
- Examining the causes of floods, i.e., natural, and human-induced causes.
- Outlining the impacts of ongoing floods on Khartoum residents.

Abstract: The Blue Nile (Ethiopia) and White Nile (South Sudan) upstream catchments had significant rains that dramatically raised the Nile's water levels, flooding parts of the capital Khartoum. Sudan faces a serious flood problem since Khartoum, the country's capital, frequently experiences flooding. The review begins by categorizing the various floods that occur in Sudan, considering regional variations and each one's distinct characteristics. It examines the hydrological and meteorological elements, such as the Nile River's impact, seasonal trends, and heavy rainfall, that cause floods to occur. The research also explores human-induced causes such urbanization, insufficient drainage systems, and changes in land use, offering light on how these variables increase the danger of flooding. The study then describes the direct and indirect effects of the continuing floods on Khartoum citizens. Investigating the negative effects on public health, infrastructure, agriculture, and the general socioeconomic makeup of the city, it focuses on the social, economic, and environmental consequences. This review study seeks to offer a thorough overview of the several flood types that can occur in Sudan, with a focus on Khartoum. It shows the impacts of recurring flood episodes on Khartoum citizens while examining the causes of floods, including both natural and human-induced aspects. To increase Khartoum's and its citizens' resilience in the face of flooding, it highlights the urgent need for coordinated and sustainable flood management techniques.

Keywords: Sudan; Khartoum; flash floods; drainage systems; climate change

Introduction

Flooding is the occurrence that has the greatest global influence on human population^[1, 2]. Extreme hydrometeorological events are becoming more likely, due to changes in land use, the climate, the loss of flood storage along rivers, and changes in agricultural practices and land use management^[3-5]. Several studies and analyses demonstrate that the repercussions of climate change forecast devastating floods^[6]. Floods are estimated to have caused 43% of all verified natural catastrophes between 1995 and 2015. the number of people vulnerable to floods is anticipated to exceed 2 billion by 2050^[6]. Due to the concentration of major activities that produce greenhouse gas emissions in urban areas, cities are the main contributors to climate change^[7]. Impervious surfaces rise as a result of urbanization, which reduces the amount of water that may seep into the soil and increases the amount of water that runs off the surface^[8]. Additionally, urbanization is often accompanied by the artificialization of urban rivers, which further increases the risk of water overflows^[9, 10]. The

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globe is also seeing a wave of population relocation to cities, which leads to an increase in the amount of land used and impervious to water. Cities were vulnerable to flooding as their populations grew, either as a result of high-intensity rainstorms or because of their placement in valleys or along seasonal rivers, making them directly affected by floods.

Floods in Sudan

Flooding is one of the common natural disasters that affect people and infrastructures all across the world^[11, 12]. According to report that the year 2007 was distinctive in Africa as floods due to heavy rain events resulted in 869 deaths and approximately 2.5 million displaced people from all West African countries, Sudan and Chad^[13]. Sudan is located within the scope of the African countries most affected by climate change, next to Senegal, Mali, Nigeria, etc., (fig.1). In the last decade, Sudan has witnessed floods on an almost annual basis. Most of the Sudanese states are directly or indirectly affected by floods. Studies predict a more extreme future in flood phenomena. The autumn season in Sudan begins mostly in July and continues during August to end in September, but most of the rain falls in August, which leads to sudden floods in many areas. The 1988 and 2006 rainstorms were so exemplary in Sudan, the former was a unique event that resulted in 3 million victims while 10,000 damaged houses, 167 death, and 160,000 distressed people were reported due to the latter event^[13]. Explain that floods in Sudan forced people to move and change their activities. Severe flash floods were recorded in 1962-1965, 1978-1979, 1988, 1994, 1998, 1999 and 2006^[14].

The floods that occur in Sudan, can be divided into three categories based on the main cause: urban flash floods by rain storms, floods caused by the Nile River flooding the areas adjacent to the river; and valley floods caused by seasonal rivers and floodplain assembling rain water in the main corridors that drains into the Nile River. Previous research in Sudan evaluated and predicted flood effects across various states. Prior studies have shown that most states are particularly at risk from flooding^[14-17]. Other studies have been applied to the White Nile and Blue Nile areas, and the results show that the floods still rise and fall with the annual rainy season in the Ethiopian highlands^[18]. Furthermore, drought and flooding have affected the land use and land cover (LULC) around rivers all across the world^[12, 19, 20].

