MANAGING FLOODING IN RESIDENTIAL AREAS OF NAIROBI: A CASE STUDY OF SOUTH C

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ABSTRACT
This paper is objected at examining how flooding in urban areas have occurred over time, its causes, effects and possible remedies to the phenomenon. It is premised on the view that urbanization leads to an increase in percentage of land covered by the built up environment consequently reducing ground water absorption rates, increasing storm water flow on pavements and tarmacked areas. This phenomenon is detailed out by taking South C as the focus area being the most affected residential area by floods during rainy seasons in Nairobi. The paper analyses data collected through multi-dimensional approach; Quantitative and qualitative methods. The study identifies the causes of flooding as uncontrolled development, poor infrastructure maintenance, changes in Land use and increased population density and poor solid waste maintenance. It therefore proposes Management of storm water drainage systems, establishment of specific building by laws in flood areas and enforcement of development control measures, Multi-dimensional and intergovernmental approach as well as stakeholders' involvement to flood management as possible interventions to curb flooding.

KEYWORDS- Flooding/ Urban/ Urbanization/ Land/ Absorption/ Management/Nairobi.

I. INTRODUCTION

Urban flooding has been experienced over decades in Kenya. However, it can be argued that sufficient attention has not been given to deal with this problem. In the past, any strategy on flood disaster management largely focused on riverine floods affecting large extents of rural areas. Urban flooding is significantly different from rural flooding as urbanization leads to coverage of large parts of the ground which was open with roofs, roads and pavements and in the event of heavy/ high intensity rainfall, there is higher runoff which increases the flood peaks as the absorption rate of water to the ground is low or nonexistent.

Urban areas are densely populated and people living in vulnerable areas suffer due to flooding, sometimes resulting in loss of lives. In a report by the World Bank, (2006) on urban flood prevention and drainage, it was noted that it is not only the event of flooding but the secondary effect of exposure to infection that also has its toll in terms of human suffering, loss of livelihood and in extreme cases, loss of life. Increased urban flooding is widespread and poses a great challenge to urban planners/managers, engineers and architects in the world over. Problems associated with urban floods range from relatively localized incidents to major incidents, resulting in cities being inundated from hours to several days. Therefore, the impact can also be widespread, including temporary relocation of people, damage to civic amenities, deterioration of water quality and risk of epidemics (Hellmuth et al, 2007). Rukmana, (2010) observed that the impact of urban floods is also distinctive given the higher concentration of population and assets in the urban environment. He summed up his paper on annual flooding by noting that urban settlements also contain the major economic and social attributes and asset bases of any national population, so that urban flooding, by causing damage and disruption beyond the scope of the actual floodwaters, often carries more serious consequences for societies. In addition, poorly planned and unmanaged urbanization process has also contributed to the growing flood hazard due to unsuitable land use change (Abhas et al, 2012). As cities and towns swell and grow outwards to accommodate population increase, large-scale urban expansion often occur in the form of unplanned development in floodplains in coastal and inland areas alike, as well as in other flood-prone areas. Smith (2002) notes that flood occurrence can be at any time, but weather/climate patterns have a strong influence on when and where they will occur. He also identifies land use practices in the upper catchment areas as contributory factors to the enhancement of surface water run-off and flooding. Unplanned human occupation in the lowlands can also contribute to more flooding due to possible blockages of water ways by the human activities in place.

In Kenya, the impact of flooding was demonstrated by the 1997/1998 El Nino which led to severe loss of lives, property and infrastructure destruction as well as disruption of the communication networks. Pardon et.al (2013), noted that the El Nino-induced floods of 1997–1998 caused some public and private property damage of worth 151.4 million US dollars. This figure did not include the number of people who lost family members, savings, property and economic opportunities. In 2003 and 2014 a heavy down pour was also witnessed in Kenya with most of Kenyan urban areas were affected. Nairobi and Narok Counties were the most affected regions in the country. In Nairobi, South C was the epic centre of flooding resulting in the loss of properties and destruction of infrastructure (roads, power lines, sewerage systems, etc.) while at the same time it took a long time of waiting for the floods to subside. This greatly affected the residents' daily lives and caused routine disruption as well. It should be noted that floods occur in different places and forms depending on the nature of terrain and rainfall intensity; most floods occur due to intense rainfall over a short period of time.

Forms of Flooding

- Upstream flooding

Upstream flooding occurs in regions which experience within a small area, large amounts of rainfall over a short period of time. Here, with little or no effect on areas downstream, the local area may flood with water rising and flowing away quickly after the storm has passed (Stephen, 2015). Its lag times are usually measured in days. Narok and its environs in Kenya is a good example of upstream flooding.

- Downstream flooding

These are long duration floods that normally occur over an expansive region in a segment of a stream. This nature of floods affects tributary streams as well as larger streams as a whole. Their recorded lag times are longer as tributary streams constantly increase the discharge into larger streams. A number of them have occurred, with the famous one being the great Mississippi river basin flood of 1993 (Stephen, 2015). In Kenya, the 2008 Nyando River sub basin flood in Nyanza that affected 2,541 people according to a report done by Ministry of Water and Irrigation on flood mitigation strategy in 2009 is a good example of a downstream flood.

- Flash floods

These types of floods occur when heavy rains are experienced over a short period of time with a low infiltration rate. The difference with upstream floods is that they have very little lag time that may be only a few hours unlike upstream floods which are usually over a few days. Therefore, in essence, upstream takes more time than flash floods (Stephen, 2015). Flash floods are usually more intense and considered more destructive to properties than human lives due to its nature of occurrence with little or no warning. An example of flash floods in Kenyan urban areas occurred on the night of 12th May 2015 in South C due to the heavy rainfall which was triggered upstream of Ngong river (which passes through South C) resulting to flooding menace in the area and its environs. This led to a lot of damage with most roads becoming impassable forcing motorists to be on roads for long hours (Standard Paper, 2015).

