American Journal of Climate Change, 2023, 12, 80-99
https://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

The Risk of Flooding to Architecture and Infrastructure amidst a Changing Climate in Lake Baringo, Kenya

Nyakundi Victor*, Plal Eric, Kandu Kyeba

Department of Architecture, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
Email: *victor.nyakundi@jkuat.ac.ke

How to cite this paper: Victor, N., Eric, P., & Kyeba, K. (2023). The Risk of Flooding to Architecture and Infrastructure amidst a Changing Climate in Lake Baringo, Kenya. *American Journal of Climate Change, 12,* 80-99.
https://doi.org/10.4236/ajcc.2023.121005

Received: October 14, 2022
Accepted: March 5, 2023
Published: March 8, 2023

Abstract

Climate change has grown more apparent in recent years with people becoming more aware of its potentially disastrous consequences. Flooding is one of the many consequences of a changing climate in Kenya known to cause immense devastation resulting in the loss of lives and property. This paper discusses the risk of flooding in Kenya as one of the many outcomes of climate change in the face of urgency to adapt Kenya's built environment to flooding which is likely to continue to prevail in the decades as a result of the looming climate change. It also sought to evaluate the physical, traumatic, and psychological effects on communities affected by flood events. This cross-sectional survey, both qualitative and quantitative in nature, executed between 13th January 2021 and 14th July 2021 with 132 respondents along the western shoreline of Lake Baringo, near Marigat Town focused on the flood levels, structures, their materials, and quantities. Results show that the area covered by Lake Baringo increased by 18% from 236 km^2 to 278 km^2. The depth of floods ranged from 0.3 m to 1.2 m and exceeded 1.6 m during heavy rainfall up to 3.2 m with homes completely submerged by the lake. Flooding was experienced more by residents living in low areas nearer to the shoreline of the lake as compared to those living on higher grounds. 100% of the structures didn't have the architectural technology to withstand the impacts of flooding with 59% of housing made of corrugated iron sheets both on wall and roofing, 22% of mud houses roofed with either corrugated iron sheets, 10% being timber with thatch and only 8% stoned walled houses. This predisposed all the residents to the harmful impacts of flooding. Piled sandbags by locals as a mitigating measure proved inadequate to withstand the forces of the rising waters. Flood walls were built around local lodges near the lake but the rising water level quickly breached these defences. The study recommends that county and national governing authorities develop flood adaptation strategies for resilience. These include long-term land-use planning, the establishment of early warning systems, evacuation plans, identification of vulnerable or high-risk populations, measures to ensure water quality, sanitation, and hygiene. Flood-resilient architecture including stilt and floating houses that mechanically rise and fall with respect to the highest water mark are recommended during flood events. Bridges on swollen rivers and resilient construction materials like reinforced concrete are to be used for sustainable development for flood risk adaptation.

Keywords

Architecture, Climate Change, Flooding, Risk, Lake Baringo

1. Introduction

Flooding is not a new phenomenon yet in these modern times, flooding has become an imminent threat (Kundzewicz et al., 2014). Flooding is a calamity because of the way flood-prone areas which have been built upon. Against the backdrop of the rapid increase in population, urbanization trends, and climate change, there is a shift in the causes of floods and their effects have accelerated. Some of the main causes are closely linked to changes in land use and land cover (Kundzewicz et al., 2014). WHO (2002) reports that flooding is one of the numerous outcomes of climate change across the globe and according to recent studies and projections, levels of precipitation are expected to increase in the coming years and are likely to cause substantial destruction of the built environment. Some of the effects of floodwater on buildings include submersion which can cause varying extents of damage including peeling paint, stains to structural collapse.

Global precipitation patterns have been disturbed by climate change, resulting in increasingly intense storms. Rain-related flooding will be more likely as precipitation intensity and variability rise. At the same time, extreme drought and aridity will become more common in continental interiors, particularly in the subtropics (Stout, 1990). Empirical evidence has shown structural failures leading to an increased risk of the effects of flooding as can be seen in **Figure 1**.

Figure 1. Abandoned houses around the lake (Source: Author).

During a flood, the effects on people are numerous. The health of the affected communities is threatened by an increased risk of waterborne diseases, as lives are at peril and the traumatic flood experience itself is difficult to endure. Following a flood event, outcomes are often assessed in terms of the physical impacts on infrastructure and buildings. However, the traumatic and psychological effects of flood events can be just as if not more devastating. Residents are left stranded in their homes, and many lose their livelihoods as their homes become uninhabitable and businesses are ruined by the overarching effects of floods (Barsley, 2020).

Kenya's great lakes are flooding, in a devastating and long-ignored environmental disaster that is displacing hundreds of thousands of people (Baraka, 2022). Natural regions of woodland, swamp, and marshes, as well as barrier strands, that have evolved over millennia to absorb flooding and storm impacts have been impacted, removed, or otherwise impaired by development encroachment. Located in Rift Valley-Kenya, the Mau Forest, for example, holds the main rivers which form the catchment area that provides water to the western region of the country. Deforestation in Mau Forest is rampant. In addition, land cultivation continues to be practiced near the sources of these rivers. The result has been increased flooding downstream and extensive soil erosion (Awer, 2004). This spurs the need for infrastructural designs which are more conscious and integrative of the risk of floods.

Lake Baringo and other lakes in the rift valley are rising and this can be mainly attributed to increased rainfall over the past years occasioned by a changing climate. The lake is dotted by huge settlements of people around it since its located in a semi-arid area. The human dependency on this lake is so huge to an extent that a slight increase in the levels has caused resorts to be flooded disrupting tourism and other economic activities, schools have closed affecting education, roads are impassable, other critical infrastructure destroyed and the health of the community impacted due to water contamination.

This paper is very significant in ensuring adaptive Pathways for resilient Infrastructure and policy planning for disaster and climate-resilient infrastructure. It focuses on these risks and proposes resilience strategies to address these worrying patterns on the need to develop flood adaptation strategies for resilient housing and human health.