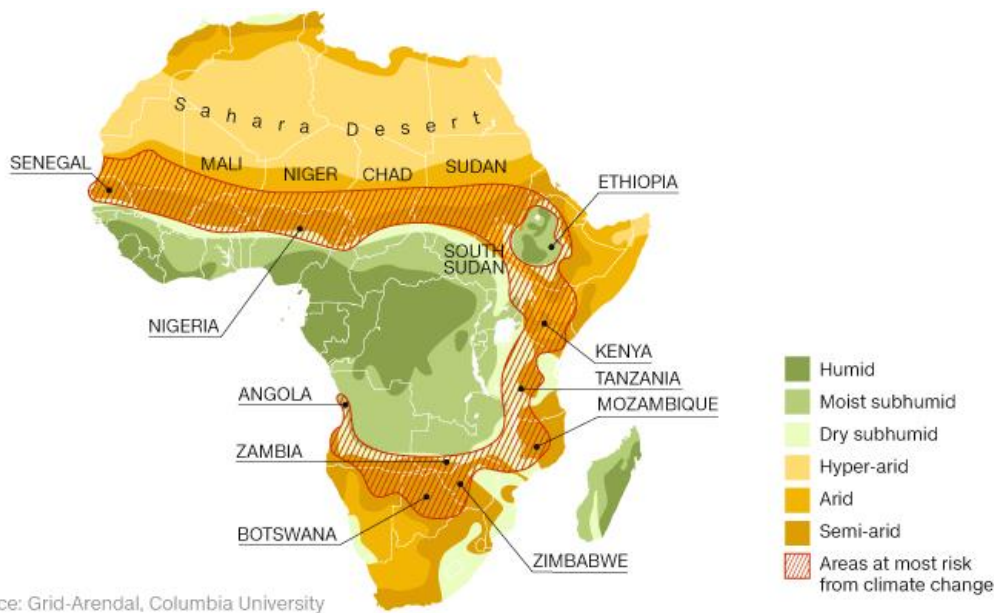


Fig.1 Climate change increases desertification risks for semi-arid regions across Africa^[21].

Floods in Khartoum

Khartoum State—the capital of Sudan—is located within sub-Saharan Africa. It consists of three major cities Khartoum city and the other two cities of the state, i.e., Omdurman and Khartoum North. During 1941–2005^[22, 23]. Despite the warming, which leads to rapid evaporation, and the decades of drought, high-intensity rainstorms during the wet season, such as the one experienced in 2009, have become more frequent since the last two decades^[13, 24].

These events resulted mostly in floods, as in the years 2003, 2007, and 2009 [13]. Khartoum is at risk of flooding due to the concentration of rainfall in a few heavy showers [16]. It is the arid semi-arid zone of central Sudan, characterized by short-term floods [25]. The authors reported that inappropriate design of hydraulic structures such as culverts, sideway ditches, and rainfall canals shall cause floods and create severe damage to the surrounding areas. The annual rainfall in Khartoum region varies spatially from north to south and ranges between 150 mm in north to 200 mm in the south [26]. Prior studies have shown that Khartoum state is particularly at risk from flooding [14-17, 27]. The authors said that ,when the level of the Nile rises, many areas adjacent to the river are affected, for example, the Kalakla region, Tuti Island and some areas of northern Khartoum, such as the Al-Jili area, Wad Ramli, and others, and the Al-Fatihab area in Omdurman [28]. Some areas that are independent as urban areas are located in valleys, depressions and crossings of seasonal torrents. There are also some other areas in the state of Khartoum that are swept by valley floods due to the rain in the highlands at areas outside Khartoum, so that the floods is make its way through the sewers to the Nile River.