Flooding in urban areas

Action AID (2006), identified in its book on Climate change, urban flooding and the rights of the urban poor in Africa four major types of flooding within urban areas. The types are stated as:

- Localized flooding

Localized flooding was identified to occur several times yearly in slum areas due to the nature and few number of drains and compacted pathways in between dwellings that tend to be converted to streams after intense rains. These path ways due to poor solid waste management in those slums tend to be frequently blocked by waste and debris.

- Flooding as a result of small streams in urban areas

Another form of urban flooding identified takes place when small streams in urban areas rise promptly after heavy rains, but often pass through small culverts across the roads. Although most of the culverts were found to have been adequate during the design time, higher flows that exceed their capacity tend to be observed due to the inevitable structure developments in urban areas as well as storm intensity due to factors such as climate change. On top of the storm, the drainage channels over time may have accumulated a lot of debris that they are literally smaller than they were during the design time.

- Flooding as a result of changes in land use upstream

Apart from the rising of minor streams in urban areas, urban flooding is witnessed when main rivers channeling through urban areas are affected by changes in land use and engineering developments upstream leading to rechanneling of main rivers. High flows may occur due to dam operations like the hasty release of stored water leading to sudden flooding of urban areas. Sometimes, urban growth may expand over a section of floodplain, hence making some of the urban areas ground level below flood level. This in turn reduces the area into which floods could naturally overflow hence causing devastating urban flooding.

- Flooding in lowland areas as well as coastal cities

The final nature of urban flooding occurs in lowland areas as well as coastal cities. This is seen during the wet season when rain and river water combine to elevate the height of water level in marshy areas that would have been swamped naturally at certain times of the year. In addition to the wet season, storm waves can also convey flooding to such areas.

2.4 Causes of urban flooding

The work carried out by the Government of India through its National Disaster Management Authority informs management of flooding menace and provides a vivid understanding of urban flooding clearly differentiating it with rural flooding. The team categorizes urban flooding being significantly different from rural flooding in that, urbanization leads to developed catchments which increases the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times. In their management paper on National Disaster Management Guidelines, they point out that flooding occurs very quickly due to faster flow times, sometimes in a matter of minutes. Abhas J. et.al (2011) on the other hand noted that flooding encompasses flow of water over localities which have been normally dry. He identified sources of floodwater to be from the sea in the form of storm surge, from glacial melt, snowmelt or rainfall which can develop into riverine or flash flooding as the volume of water exceeds the capacity of watercourses and from ground infiltration. In addition, flooding could as well occur as a result of failure of watercourses or man-made water containment systems such as dams and reservoirs. A number of causes of rising cases of urban flooding have been identified as:

- Climate change

World Meteorological Organization (2007) in its report on flood management tools summarized a number of climatological changes observed over a period of time. It notes that the warmest years have been recorded since 1998 hence the global mean sea level has been increasing faster than at any other time in the past 3,000 years, at approximately 3.4 mm per year from 1993 to 2008. World Meteorological Organization (WMO) associates these changes with Global warming. Meteorological patterns alterations associated with a warmer climate during the second half of the previous century are possible drivers of increased impact of meteorological disasters such as flooding which has been observed over time. In the World Bank (2010) report on climate risks, it stated that projected patterns of climate change could have a compounding effect on existing flood risks by: enhancing the rate at which the sea level rises, and changing local rainfall patterns as well, that could lead to more frequent and higher level riverine floods and more intense flash flooding. This has actually been seen in some of our urban centres in Kenya.

- Global warming

Sunlight is the source of global warming. When light from the Sun reaches the Earth, 30 % of it is reflected back into space by clouds, atmospheric particles, reflective ground surfaces, and ocean waves. The remaining 70 % of the light is absorbed by the air, land, and oceans, heating the planet's surface and atmosphere. Some of the outgoing radiation, however, is re-absorbed by water vapor, carbon dioxide, and other gases in the atmosphere which are commonly known as greenhouse gases because of their heat-trapping capacity. This causes re-radiation back toward the Earth's surface. Over the past 250 years, humans have been artificially raising the concentration of greenhouse gases in the atmosphere at an increasing rate according to Riebeek (2007). By 2004, humans were pumping out over 8 billion tons of carbon dioxide per year. Some of it was absorbed by natural sinks like forests and the ocean, and the rest accumulated in the atmosphere. Once these greenhouse gases get into the atmosphere, they stay there for decades or longer. According to the Intergovernmental Panel on Climate Change (IPCC), since the industrial revolution began in about 1750, carbon dioxide levels have increased by 35 % and methane levels have increased by 148 %. This has led to increased concentrations of greenhouse gases which in turn have made it more difficult for thermal radiation to leave the earth, and as a result, the earth has warmed more. The high temperatures have led to high levels of evaporation consequently leading to the high rainfalls witnessed.

- Changes in land uses

Changes in the use of land contributes to the increased flooding as it reduces the flexibility of the ground to seep, absorb and store excess flowing water. When a water catchment area is altered by changing its use into a built environment, it may consequently contribute to increase in urban flooding downstream as the said absorption rate of water by the ground will have been greatly minimized. New infrastructure developments such as transportation networks may lead to introduction of elevated structures hence obstruction of previous natural flow paths consequently contributing to the flooding phenomenon.