2. The Risk of Flooding Amidst a Rapidly Changing Climate in Kenya on the Built Environment

The consequences of flooding on the built environment are numerous and may lead to expensive damage, not only to water and contaminants but also to material damage. Pistrika et al., (2014) report that during construction or the renovation of a building, measures must then be adopted to increase the resilience capacity of a building to floods. As shown in **Figure 2**, this analysis focuses on the strategies of flood architecture currently being implemented as a mitigation response to flooding. United Nations (2021) stresses an ever-increasing

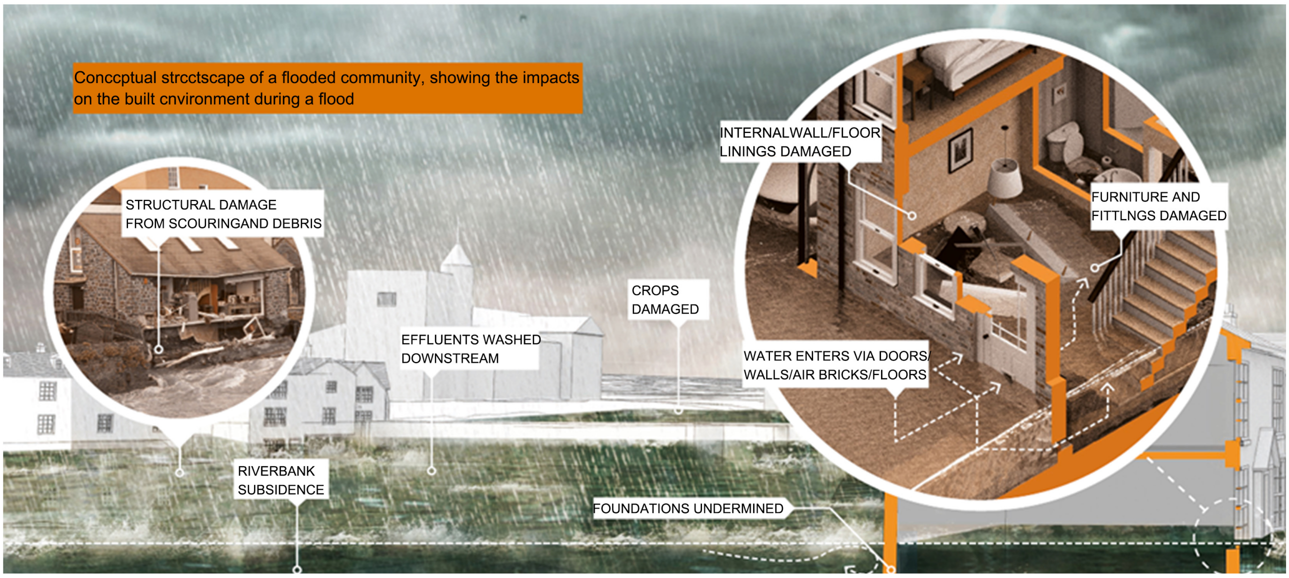


Figure 2. Risks associated with flooding (Source: (Barsley, 2020)).

urgency for man and nature to thrive together with the looming threat of climate change. Floods have caused massive displacement of people; therefore, there is a general acceptance of the need to co-exist with floods (Pistrika et al., 2014).

In addition, there is a need to increase personal safety, and people's sense of security, the preservation of their mental and physical well-being, decrease flood recovery time, and protection of property. Flood-prone areas. Pistrika et al., (2014) further reports that relocating can disconnect people from their livelihoods in flood-prone areas (e.g., fishing and farming) and cause significant social upheaval as these are often their ancestral homes.

If those who are vulnerable to floods are to remain healthy, adopting flood-resilient strategies is one of the best solutions to the flooding problem. They need to continue dwelling within their homes during and after flood events. Another negative outcome of the strategy to flee and abandon flood-prone areas includes the potential of overcrowding inland zones if mass migration occurs (Pistrika et al., 2014).

2.1. History of Flooding in Lake Baringo and Neighbouring Rift Valley Lakes

If we go back in time, the Rift valley lakes as shown in **Map 1**, have had higher water levels. (Avery, 2020) agrees that we are seeing now is not something new." Sean Avery, a hydrologist who has lived in Kenya since 1979, has further pointed out that the current level of Lake Baringo is no higher than it was in the 1970s or the 1900s (Baraka, 2022). Theories have emerged on why the waters have been rising with some researchers claiming the tectonic movement of the Rift valley could be the cause of the current expansion of the lakes.

The government of Kenya in its report in 2021 further explains that this has been dismissed by hydrological experts with experts claiming that in fact, Lake

Map 1. Position of the various Rift valley lakes whose levels have been rising (Source: Baraka, 2022).

Victoria was also rising, despite not being on either branch of the Rift valley. Experts have reported that what was happening is a result of the climate crisis. There had been more rain in the Kenyan and Ethiopian highlands, and the volume of the rivers feeding these lakes had increased. Since 2010, Kenya has received more rainfall than usual, the yearly average has been signed up on the 2010s 650 mm almost every year since. In 2019, Kenya received the third most rainfall it had ever recorded (Government of Kenya, 2021).

In May this year, Lake Naivasha reached its highest level since 1932. The lake's expansion has flooded developments, such as surrounding flower farms. Yet, like the other lakes, Lake Naivasha's waters have historically been higher (Avery, 2020). The lake is 1.4 vertical meters short of its official riparian boundary. In 1917, the lake was 2.4 meters higher. In earlier centuries, the lake was at least 13 meters higher. Lakes Nakuru, Bogoria, and Baringo have also risen to their highest levels in decades, inundating roads and building infrastructure, yet they also are not as high as they were in the early part of the last century. Lake Turkana's current level was also reached in the 1970s and early 1900s, and in 1896 it was 14.6 meters higher (Avery, 2020). Regional lake water levels were higher still during the Holocene, up to 10,000 years before the present, during a wetter period. For instance, Lake Turkana was 100 meters higher and Lakes Bogoria and Baringo had risen high enough to merge into one lake. Present-day Nakuru and Naivasha townships would have been underwater (Avery, 2020).