Causes of floods in Khartoum

There are many human-induced causes of flooding. Urbanization has become a major cause of flooding in cities and a river is more likely to flood when its drainage basin is in an urban area. Inadequate drainage in some urban areas is a major cause of flooding [29]. Improper management of urban spaces leads to flooding due to plastic wastes clogging gutters. Heavy rainfall and the Nile's increasing water capacity have caused flash floods in various parts of Sudan [30-32]. concluded that the main causes of flooding in Khartoum were flash floods, coastal floods, or river floods, but urban flooding in particular negatively affects built-up areas [33]. Urban flooding in Khartoum is caused by natural flooding in the absence of a good drainage system. The flooding occurs when a city's sewage system and drainage canals do not have adequate capacity to accommodate high-intensity rainfall. If land is converted to urban areas with roads, buildings, and other infrastructure, the land loses its ability capability to absorb water. a study evaluated the environmental effects of Khartoum on the city and concluded that poor infrastructure and lack of preparedness were are the main causes of disasters from floods in Sudan [14].

Nile river floods

Rising floods in the tributaries of the Blue Nile (BN) and White Nile (WN) have an ongoing impact on Khartoum residents' lives and infrastructure [34]. Studies have been conducted in the WN and BN regions, and the findings indicate that the floods still rise and decrease according the yearly rainy season in the Ethiopian highlands [18]. The strongly seasonal Blue Nile reaches its greatest flow between July and September after Ethiopia's summer rains, resulting in some natural Nile flooding each year [35]. It is commonly known that there is an agricultural area along the Blue, White, and Main Niles that occasionally floods. Higher locations along the Nile, above the current flood levels, are home to older, traditional villages. Damaging floods that extend beyond the normally flooded zone occur only after exceptionally wet rainy seasons over the Blue Nile's headwater region in Ethiopia [36]. Every year, the Blue Nile flood partially blocks the White Nile's flow, raising the White Nile's water level to that of the Blue Nile. Because the banks and land east of the White Nile near the confluence are lower than those of the more incised Blue Nile fig.3 [37, 38]. Only when the water level at the Blue Nile river gauge exceeds 16.5 m, or at an altitude of 376.5 m, does significant flooding occur fig.2 [24].

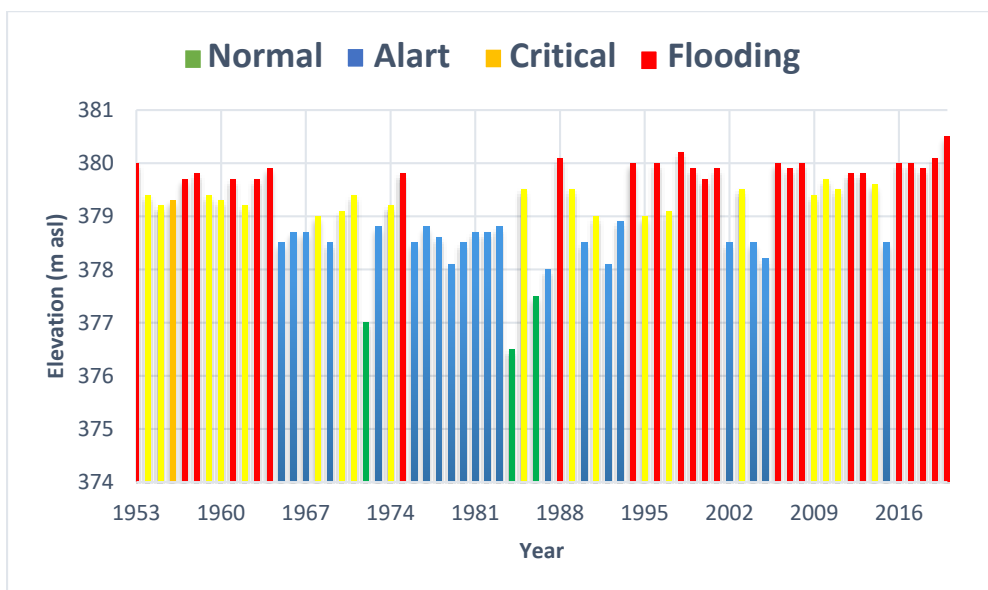


Fig.2 Maximum daily water level of the Blue Nile at Khartoum gaging station, Sudan [34].