- Upsurge of urbanization rates

Wheater and Evans (2009) were critical of the changing land use, with most open grounds being covered with buildings which in turn increases the percentage of impermeable surfaces leading to enhanced overland flow consequently reducing infiltration. Changing land uses affects the natural water storage, alters natural watercourses with their capacity restricted or more narrowly channeled. Possible flood hazards could occur due to the periodic narrowing and obstruction such as bridges and culverts which are erected in urban areas to facilitate water flow on designated areas. Narrowing of water channels leads to faster water movement causing alteration in downstream flow and the overwhelming run-off water is transported to the drainage system creating high discharge in a short time. This could lead to destruction of the drainage systems in place hence overland flood flows. The water which could be conveyed through this land is now either diverted by the developments causing increased hazards elsewhere or alternatively could continue to flow through the settlement causing increased flood hazards on the developments as they cannot be infiltrated due to the covered surfaces by pavements.

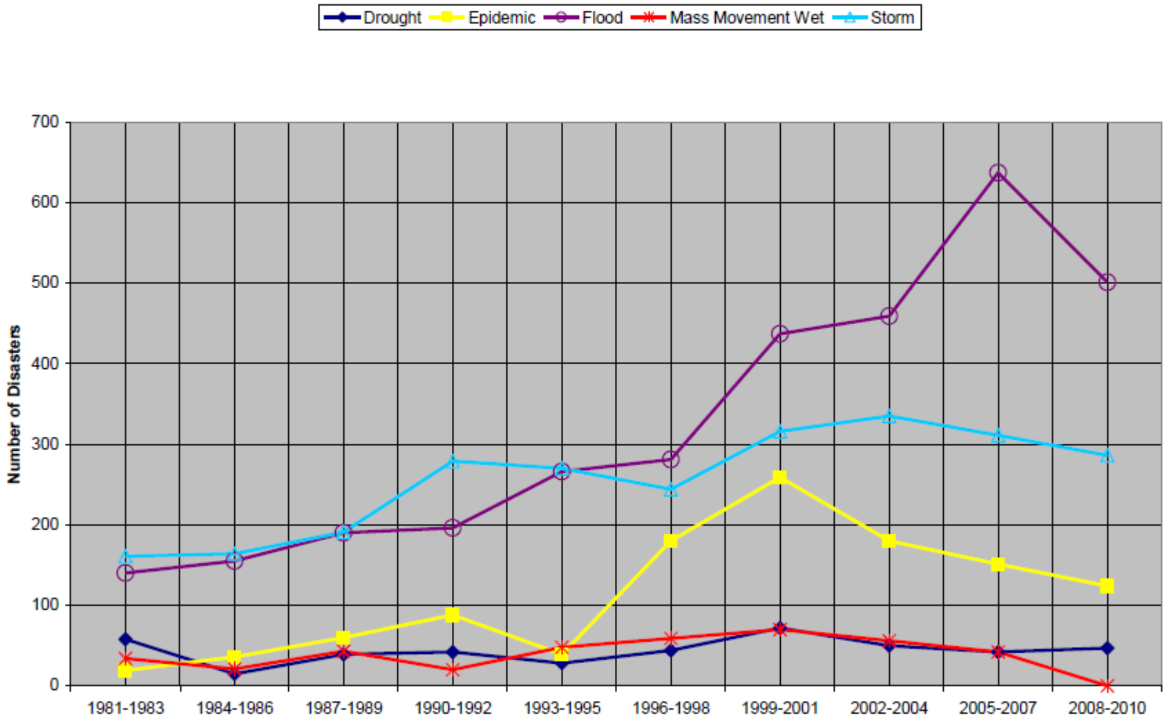
- Dilapidated infrastructure

There is quite a bigger probability of increased flood risk where the infrastructure is old, dilapidated, lack of operations and maintenance in urban areas (Abhas J. et.al, 2011). This is often observed in both developing and developed countries, as proper maintenance of such infrastructure facilities goes with a sizeable number of urban management bodies which most of the times may not be the core business. For instance, devastating floods in New Orleans in 2005 was blamed on the lack of adequate maintenance of levees (embankments, walls, banks) that were in place. Another case in point of a disastrous scenario that occurred due to negligence of operation and maintenance of infrastructure as well as poor planning was the Buffalo creek flood in 1972, where 125 people were swept away, 1121 injured, more than 4000 left homeless and 507 houses were destroyed.

Impact of flooding

Urban flooding is a worldwide phenomenon which has caused destruction and economic losses over time and will continue to do so if not managed. According to the Centre for Research on the Epidemiology of Disasters (CRED), flooding in 2010 alone affected 178 million people and amongst all natural disasters recorded, the occurrence of floods was the most frequent. Statistics on Disasters recorded between 1980 and 2010 showed that flood events were becoming more frequent with time. Research conducted overtime based on disasters that frequently transpired implied significant shift in the pattern and intensity of flooding consequently resulting in increased hazard for the growing world urban population (Abhas J. et.al, 2011). Chart 1 below shows the statistical analysis for water related hazards between 1980 and 2010.

Chart 1: Trends in reported water-related disasters - After Adikari and Yokhitani 2009



Source: *Abhas J. et.al, (2011)*

Flooding is seen to be increasing faster than other related phenomena. Projected future increases in hazards due to climate change are predicted to impact differently in different regions, but an increase in flood hazard is a common future expectation. The subsequent increase in hazards recorded and observed is compounded by the global trend in urban population. IFRC (2010) indicates that half the world's population lives in urban areas, with two-thirds of this in low- to middle-income nations. They also note that urban population is growing at a much higher rate than the world rural population at 2.1%, especially in the developing world with 3.3% in the Middle East and Africa, and 2.7% in Asia-Pacific. United Nations (2015) noted that globally, more people live in urban areas than in rural areas, with 54 % of the world's population residing in urban areas as at the year 2015. The report makes a comparison between 1950 and 2050 in that in 1950, 30 % of the world's population was living in urban areas and by 2050, it is projected to be at 66 % of the world's population. This shows that there is a very high rate of urbanization, increasing areas covered by the built environment to accommodate the urban population, subsequently increasing surface run off of storm water due to minimal water infiltration hence possible flooding occurrence. Clare (2005), in her research book on the impact of flooding on urban and rural communities, categorizes flooding into the following categories:

- Economic impact

Floods cause damages that have financial costs to restore the damaged properties back to normal. This costs include: clean-up costs, repair costs, relocation charges, the costs of living in temporary accommodation and even the costs of having value of a house lowered or made harder to re-sell because it has been flooded or is in a defined floodplain.