Other experts have attributed the frequent flooding and massive soil erosion to desertification caused by the felling of trees for charcoal burning and cultivation along the rivers and natural water catchment areas. Climate change, soil runoff into the lake, making it shallower, and geological changes are also cited (Kangogo, 2022). Throughout the 2010s, the lakes rose slowly, and tens of thousands of people were forced to move from their homes. Then, at the start of 2020, after a particularly vicious period of rain in Kenya's highlands, the lakes' expansion accelerated (Baraka, 2022).

By September 2013, after further investigation and mapping, it was clear how extreme the damage was. In Baringo, schools had been flooded and people had been displaced. Lake Nakuru, which was previously enclosed by a national park, now extended beyond it, had increased in size by 50% (Baraka, 2022). The rapid expansion of Lake Baringo started in December 2019. Baringo is a desert area but for about three months, residents of the area expected that when the heavy downpours of March 2020 subsided, the lake would retreat. Instead, it kept rising spreading to their homes and resorts as shown in **Figure 3**. In March 2020, as Covid spread, schools across the country closed. When they reopened seven months later, 11 schools in Marigat had been completely submerged by the lake (Baraka, 2022).

2.2. Impacts during Flooding

When floods occur, substantial infrastructural damage is caused, for example, bridges are washed away, roads marooned, and floodwater gets contaminated with raw sewage. Additionally, structural failures occur when dynamic and hydrostatic loads and debris impacts affect buildings. Moreover, foundations can be undermined by erosion and scouring. Properties are also displaced by buoyancy forces (Barsley, 2020). Flooding also disrupts services and causes loss of infrastructure and lives as shown in **Figure 3** and **Figure 4** (Chebii et al., 2022).

Figure 3. Bus ferrying BBI supporters to Kitui plunges into River Waani in Mbooni, Makueni. Photo: Kambaland updates. Source: UGC Read more: https://www.tuko.co.ke/338009-bus-ferrying-bbi-supporters-kitui-plunges-swollen-river.html.

2.3. Impacts after Flooding

The deluge and residue that is left behind after flood retreats are often pungent and contaminated. This poses a health hazard to the local community. Injuries, infections and infectious disease outbreaks, poisoning, and increased mental health problems have all been reported after floods (Chebii et al., 2022).

Displacements, shortages of safe water, injuries, loss of access to health care, and delayed recovery are all long-term health implications as shown in **Figure 5** and **Figure 6**. The problem of adapting the built environment to the threat of flooding in the face of a fast-changing climate is complicated and multi-faceted, but as explored in this section, there are a variety of techniques that can help to minimize residual flood risk while also increasing the quality of life.

Displacement of families is normally experienced as shown in **Figure 7** and **Figure 8**. A classic case is Lake Naivasha in which flower farms which predominantly

Figure 4. Floods from seasonal rivers have blocked roads in Turkana County, Kenya, October 2019. Photo: Kenya Red Cross Society (KRCS).

Figure 5. Tourist lodges at Lake Baringo now submerged. Photograph: Celine Clery/AFP/Getty.

Figure 6. Crocodiles swim next to a group of people at the shore of Kampi Ya Samaki in October 2021. Photograph: Daniel Irungu/EPA.

Figure 7. Families displaced at Uwanja wa Ndege IDP Camp (Source: Author).

Figure 8. Swelling lakes a man rows his boat between green houses at a flower farm in Niavasha, Flower farms are the most affected in the region as Lake Naivasha expands.

are Kenya's largest export to Europe, are submerged making it impossible to grow the cut flowers in the greenhouses. This affects business which in turn affects the economy and leads to the loss of jobs.

3. Methodology

This cross-sectional study collected data from 132 respondents through questionnaires, interviews, and observation through a survey carried out over 6 months as shown in Map 2 and Map 3. The qualitative and quantitative research methodology focused on the flood levels, structures, materials, and quantities since the research is a survey. Key informants included professionals and community leaders. The data for qualitative analysis came from the opinions expressed during the Focus group discussion. The qualitative information was transcribed and examined using themes. The data were summarized using matrices, and the analysis was then presented thematically in narrative form. Direct quotes have been used to show how data was obtained. Quantitative data obtained from questionnaires were analysed and presented in tables. This qualitative and quantitative study gathered information on the existing threat of floods as shown in Figure 9.