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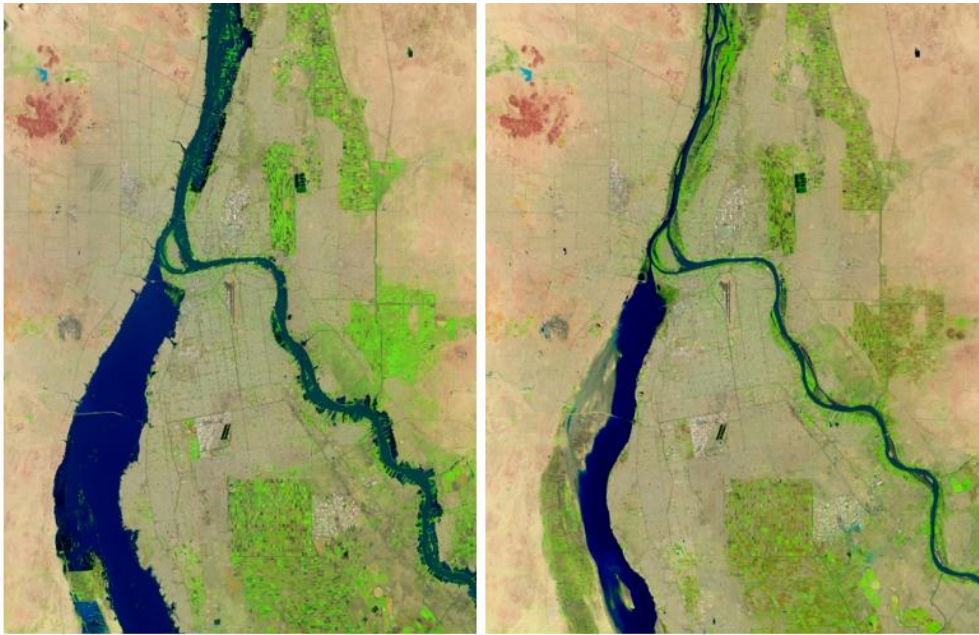


Fig.3 flooding in Sudan’s capital, Khartoum, on September 2, 2020 (right), compared to a more typical rainy season in September 2016 (left) ^[39].

Floods in the valleys

The Khartoum area is a flat flood plain governed by watershed behavior^[40]. north Khartoum has three, main valleys and catchments for seasonal floods Wadi Soba and Wadi Lakhdar, Wadi Al-Silite. As in figure4 Omdurman has two main catchments for rainwater, which are (Khor Abu Anja) and (Khor Shambat).The Maraa'a Al -Sharif area witnessed devastating floods in 2013, because Wadi Soba crosses through the region and intersects with Al-Alafoun Street to pour the Blue Nile. Alilafon Street is located on the Blue Nile River's eastern flood plain. Eight seasonal streams (including Wadi Soba) and irrigation canal cross it (Fig.4). Following the catastrophe, investigation revealed that existing culverts were inadequate to securely transport stream water to the Blue Nile plain. Resulting in stream water blockage east of the roadway, floods, and urban area damage in Sharqu ElNeil^[26].