- Non-economic losses

This is in terms of loss of items of sentimental value, for instance memory items like photographs as well as the feeling of loss of homes that have been sentimentally attached to certain activities. This may also include emotional torture as well as psychological mistreatment by the change of homes and relocation as whole.

- Impact on physical and psychological health

The health effects caused by flood occurrence could result from the phenomenon itself, disturbance and problems arising from trying to recover and from the anxiety about the risk of flood re-occurring. Clare (2005) clarifies that probable health effects could be considered at three time periods as indicated as: (i). Instant effects: death by drowning, injuries due to being struck by falling trees, over-exertion during the event, electrocution, exposure to contaminants and even the stress of the scenario itself; (ii). Medium term effects: gastrointestinal illnesses, cardiovascular disease from over-exertion during recovery and clean-up processes, cuts, strains and even respiratory illnesses; Longer term effects: majorly categorized as psychological effects. In addition, in terms of population density in urban areas due to close proximity of people to one another within an urban environment, there is a higher probability of their being an epidemic of illness, especially if sewer flooding is involved.

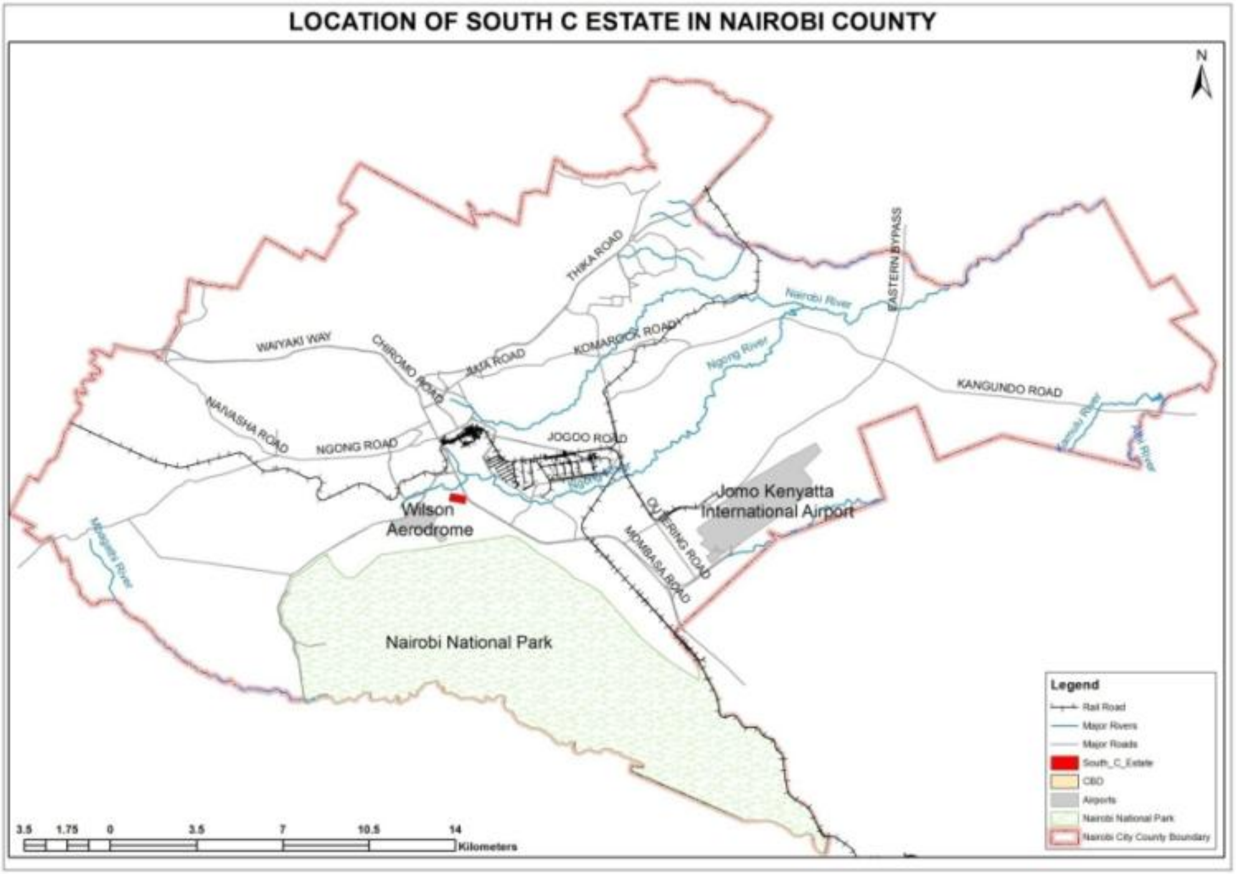
- Impact associated with evacuation and temporary accommodation

These impacts include both the effects of having to leave home and those of having to live away from home (Clare, 2005). If there are large numbers of people to be relocated, it will put pressure on existing services, and may mean that people/residents have to live in confined and overcrowded conditions, or have to move a distance from their homes to get safer places to live while floods are being witnessed.