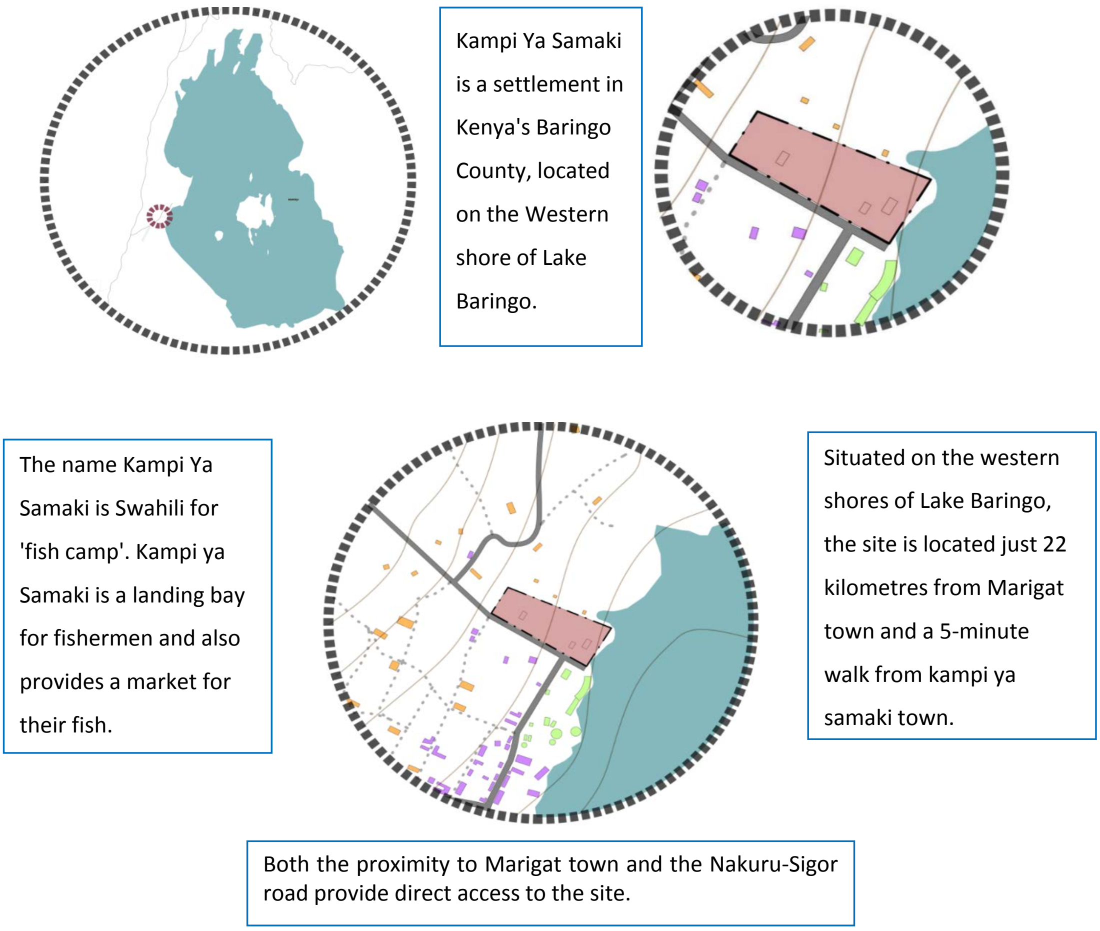


Figure 9. Data collection sites (Source: Author)

4. Results and Analysis

The findings of the research were analysed as presented in this chapter as discussed below. These involved mapping out the area for flooding, understanding the demographics and the effect of the floods to the residents.

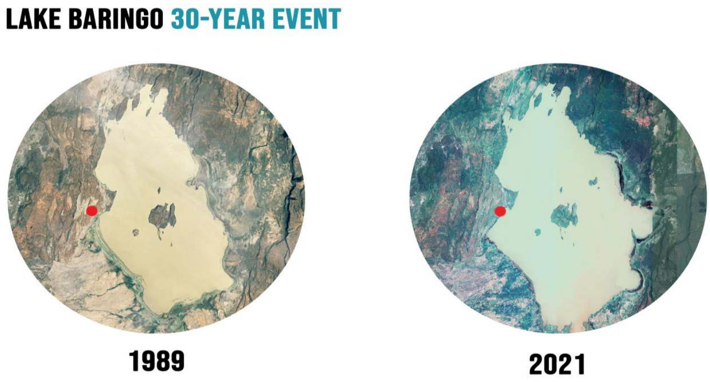
4.1. Flood Mapping and Patterns around the Study Area

The area around Lake Baringo falls within the lowland of Baringo County and is characterized as largely a semi-arid area with complex soils (Muia et al., 2021). Studies show that the impact of flooding of the lake level rise saw Lake Baringo increase the area under flood water from 143.6 km^2 in January 2010 to a high of 231.6 km^2 in September 2013, an increase of 88 km^2 or 61.3% (Muia et al., 2021). Muia et al. (2021) reports that a male key informant, and elder of the Ilchamus community who lives on Kokwa Island, had not seen this kind of flooding. The last time lake reached this level of flooding was fifty years ago. Esqually, there is documentation that the alternating cycles of droughts and floods not only destroy the livelihood sources but also severely undermined the resilience of the people living in the affected areas (Muia et al., 2021).

It is important to point out that while the data for this paper was collected in 2021 as of the time of writing this article, the situation is still as challenging as the water levels have remained high. By the end of 2020, one of Kenya's wettest years on record, Baringo had risen by several meters, and had claimed 34 sq·mi. of land (Muia et al., 2021). Recent reports show that the area covered by Lake Baringo has grown from 236 km^2 to 278 km^2 which accounts for about an 18% increase. The depth of floods usually ranges from 0.3 m to 0.6 m and exceeds 0.6 m during seasons of heavy rainfall. Residents living in low areas nearer to the shoreline of the lake experienced severe flooding as compared to those living on higher grounds. The depth of the floodwater usually ranged from 0.3 m up to a staggering 2.7 m where some homes were completely submerged by the lake as shown in **Maps 2-6**.

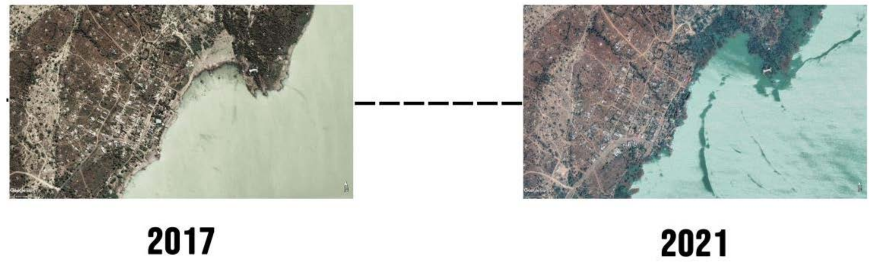
4.2. Demographic Characteristics of the Respondents

PARAMETER	*DEMOGRAPHIC CHARACTERISTICS*	*PERCENTAGE (%)*
Gender	Female	30
	Male	70
Length of Residence	Less than 20 years	23
	More than 20 years	77
Age Bracket	18 - 34 years	62.5
	35 - 50 years	15.6
	Above 50 years	21.9
Education Level	No formal education	12.5
	Primary School Level	31.3
	High School Level	24.9
	Tertiary Institution Level	31.3