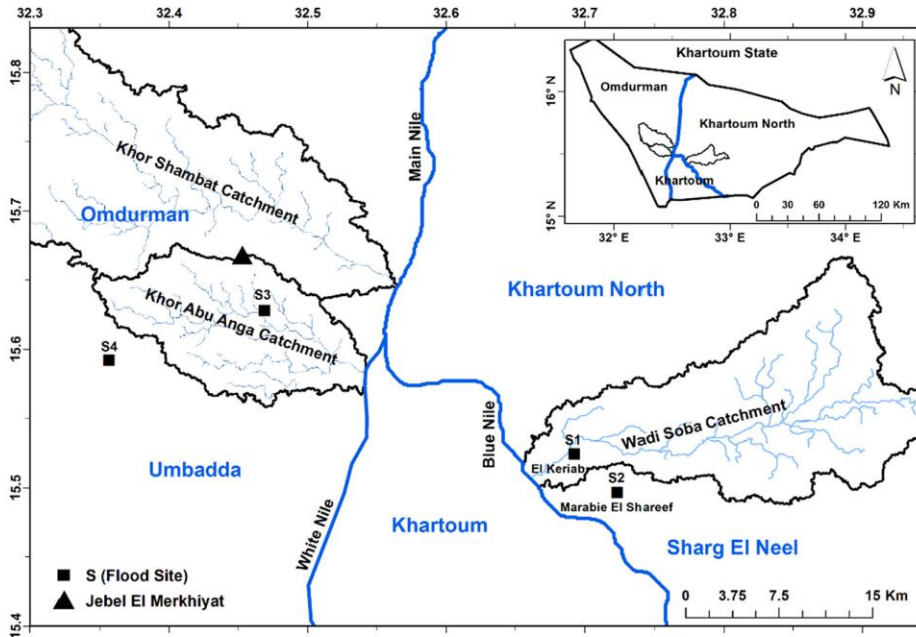


Fig.4 Main valleys and catchments in Khartoum^[17].

Urban flooding by rainfall

Khartoum is a good example of a dry urban climate with highly fluctuating rainfall, resulting in urban floods^[16]. In the absence of an effective drainage system, natural flooding causes urban floods^[33]. Observations in Khartoum during summer rain storms indicate that every storm with a total rainfall of more than 10 mm causes overland flow and flooding of local topographic hollows^[41]. Over 80% of the annual rainfall is received in 3 months (July–September)^[16]. Their research discovered that rainfall magnitudes of 13.1 mm equal the design capacity of Khartoum City drainage network. Aside from that, a frequency analysis of the daily rainfall maxima revealed that the 30 mm rainfall, which causes flooding, has a recurrence period of 1-2 years^[16]. This amount of rain generates a runoff volume four times the capacity of the drainage system. As a result, the city will be inundated. This is because, during the rainy season, the discharge sites as the City Center drainage system at the Blue Nile and White Nile function as flood control measures because the rainy season in Khartoum State coincides with the flooding time of the two rivers. In the current situation when the Nile River rich peak level at the Khartoum station, the main gates of rainwater drainage had been flooded with the Nile water as result to its low level. Fig.5 Pumps are used to toss the water from inside the drains directly into the Nile River without opening the gates of discharge. This method in dealing with rainfall is flawed because the pumps operate manually, and it needs a labor is required to follow and operate it during raining. Furthermore, the capacity of the pumps used does not cover the outflow rain water.



Fig.5 Outlet discharge and the pump used.

Impact of flood

Floods are natural hazards associated with severe socio-economic losses and environmental impacts. The impact of flooding varies both spatially and temporally. It could also be direct or indirect. The direct impacts of floods are closely related to the depth of inundation of floods water^[42]. The extent of a flood has a direct relationship for the recovery time of crops, pastures and the social and economic dislocation impact to populations. The impact of floods is considered far reaching with the aftermath effects such as flood-induced disease epidemics. Disease outbreak is common, especially in less developed countries. Malaria, Typhoid and Cholera outbreaks after floods in tropical countries are also common stated that physical damage to property is one of the major causes for tangible loss in floods^[43, 44]. This includes the cost of damage to goods and possessions, loss of income or services in the floods aftermath and clean-up costs. impact of floods in urban areas can be particularly high, due to both the direct damage caused through the inundation of property and critical infrastructure (e.g., electricity substations, bridges, and drainage systems) and the indirect consequences, such as the loss of productivity and business opportunities^[45] (Fig.6). the quality of housing and infrastructure play a major role in determining the extent of the flooding hazard where unplanned housing and insufficient or inefficient drainage systems increase the risk of damage^[46]. Flooding is one of the common natural disasters that affect people and infrastructures all across the world, in Sudan, it has forced people to move and change their activities ^[11, 12, 14]. Heavy rainfall and the increasing water capacity of the Nile have caused flash floods in different places in Sudan^[30-32]. a research evaluate the environmental and water-level changes on the land at the confluence of the Blue Nile (BN) and White Nile (WN) in Khartoum and central Sudan^[47] ; it showed that the climate was wetter during times of high White Nile floods. Some studies showed that Khartoum area is particularly at risk from flooding^[14-17, 27] . Land use/Land cover LULC changes and the impact on Blue Nile streamflow, and they concluded that the rate of streamflow change is strongly correlated to LULC^[48]. The sedimentation affects Blue Nile streamflow velocity. Therefore, Blue Nile floods should be expected to change land use, especially after constructing the Grand Ethiopian Renaissance Dam^[15]. Similarly , a study used RS–GIS to evaluate land use and change around White Nile, and their results showed that the soil characteristics were influenced by the LULC changes attributable to past flooding^[49]. Other studies have been applied to the White Nile and Blue Nile areas, and the results show that the floods still rise and fall with the annual rainy season in the Ethiopian highlands^[18]. a Study evaluated Khartoum environmental effects on the city and concluded that poor infrastructure and lack of preparedness were the main causes of disasters from floods in Sudan^[14]. Although previous studies and researchers' efforts concluded many significant results and recommendations for the effects of White Nile and Blue Nile floods on Khartoum city, the floods continue to threaten the city and affect people and structures^[37].

