ANTHROPOGENIC FACTORS THAT CAUSE FLOODS IN MUKURU SLUMS, NAIROBI CITY COUNTY, KENYA

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ABSTRACT
Urban slums are facing increased challenges of flooding scenarios that hinder their development. Increased flooding events in informal urban settlements can be attributed to humankind alteration of the environment. The study sought to determine anthropogenic factors that caused floods occurrence in Mukuru slum. The study used a cross-sectional survey research design. Stratified random sampling technique was used to collect data from a sample size of 100 respondents. According to the study findings, 32%, 28% and 19% of the respondents stated that poor solid waste disposal, uncontrolled development and clearing vegetation along rivers and wetlands respectively triggered the occurrence of floods in the study area. Human alterations also led to changes in land use land cover patterns in the area. The integral recommendations of the study were: demolition of illegal houses built above the open drains and riparian reserves, restoration of wetlands that act as floods buffer zones by planting trees.

Keywords: Informal urban settlements, anthropogenic factors, wetlands, riparian reserves, flood buffer zones, vulnerability, resilience

1. INTRODUCTION
The United Nations International Strategy for Disaster reduction categorized floods as hydro-meteorological hazards (Baariu, 2017). Among the natural disasters, floods occur more frequently and cause widespread damages to properties and a high number of fatalities (Doocy et al., 2013). Urban informal settlements have started to experience frequent flooding scenarios due to impacts of rapid urbanization and other human activities that have altered the environment and increased the volume of storm water that causes floods. Across the globe, the rate of urbanization has been on the rise, with 54% of the world population, which is close to 3.8 billion people residing in urban areas (UNDESA, 2014). Increased urbanization and urban population have resulted in the emergence of several urban informal settlements that have been built in ecologically fragile areas prone to flooding.

Studies that have been carried out worldwide on flood risk, vulnerability and resilience have revealed that flooding events in urban slums of most developing nations were as a result of paved urban surfaces, insufficient drainage systems and inadequate green spaces to allow infiltration of storm water (Baker, 2012; Gupta & Nair, 2010; Werlin, 2006). In major cities in Asia, Latin America and Africa, the occurrence of floods have been on the rise, especially in the informal settlements (UN-Habitat, 2011). The occurrence of flooding events in urban slums of major cities is mainly attributed to unsustainable human practices that results to changes in the land use land cover (LULC) of the urban areas (Gupta & Nair, 2010). Unsustainable human alterations of the environment in the urban areas include clearing urban green open spaces, draining urban wetlands, poor waste management that occur due to expansion of the urban areas. Variations in land use land cover in the urban area have led to decline of vegetation cover and wetlands that act as flood buffer zones. The decline of flood buffer zones has increased the vulnerability of the urban poor to floods, especially those residing in slums. The fragile ecological areas that most urban slums have been established include wetlands and riparian reserves which are regarded as potential flood zones. Rapid urbanization and increased urban growth have led to diminishing housing opportunities. Lack of housing opportunities in urban areas has resulted in the emergence of urban slums as the costs of setting up houses and renting in these areas is low. The growth of slum population has forced a significant number of people to invade potential flood zones to set up more houses, thus making them more vulnerable to floods. According to Hou et al. (2015), it is estimated that by 2030, the number of urban dwellers that are prone to flooding will rise to 50%. The continued alteration of the urban environment either by clearing urban green open spaces, poor waste management, draining of urban wetlands and building in the urban riparian reserves will increase the vulnerability of the urban slum dwellers to floods risks.

2. MATERIALS AND METHODS

2.1 Study area
Mukuru slum is an informal urban settlement and second biggest slum in Kenya after Kibera slum. The population is estimated to be over 100,000 people who live in different sections of the slum (“Mukuru-A History in Names,” 2014). The slum is situated along Nairobi-Ngong River and on the wastelands between industrial area, Outer Ring road and Mombasa road. Some of the villages found in Mukuru slums include Mukuru Kwa Njenga, Mukuru Kwa Reuben and Sinai (“Mukuru-A History in Names,” 2014). The slum is located between the following coordinates 1.1845°S and 1.1930°S, 36.5145°E and 36.5315°E. The study area map is provided in figure 1.
2.2 Study design
A cross-sectional survey research design was used. The design allowed the collection of data at one point at a time by use of surveys to report findings on anthropogenic factors that caused floods. Cross-sectional survey research allowed the use of both quantitative and qualitative approaches to collect and analyze data.