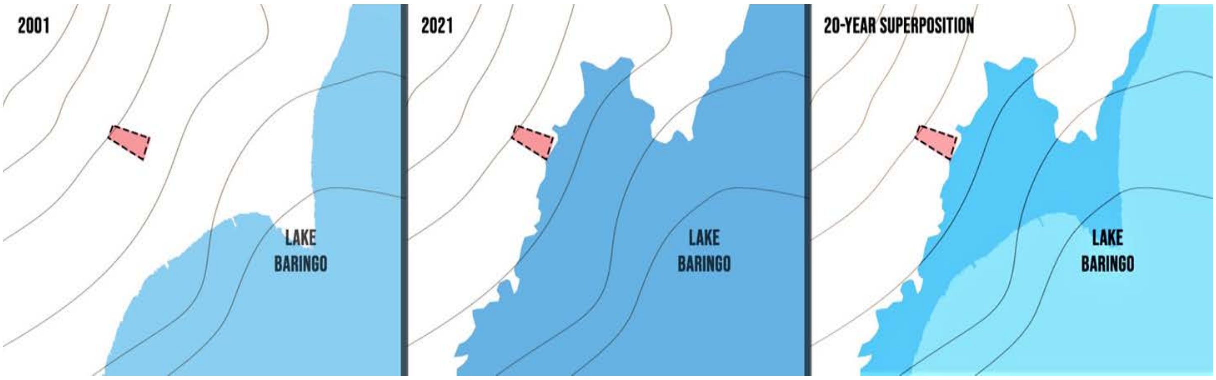


Map 2. A 30-year flood event (Source: NASA Earth Observatory images by Lauren Dauphin).

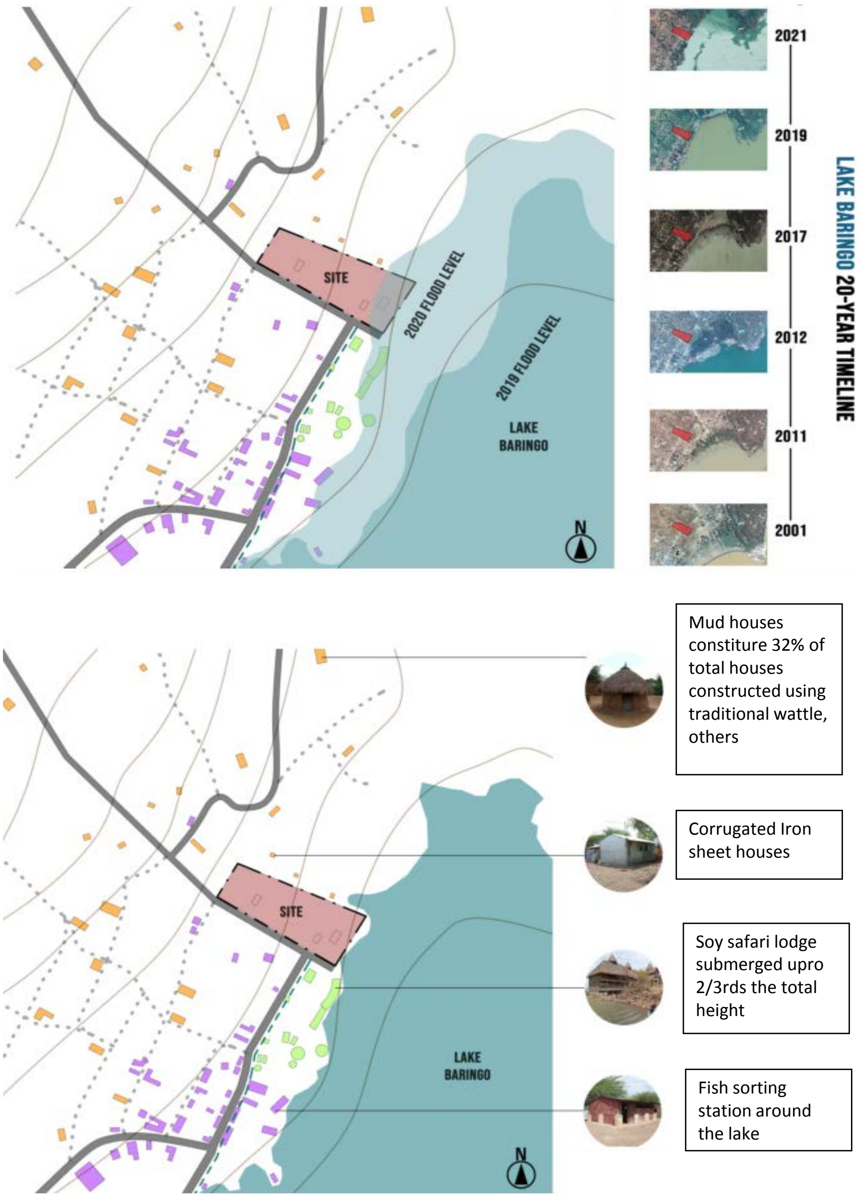
Map 3. Timeline of the flood from 2001 to 2017 (Source: NASA Earth Observatory images by Lauren Dauphin).



Map 4. Timeline of the flood from 20017 to 2021 (Source: NASA Earth Observatory images by Lauren Dauphin).



Map 5. Water land cover changes in L. Baringo (Source: Author).



Map 6. An analysis of the flood conditions on the site and a 20-year timeline of the flood (Source: Author).

Gender and Age—From the table above, the male who are the dominant land owners in the area accounted for 70% of the respondents. The statistics on their length of stay was key since this would give a clear history of the changing patterns and water levels observed over time around the lake. The population above 60 years who accounted for 21.9% gave historical data on the rising levels from between 1960s up to the present day.

Length of Stay around Lake Baringo—As shown in Figure 10, more than 77% of the respondents had stayed around Marigat Town for more than 20 years hence gave data on the spells where the lake experienced high and lows water levels. As shown in Figure 11, 15% of residents who have spent more than 30 years in the area have a clear account of the lake water patterns in terms of flooding.