II. THE STUDY AREA: SOUTH C, NAIROBI

Population growth throughout Kenya is one of the highest recorded units in the world according to World Bank report of 2014 which was at 2.64% with an urbanization rate of 4.34%, world fact book (2016).The report attributed this to the blend of high fertility rate and relatively young population implying high growth persisting for some time. The study area lies within Nairobi city which has experienced over time one of the highest growth rates of 4.1% per year. World fact book notes that it is the highest than any city in Africa and estimates that Nairobi's population will reach 5 million in 2025. South ‘C’ has an area of 15.10km^2 with a population of 47,202 according to the 2009 population census report. The estate was chosen for study due to its unique nature of being the most affected by floods within the Nairobi city. It is characterized by Bungalows and maisonettes with a few Multi storey dwelling Units coming up. It is largely zoned as a residential area under Zone number 10 classified under Nairobi City Development Ordinances and Zones with a central commercial centre. South C has been experiencing one of the worst flooding menaces in Nairobi over time with damages reported within the estate each time there are heavy rains within the city and its environs. This scenario has led to property destruction, discouraged investors within the neighbourhood, poor and inefficient transport systems due to diversions during flooding as well as difficulty in accessing the estate during flooding periods. In spite of all these problems, not much has been done to correct the major causes of flooding in South ‘C’ in particular and within the city in general.

Figure 1: Location of South ‘C’ Estate.



Source: *Adapted from Kenya GIS data*

There is quite a bigger probability of increased flood risk where the infrastructure is old, dilapidated, lack of operations and maintenance in urban areas (1). This phenomenon is frequently observed in most countries, as appropriate maintenance of such infrastructure facilities requires a sizeable number of urban management bodies which in most times may not be the core business. The city of Nairobi has challenges in terms of its management where the roles of different departments are not clearly spelled out hence overlapping. This has led to each department evading the roles/responsibilities of management of infrastructure claiming to be the responsibility of the other.

South ‘C’ is located in the lower eastern part of Nairobi County having its close proximity to the rift valley region. This has direct link with the unique geographic phenomenon of the great rift valley which divides the City into two halves: eastern and western regions, with the eastern stretching from North-South from Ruiru, across Eastlands, Industrial Area, the Nairobi National

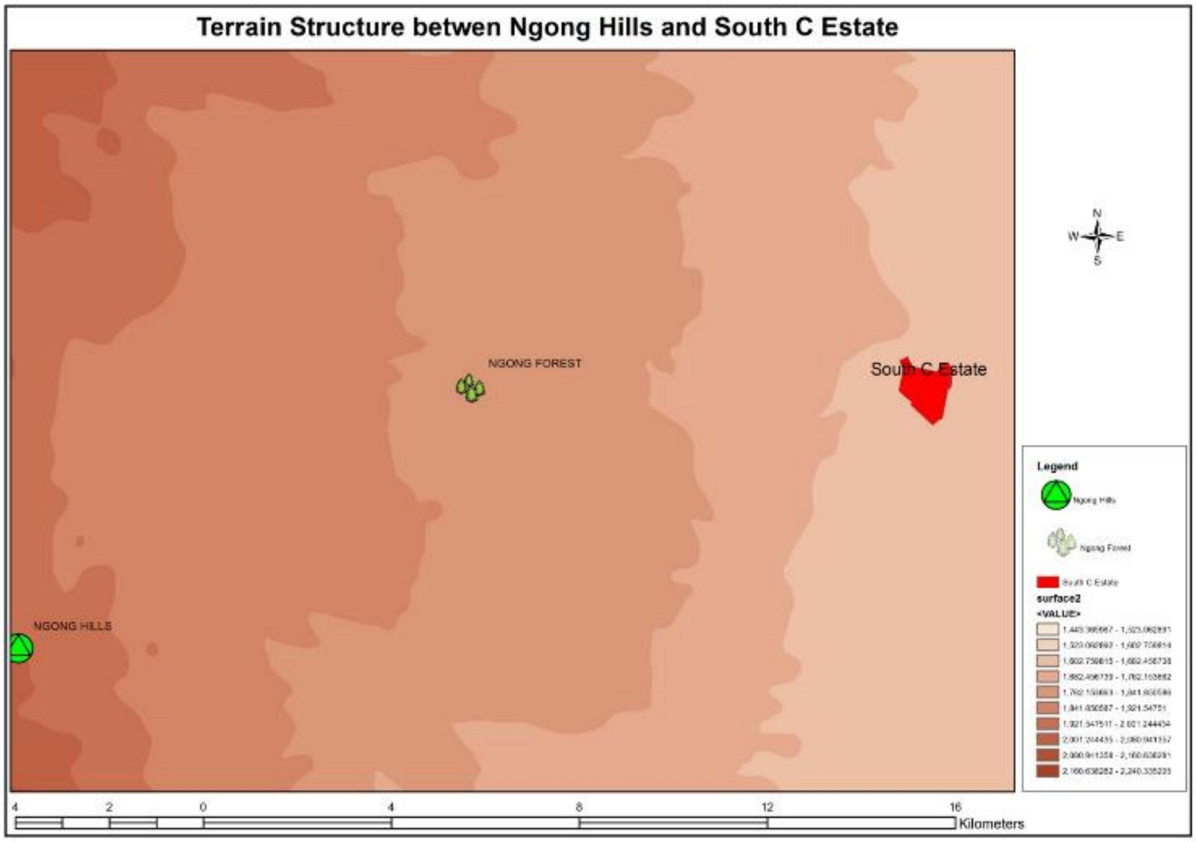
Park to Rongai in the South while the western stretching from Karen, Langata, Ngong' road, Westlands, Parklands, Gigiri to Kiambu. The eastern side has a higher altitude of 1700 MASL compared to the western side of the city with an altitude of 1600 MASL. The difference in height manifests itself clearly along the low-high divide that cuts across the city, a feature that sees sudden steep ascents as well as descents in various parts of Nairobi. The slope that marks this divide runs from Rongai cutting across Magadi road near Multimedia University and extends all the way across the National park as shown in Figure 2 with the black line roughly indicating where the slope is located across the city.