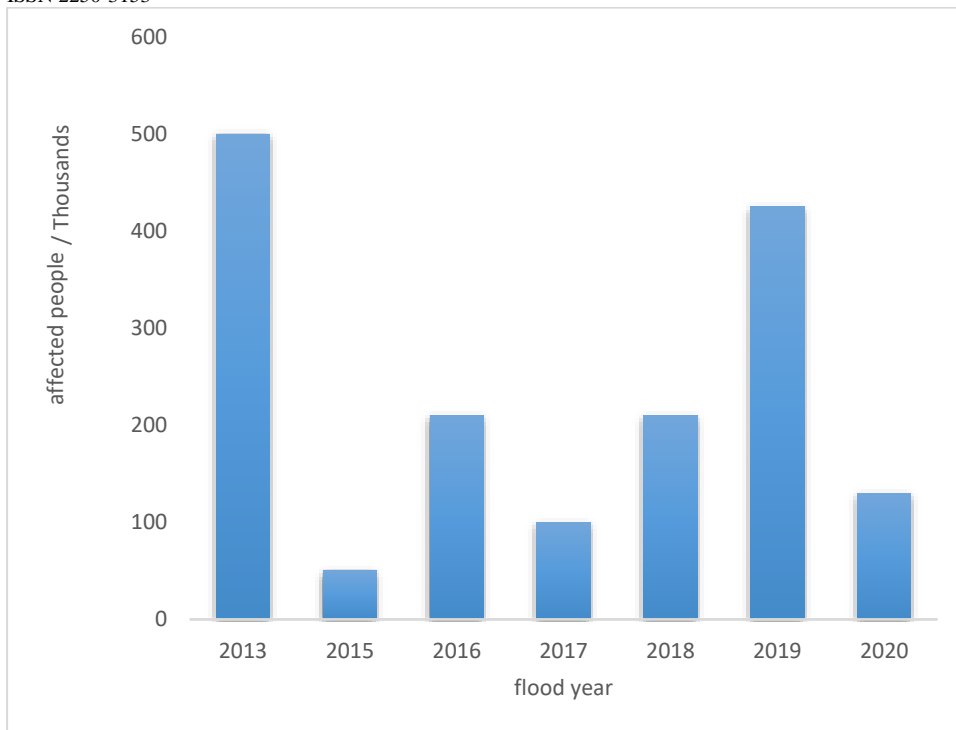


Fig.6 People affected by floods in Sudan^[30, 50] .

Conclusion

Sudan has a major flood problem, and the country's capital, Khartoum, is frequently flooded. The review classifies the many floods that occur in Khartoum, taking into account regional variances and each one's unique characteristics. The review showed that there are three types of floods that occur in the city of Khartoum, namely the flood of the Nile River, which causes flooding of large areas of the city of Khartoum that lie on its banks, and as a result of the rise in the level of the Nile associated with the levels of rain in the sources. valley floods and they occur as a result of the presence of residential areas within the valleys of seasonal floods and the urban floods resulting from the inefficiency of the rainwater drainage network in the city of Khartoum. All of these reasons lead to inevitable disasters due to the floods in the city of Khartoum, and the consequences of them lead to health disasters with the spread of diseases and economic and social effects, with the push of many residents to displacement and the change of living systems in the region. The study indicates that a coordinated and sustainable flood management method is required to alleviate Khartoum's flood problem.

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