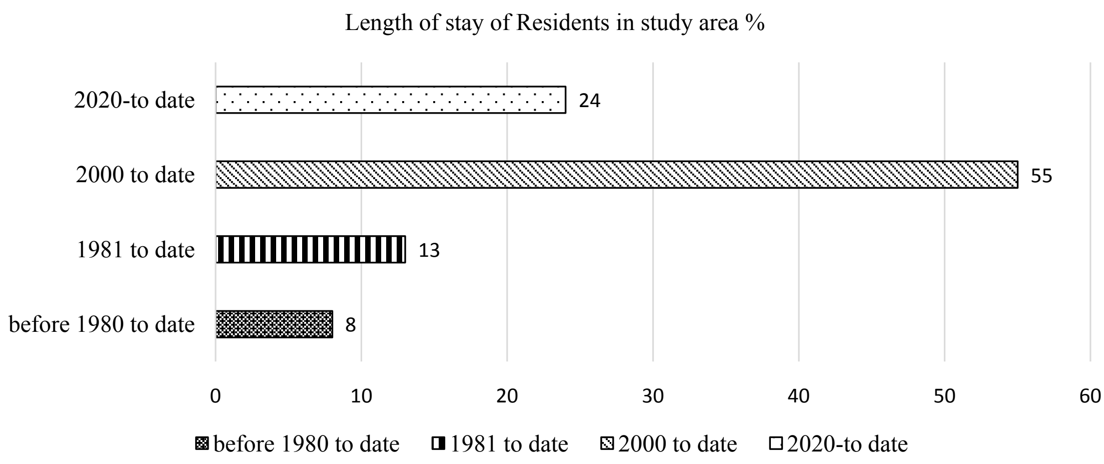


Figure 10. Length of stay of residents in study area % (Source: Author).

Figure 11. Flood rise levels in photos in affected houses (Source: Author).

55% of the residents experienced flooding in 1983, 2019, and 2021 and can give a clear account of the water levels from 2000 to date. The findings clearly show that the lake is currently not at the position it was and there has been a clear rise in the levels leading t displacement from flooding.

4.3. Flood Events in the Study Area

Flood period—The average time experienced by the respondents was estimated at 2 years. Some 34.2% of houses were flooded for longer than 1 year.

Flood speed—89% of respondents felt it was still water that was steadily rising (within a few days) until the floodwater attained its highest level.

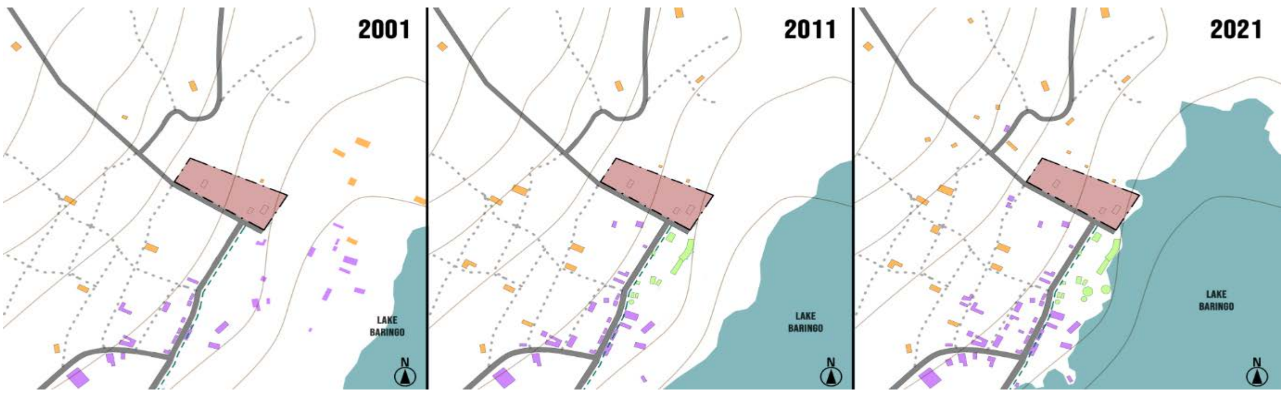
The direction of flow: It was outwards from the lake itself and came through the shoreline. It was very rare that the direction changed because of drainage canals and small ponds. Also, respondents who lived close to Lake Baringo experienced flooding from the Rivers Ndau and Perkerra as shown in the kampi ya samaki Map 7.

Flood depth: Figure 11 and Figure 12 show that 41% of houses were more than 1.8 m, 26% were between 0.9 m and 1.8 m, and 33% were between 0.3 m and 0.9 m, respectively. This average depth further shown by Figure 11 is about 1.6 metres and sometimes exceeding 3.2 m which is too deep for humans to comfortably stay posing a risk of drowning, loss of lives, loss of household commodities among others and sometimes fully submerging houses.

Flood damage: The respondents for the survey were selected from those affected by the flood disasters and some were not living in their original homes. 42% of houses were damaged/submerged completely and 58% were partially damaged. 80% of respondents lost their movable property, 60% completely lost their crops, and 12% completely lost their livestock. From the survey, 4% of respondents noted infrastructural damage.

4.4. The Effect of Flooding on Various Building Typologies

There were various building typologies in the study area. These include Mud, stone, timber, and corrugated iron sheet houses.



Map 7. Direction of flow of the lake water towards Kampi ya Samaki Town (Source: Author).

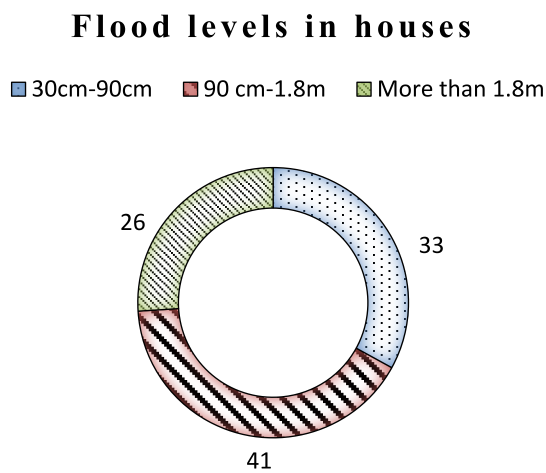


Figure 12. Flood rise levels in centimetres in affected houses (Source: Author).