Figure 2: Map showing change in altitude across Nairobi city

Source: Adapted from Google 2016

The difference in height between the eastern and western side of Nairobi determined the zoning of the city consequently delineating the affluent and working class areas. The above slope greatly impinges on the drainage of Nairobi. Water flows rapidly eastwards whenever it rains and upon reaching the Eastern plains, the water spreads out forming a flood plain that is best seen in the National Park. This explains why certain areas of the city, South 'C' included experiences flooding whenever rainy season sets in. These are the areas that lie adjacent to the slope as in blue detailed on Figure 2 above.

Figure 3 : Terrain structure between Ngong Hills and South C Estate

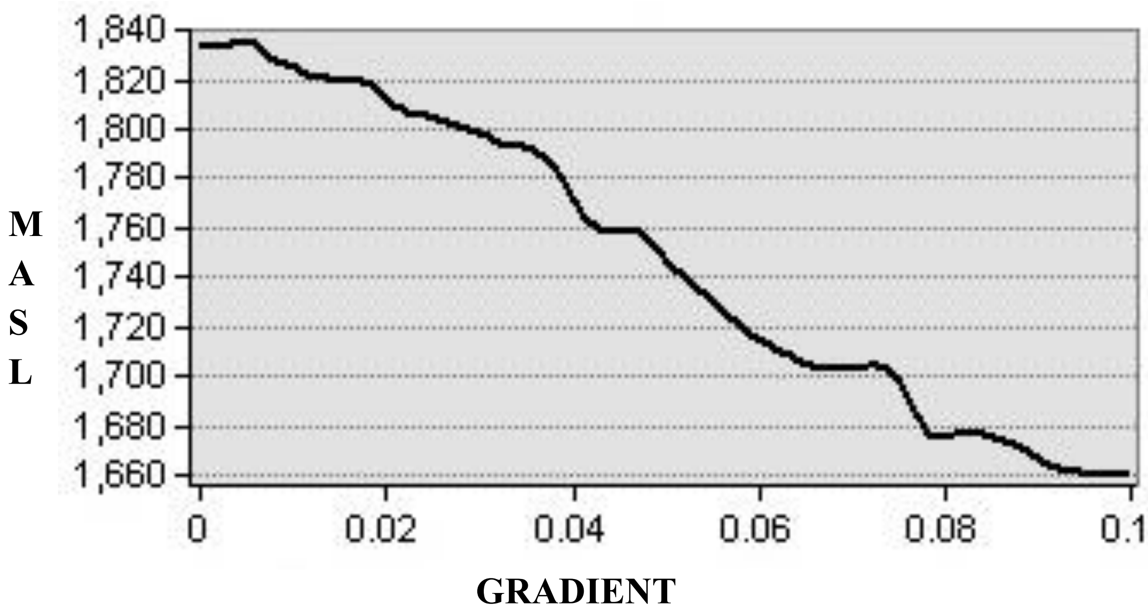


Source: Adapted from Kenya GIs data

4.2 Terrain and profile analysis

Terrain structure as indicated in Figure 2, running from Ngong down to South C shows a continuous decline in Height above sea level from 2,240.335205 MASL to 1,443.365967 MASL. This shows clearly that South 'C' is located at one of the lowest levels. This has been one of the contributory factors to flood occurrence as storm water from the high altitude level end up within South 'C' and its environs. The profile graph as shown in Figure 4, indicates the slope inclination from Ngong forest area at **1840 MASL** to surrounding areas of South 'C' at **1660 MASL** (Profile graph shows the lowest height from the picked highest level in Ngong area and the highest height from the lowest level picked around South C). The profile graph indicates how the terrain runs from the west of Ngong areas to the East of Nairobi area, South 'C' include. From the slope, due to nature of flow of water through gravity, the flow of storm water during rainy seasons can be determined ending up in South 'C' being at the lowest altitude, hence the witnessed floods over time.

Figure 4: Profile graph between Ngong hills and South C



Source: Adapted from Kenya GIS data.

III. METHODOLOGY

The core of this study was based on an analysis of existing situation in Nairobi's South C with the aim of understanding management challenges that have contributed to occurrence of flooding every time it rains and how proper management structures can be established to control the menace. The methodology was geared towards realizing the objectives of this study of examining the causes and impact of flooding to urban residents, the existing management structure of the city responsible for flood/storm water management and the possible mitigation measures that can be put in place to deal with the perennial flooding phenomena. The study was contacted systematically using both qualitative and quantitative research methods. Secondary data was collected through literature review from periodicals, books, Government documents, research thesis, internet sources as well as any other pertinent documents related to the topic of study. This was purposed to synthesize information, arguments and concepts on flooding based issues. For primary data, the study undertook field surveys which involved carrying out of field study on site, visits to relevant offices and government departments especially those mandated with managing storm waters/floods and related activities. This included City Engineer, City planning and surveying offices, and National Environmental Management Authority. Key informants were purposefully sampled for interviews in government offices so as to be able to access information from targeted officers. Simple random sampling was used in interviewing occupants/tenants of the study area. This was meant to avoid any form of bias in collecting data as well as diversifying information to aid in project research as well as increase percentage of data accuracy. Quantitative method involved majorly the usage of questionnaires and group discussions. Qualitative method involved observation and recording of what was considered as possible contributors of flooding incidences within South 'C' and its environs. This included recording of information on nature of drains, built up area and the nature of developments within the area that was deemed to influence occurrence of flooding. Maps and data from GIS were used to gain clearer information on drainage systems and terrain of South ‘C’ and its environs, mapping it out for analyis purposes. In addition, hhotography was used to capture the existing situation of the study area thus collection of the physical conditions of South ‘C’ and its environs.

IV. FINDINGS OF THE STUDY

The aim of the study was to examine the major contributory factors to flooding. After data was collected, pieced together and analyzed, a number of factors were identified to be the causes of flooding. These identified factors are outlined below.

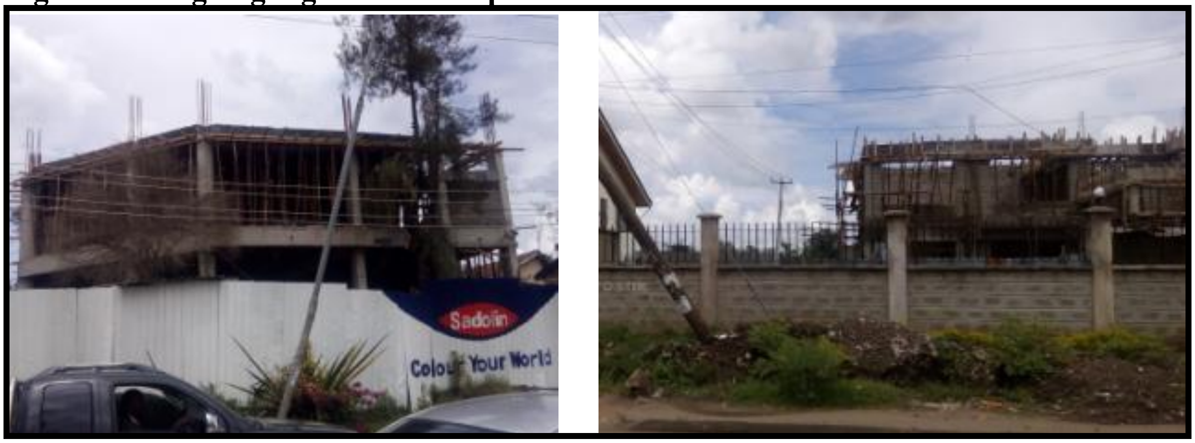
Uncontrolled development

Flooding occurrence in South C starts from the upper regions of Rongai and Ngong hills area ending up in South C which is on the lowest level with the problem of lack of exit point of storm water especially at the point where Muhoho Avenue meets Pate Bay road. Flooding in the study area, has been immensely contributed to by the nature of uncontrolled developments leading to more percentage of ground coverage as well as encroachments on road reserves blocking drainage systems. Maps detailed out by the professionals (planners and surveyors) haven’t been put into good use to aid in controlling of upcoming developments, regardless of increase in knowledge of how and where floods have frequently occurred, resulting in predictive flood maps. The uncontrolled developments have led to increase in density in areas that were previously low density including, Rongai, Ngong, Langata and even South ‘C’ itself with the introduction of high-rise buildings as well as commercial nodes. This has resulted into increased plot ratios and coverage well above the laid down guidelines of Nairobi City Development ordinances and Zones. This has greatly contributed to occurrence of floods in study area as witnessed over time.

Figure 5: Original character of South C

Source: Fieldwork, 2016

Figure 6: On-going high rise developments in South C



Source: Fieldwork, 2016

Poor infrastructure maintenance

It is characterized by inadequate maintenance of the existing drainage systems leading to blockage of culverts hindering free flow of water. Waste materials, silt as well as extensions have led to blockage of these drainage systems, hence even little amount of down pour leads to instant flooding due to blockage of water ways down the drainage system (Figure 7). In addition to blockages of drainage systems, there is little or no sign of their rehabilitation as well as replacement, renewal of the aging infrastructure with the increasing population in urban areas.

Figure 7: Clogged drainage systems

Source: Fieldwork, 2016

4.5.3 Changes in Land use and increased population density

Within the study area and its surrounding environs great changes in land uses to accommodate the rising population by providing residential as well as commercial services is evident. This has been done with less or minimum consideration of drainage as well as infrastructure needs which has consequently led to overwhelming of the capacity of the existing drainage systems visa vis the population they serve. With the above changes, there has been an exposure of receptors to the risk of flooding. Rising land demand due to population increase, has resulted to increase in land prices, according to City county land valuer: Ksh.30, 000,000 per plot of 1/4 of an acre in the year 2015, which was Ksh.10, 000,000 between the years 2000 and 2005. This situation has consequently led to illegal developments of available open spaces for commercial as well as residential purposes consequently reducing ground coverage percentages.

4.5.4 Poor solid waste maintenance

Nairobi city has a poor solid waste collection problem and South C is no different. Solid waste is thrown along the road side by residents. These waste ends up in drainage systems blocking the drainage channels. Figure 7 shows the nature of solid waste materials dumped on drainage systems hindering free flow of storm water.

Figure 7: waste poorly disposed off on the drainage system

Source: Fieldwork, 2016

A summary of causes of floods as per the interviewed respondents

From the statistical analysis, poorly maintained drainage system was rated highest by 36% of the interviewed respondents to be the major contributory factor for flooding phenomenon witnessed in South C. This was attributed to blockage of drainage systems by non-degradable waste materials as well as silt which is not cleared regularly from the drains. As a result the drains have been rendered ineffective as storm water cannot flow through efficiently leading to overflows on roads as well as paved areas. This consequently led to flooding over time. Another noted cause was the inadequate capacity of the drainage according to 21% of the respondents due to the changes in factors such as population increase consequently leading to increase in built up area to accommodate the rising population, which have increased surface run off. With the original design and size of drainage systems of 0.5 metres wide by 0.5 metres deep, the drainage systems capacities have been over whelmed by the increased storm water hence the witnessed flooding cases. This calls for the need to expand and re-design the drainage systems. Other noted contributory factors to flooding by the interviewed respondents include flat terrain at 13%, built up and paved areas at 10%, complete lack drainage systems in some sections of the estate at 9%, low altitude of the estate and nature of soils being water logged hence low filtration at 6% and 5% respectively.