4.4.1. Mud Houses

Mud structures as shown in Figure 13 consisted of 22% of all houses in the study area. Some of them were constructed using the traditional wattle and daub technique, while others with local volcanic rock filled bound together with mud as mortar and plaster. They were the most by floods when exposed to water the earthen walls were easily washed off and crumbled easily.

4.4.2. Stone Houses

Masonry structures consisted of 8% of all houses in the study area. Some of them only had walls with four courses high of masonry with the rest built with corrugated iron sheets. The masonry structures closest to the lake displayed extreme structural damage while the ones farther inland were able to withstand the floodwaters as shown in Figure 14.

Masonry houses due to their permanent nature are left free-standing but critical building elements like windows, corrugated iron sheets, and doors which are more valuable to the owners are removed and owners relocate with them. These masonry houses are left in a dilapidated state and prone to damage.

4.4.3. Corrugated Iron Sheet Houses

As shown in Figure 15, Corrugated iron sheet structures consisted of 59% of all houses in the study area. Most of the affected people were able to recover the iron sheets after the flood events.

Figure 13. Mud houses (Source: Author).

Figure 14. Damages on stone walled houses (Source: Author).

The timber frames of these structures, however, were susceptible to damage from the force of the floodwater and rot.

4.4.4. Timber Housing

Timber structures with thatch as shown in **Figure 16** consisted of 10% of all houses in the study area. Some of them were constructed using traditional wood and nails others were tied with sisal. They were affected by floods since the untreated timber was exposed to water and rot. 70% of the timber houses were also thatch which caved in and rot upon exposure to heavy downpours.

5. Discussions

The increased water level in Lake Baringo is rising as a result of a changing climate and increased rainfall patterns. Muia et al. (2021) in his publication confirms that over the past decade, as the lakes in the rift valley have risen, they have

Figure 15. Corrugated iron sheet houses (Source: Author).

Figure 16. Photo showing a structure before it was submerged under rising water due to months of unusually heavy rains, in lake Baringo, Kenya. CREDIT: BAZ RATNER/Reuters.

become a source of alarm rather than pride. Baraka (2022) reports that Lake Baringo swallowed up the lesser-known Lake 94, and proceeded inland for about eight miles, while Lake Oloiden disappeared into Lake Naivasha's clutches. Lake Baringo, which is freshwater, and Lake Bogoria, which is saltwater, moved towards each other, threatening to become a single body of water, which would devastate the wildlife in both lakes. At one point, the lakes came within four miles of each other. They further drifted again and what is currently happening may be further compounded by historical patterns around the lake (Baraka, 2022).

Community leaders and other experts further reported that increased seismic activity from a nearby geothermal plant (Olkaria Geothermal Power Plant) has further compounded this factor. Second, siltation has increased the water levels of the lake. In the process, outlets of the lake have been blocked by the silt which greatly reduces the rate of discharge from the lake. Third, periods of heavy rains greatly increase the capacity of the lake when they occur. These cause destructive floods that damage homes located in low-lying environs.

Kenya Metrological Department experts indeed confirm that there had been more rain in the Kenyan and Ethiopian highlands, and the volume of the rivers feeding these lakes had increased. Since 2010, Kenya has received more rainfall than usual the yearly average has been signed up on the 2010s 650 mm almost every year since. In 2019, Kenya received the third most rainfall it had ever recorded (Baraka, 2022). While accepting that tectonic theories do not fully explain Lake Victoria's rise, hydrological experts are further convinced that anthropogenic climate breakdown is the only cause and that downplay the role of humans cannot be downplayed. Humans are doing something, but it can't explain the sudden rise. What was needed, said Kiage, was a molecular investigation of the water, to determine where it was coming from (Baraka, 2022).

Housing around the lake has also not been designed to be flood resilient. Considering the review of the most predominant structure in the area of study, one aspect was common. 100% of the structure had neither architectural designs nor materials which can stand the impacts of flooding in the area. With 59% of housing made of corrugated iron sheets both on the wall and roofing, 32% of mud houses roofed with either corrugated iron sheets or grass, and only 8% stoned walled houses, there was very minimal structural preparedness for flooding in terms of housing. This fact predisposed the residents to the harmful impacts of flooding (Baraka, 2022).

Creating a resilient environment for floods and other flood defence strategies would go a great way in helping mitigate the effects. There have been efforts in collaboration with the government to install engineered flood defences in some occupied areas around the lake. Unfortunately, these flood defences have failed to inhibit the menace of floods. Canals built by the National Irrigation Authority for the Perkerra Irrigation Scheme have to some extent helped control the flow of water, but they have not been well maintained and tend to fail due to heavy flooding. The failure is attributed to architectural designs which do not address the risk of flooding. Locals, to mitigate floods, have piled sandbags (where. These proved to be inadequate to attenuate the forces of the rising waters. Flood walls have also been built around local lodges near the lake. The unprecedented water levels quickly breached these defences.

Evacuation is one of the most consistent ways that the government is employing to mitigate the effects of flooding. Evacuation is considered to be an effective strategy for a variety of natural hazards, including floods. However, generalizations are problematic. About 75% of affected people fled their homes and sought alternative shelters. Their homes were either completely submerged by the floods or it was impossible to return to them because these areas have been encroached on by wild animals which have also been displaced by the water from their habitats. Individuals with the financial capacity bought land and resettled in the higher areas of Baringo or rented houses in Marigat Town, while the most vulnerable resettled on government land with the support of NGOs like the Red Cross. Most of the displaced people were given temporary shelter at the Uwanja wa Ndege IDP Camp. The displaced persons were sheltered in canvas tents roofed with corrugated iron sheets. They have neither timber doors nor windows. Haynes et al., (2009) consider some of the risks associated with emergency evacuations, identifying areas with badly planned subdivisions and "gated communities" as particularly problematic. In contrast, other authors characterize the UK as having a "shelter culture", with a history of sheltering during air raids of World War II (Moshenska, 2019). Haynes et al., (2009) further argue that there are benefits of remaining in place during a hazardous event. One reason for this may have been the fact that the post-disaster recovery process may be made easier by staying in place. In his review of literature on disaster response behaviour and coping mechanisms, Scanlon (1997, p. 3) suggests that: those who persevere even under the most difficult conditions may fare better emotionally than those who leave their home, no matter what the devastation (Haynes et al., 2009). Haynes et al., (2009) conclude that it is important to recognize that evacuation and shelter-in-place strategies carry inherent risks, no option is entirely risk-free. There are circumstances where evacuation is the safest option. However, this paper has shown that there are situations, particularly where an early warning is not possible, where it may be safer for people to shelter-in-place rather than attempt to travel through flood waters.