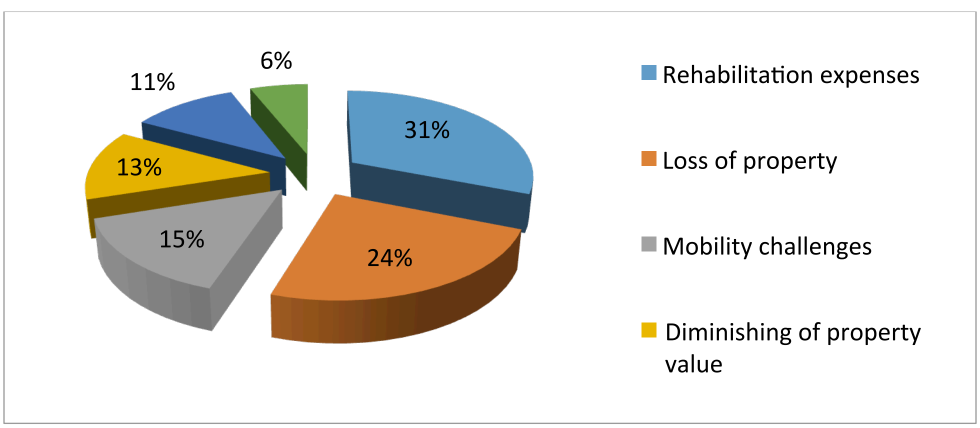
Figure 8: A Summary of causes of flooding in South C

Source: Fieldwork, 2016

4.6 Effects of flooding in South C

South C has experienced flooding cases over time that has caused destruction of properties within the estate and the infrastructure (roads, sewers, power lines, etc) that serve estate. A summary of effects of floods are shown in Figure 9.

Figure 9: Summary of effects of floods



Source: Fieldwork, 2016

Effects of floods are numerous and devastating as witnessed in Kenya and other countries of the world. According to 31% of the respondents, the main effects of floods was the rehabilitation expenses with 24% indicating loss of property as the other major effect. However mobility challenges as an effect was noted by 15% of the respondents especially those who walk on foot with 13% citing diminishing of property values especially housing units as people tend to shy away from the estate due to the flooding problem. Delays hence time loss and discouragement of investors was noted by 11% and 6% of the respondents respectively.

V. CONCLUSIONS

The results of the study showed that continuous increment of residential, commercial and road constructions on flood prone areas like South 'C' have led to reduction of land area in which infiltration could take place hence enhancing water runoff both on the surface water systems and sewers. These scenarios have led to increase of urban flooding. Drainage systems that are appropriately designed according to rainfall intensity and population projection, built and well maintained will ensure reduction in flooding in the flood prone areas. The design of drainage systems depends on the nature of the surface (rocks, soil and terrain) and the activities that are likely to be undertaken. With south C having impervious rocks, with clay soils characterized by low infiltration and relatively flat terrain, gully drainage system is the ideal system that should be considered. It is able to comfortably drain runoff water that mounts up during the period of storms if built in appropriate sizes as per population as well as rainfall projections.

The design of culverts which are critical in directing runoff from the roads should be professionally done. Under designed systems have failed to carry all the runoff water causing flooding in most parts of the city. Culverts designed must be in a position to sustain increased runoff caused by projected land development and increased coverage of built up area. It should also deliver sufficient water, sediments and debris, without drastic variations in patterns of flow. In addition it should circumvent extreme ponding at the entrance which might lead to damage of property, sediment accumulation and clogging of culvert as well as function properly after fill has settled.

Global warming has been associated with climate change over time. Change in climate has been due to emission of carbon gases from various industries and other toxic materials which have led to depletion of ozone layer. This has led to increased heat intensity hence high evaporation rate. This situation has consequently resulted in increased rainfall intensity surpassing the drainage system capacities hence the witnessed flooding cases in most of the cities roads as well other towns in Kenya, Narok and Nakuru being good examples. With this, there is an urgent need to tackle the issue of global warming caused by depletion of ozone layer, by reinforcing the existing rules and regulations, controlling emission of gases to the atmosphere by stiffening the existing penalties and putting in place stringent enforcement rules. Generally there is a type of flooding associated with global warming in urban areas known as surface water flooding. This is kind of flooding is caused by heavy and lengthy rainfall leading to overpowering of the drainage systems capacity often leading to major economic losses and devastating social and environmental impact.

VI. RECCOMENDATIONS

There is need to design a clear exit drainage system for storm water to join the one at Nairobi west out falling in to Ngong River, hence consequently controlling floods. The area had no through way drainage system hence flooding. In addition, there is need to develop a storm water database that gives a full inventory of the existing infrastructure to enable monitoring of the conditions of the drainage systems, hence identify when there is need to be repaired or and upgraded. Apart from expanding and inventory of the drainage systems, diversion of water should be done to areas of need and stored for future use.

Nairobi City county government should control developments by adhering to existing zoning regulations. For the case of South C, ground coverage should be maintained at a maximum of 35% as stipulated by Nairobi City Development Ordinances and Zones guide. This will ensure there is optimum un-built ground open to sky that would absorb excess rain water hence reducing surface run off. In addition to zoning, Afforestation should be enhanced especially in Ngong hills area where most of the runoff comes from. This will increase water absorption rates reducing surface run off downhill.

Solid waste management is a major course of flooding by blocking sewerage systems. Stringent laws and regulations should be enforced to prevent irresponsible dumping of solid waste which cause blockage of the existing drainage systems. On top of solid waste management, Multi-dimensional approach in management of flooding should be put into effect to enable proper handling of all issues that are related to flooding in our urban areas. Political, socio-economic, technological, and environmental dimensions as well as multidisciplinary and multi-directional institutional framework should be put in place to manage floods in urban areas. This is due to the complex nature of the urban areas that necessitates a wide range stakeholders to work together.

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