6. Conclusion and Recommendations

This research paper leads to the conclusion that significant flooding in the Lake Baringo area has had a devastating impact on local communities and livelihoods. Thousands of people were displaced as a result of the flooding, which interrupted livelihoods and social infrastructure as well as destroying farmlands, and killing livestock. This greatly disrupted the food supply and the running of businesses in the locale. Effective planning and design of flood adaptation strategies are needed for both housing and other sectors of the economy. This can be taken up by the County and National Governments. Long-term land-use planning, the establishment of early warning systems, communication and evacuation plans by relevant bodies like National Disaster Management Authority, the identification of vulnerable or high-risk populations, information and communication particularly to reach the people most at risk and vulnerable, and measures to ensure water quality, sanitation, and hygiene are important for flood resilience. Flood-resilient architecture that incorporates preparation, mitigation, resilience and recovery are key for resilience. Building bridges across swollen rivers and using resilient construction materials like reinforced concrete are to be used for flood risk adaptation. Other resilience measures that can be incorporated include stilt housing done on reinforced concrete columns with respect to the highest water mark at a minimum of 3.2 metres above the ground level with suspended vertical circulation systems that rise and lower during flooding. These stilt and floating houses are to be designed to either rest on oil drums or to be raised or lowered mechanically during flooding, which are better coping mechanisms for a resilient architecture. Therefore, flood resilience is key in protection of property, safeguarding livelihoods and creating a sustainably planned and designed environment for unprecedented future floods amidst a changing climate.

Acknowledgements

The authors are grateful for the invaluable support of staff at the Department of Architecture in JKUAT for their input while conducting this research. Gratitude is also due to the staff at Roberts Camp Hotel adjacent to Lake Baringo, Kenya Meteorological Department, and residents of Marigat town and Kampi ya Samaki who sacrificed their time to participate in this study and whose contribution has made all this possible.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Avery, S. (2020). *Scientists Are Worried about the Impact of Kenya's Rift Valley Lakes Flooding.* QUARTZ AFRICA. https://qz.com/africa/1918674/scientists-worried-by-flooding-in-kenya-rift-valley-lakes/

Awer, W. (2004). *The Mau Forest Complex and Catchment Basin.* WWF Eastern Africa. https://wwf.panda.org/wwf_news/?10823/The-Mau-Forest-Complex-and-Catchment-Basin

Baraka, C. (2022). *A Drowning World: Kenya's Quiet Slide Underwater.* The Guardian.

https://www.theguardian.com/world/2022/mar/17/kenya-quiet-slide-underwater-great-rift-valley-lakes-east-africa-flooding

Barsley, E. (2020). *Retrofitting for Flood Resilience: A Guide to Building & Community Design.* RIBA Publishing. https://doi.org/10.4324/9780429347986

Chebii, S. J., Mukolwe, M. M., & Ong'or, B. I. (2022). River Flow Modelling for Flood Prediction Using Artificial Neural Network in Ungauged Perkerra Catchment, Baringo County, Kenya. *Water Practice and Technology, 17,* 914-929. https://doi.org/10.2166/wpt.2022.034

Government of Kenya, & UNDP (2021). *Rising Water Levels in Kenya's Rift Valley Lakes, Turkwel Gorge Dam and Lake Victoria. A Scoping Report.* Government of Kenya and UNDP.

Haynes, K., Coates, L., Leigh, R., Handmer, J., Whittaker, J., Gissing, A., McAneney, J., & Opper, S. (2009). "Shelter-in-Place" vs. Evacuation in Flash Floods. *Environmental Hazards, 8,* 291-303. https://doi.org/10.3763/ehaz.2009.0022

Kangogo, J. (2022). *Lake Baringo Flooding Imminent-Lobbies*. The Star. https://www.the-star.co.ke/counties/2022-05-05-lake-baringo-flooding%20imminent--lobbies/

Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., Mechler, R., Bouwer, L. M., Arnell, N., Mach, K., Muir-Wood, R., Brakenridge, G. R., Kron, W., Benito, G., Honda, Y., Takahashi, K., & Sherstyukov, B. (2014). Le risque d'inondation et les perspectives de changement climatique mondial et régional. *Hydrological Sciences Journal, 59,* 1-28. https://doi.org/10.1080/02626667.2013.857411

Moshenska, G. (2019). *Material Cultures of Childhood in Second World War Britain*. Routledge. https://library.oapen.org/bitstream/id/c053c2f1-70dd-4a10-89f0-f9d489fb6e02/9781138565265_text.pdf

Muia, D. et al. (2021). Effects of Extreme Flooding of Lake Baringo on Livelihoods of Communities Lining around the Lake. *Advances in Applied Sociology, 11,* 404-414. https://doi.org/10.4236/aasoci.2021.118036

Pistrika, A., Tsakiris, G., & Nalbantis, I. (2014). Flood Depth-Damage Functions for Built Environment. *Environmental Processes, 1,* 553-572. https://doi.org/10.1007/s40710-014-0038-2

Stout, G. E. (1990). Climate and Water. *Eos*, *Transactions American Geophysical Union, 71,* 339-347. https://doi.org/10.1029/90EO00112

United Nations (2021). *Climate Change 'Biggest Threat Modern Humans Have Ever Faced', World-Renowned Naturalist Tells Security Council, Calls for Greater Global Cooperation.* United Nations Security Council. https://press.un.org/en/2021/sc14445.doc.htm

WHO (2002). *Floods: Climate Change and Adaptation Strategies for Human Health.* A Report on a WHO Meeting. World Health Organization. Regional Office for Europe.