2.3 Data collection methods
The study adopted the use of questionnaires and high-resolution satellite images to collect data.

2.3.1 Questionnaires
Data was acquired by administering questionnaires to one hundred respondents in the study area. The questionnaires were semi-structured, which comprised of both open and close-ended questions. Nassiuma (2000) sample size calculation formula was used to determine the sample size of the study area. The questionnaires were administered to households’ representatives who were randomly selected.

2.3.2 High-resolution satellite images
The study also adopted the use of high-resolution satellite images to determine how changes in land use land cover (LULC) triggered the occurrence of floods in Mukuru slum. The use of high-resolution satellite images helped to capture variations of all the land cover between 1998 and 2018 and analyze how changes in each land cover affected the occurrence of floods.

2.3.2.1 Preprocessing of the high-resolution satellite images
The high-resolution and geo-referenced images were obtained from the Statistical Analysis Systems planet software to indicate differences in land use and land cover changes between 1998 and 2018. The images had the actual color of the ground surface by the time the satellite captured the images;
hence, they were in their natural color with band 3, 2 and 1. ArcGIS was used to preprocess the images by conducting geometric corrections, atmospheric correction, topographic corrections, layer stacking, enhancing the images and clipping.

2.3.2.2 Image classification
After the image was loaded to the ArcGIS desktop software, the sample points were also loaded to give a specific land cover of a specific area within the site. The sample sites (training sites) helped in assigning the code for every class for classification. The software then ran the classification based on the training samples which were assigned to each class to get the most probable result. The result was computed for every class to ascertain how much area was covered by each land cover class. After image classification, four land use land cover were identified: bare soil, grassland, settlement and water body.

2.4 Data analysis
After data acquisition, data from the questionnaires were entered, coded and analyzed using Microsoft Excel and Statistical Package for the Social Sciences (SPSS) Software. The data collected using questionnaires were coded and analyzed using both quantitative and qualitative procedures and then summarised using tables, charts, frequencies and percentages. The researcher used SPSS to label each qualitative variable so as to transform them into quantitative data to carry out the statistical analysis. Changes in LULC were analyzed by ArcGIS desktop software.

3. RESULTS
3.1 Anthropogenic factors that cause floods in Mukuru slum
Table 1 shows human activities that caused floods occurrence in the study area.

<table>
<thead>
<tr>
<th>Human activities causing flooding</th>
<th>Frequency (f)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor solid waste disposal in the drainage systems</td>
<td>32</td>
<td>32.0</td>
</tr>
<tr>
<td>Uncontrolled development</td>
<td>28</td>
<td>28.0</td>
</tr>
<tr>
<td>Clearing vegetation along rivers and wetlands</td>
<td>19</td>
<td>19.0</td>
</tr>
<tr>
<td>Non-response</td>
<td>21</td>
<td>21.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Poor solid waste disposal in the drainage systems was attributed at 32% as the main human activity that caused floods occurrence in the study area. In the study area, 28% of the respondents identified uncontrolled development as the other human activity that triggered the occurrence of floods. Further, 19% of the respondents stated that clearing vegetation along rivers and wetlands in the study area resulted in the occurrence of floods.

3.2 Methods of waste disposal
Further, the study sought to find out the methods of waste disposal that were used in the area and their impacts on the rate of flooding. Table 2 shows the methods of waste disposal in Mukuru slum.
Table 2: Methods of waste disposal in Mukuru slum

<table>
<thead>
<tr>
<th>Methods of waste disposal</th>
<th>Frequency (f)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open drains</td>
<td>53</td>
<td>53.0</td>
</tr>
<tr>
<td>Dumping in the river directly</td>
<td>18</td>
<td>18.0</td>
</tr>
<tr>
<td>Septic tank</td>
<td>16</td>
<td>16.0</td>
</tr>
<tr>
<td>Bio-digester</td>
<td>7</td>
<td>7.0</td>
</tr>
<tr>
<td>Municipal connection</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>Burning</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Majority of the respondents at 53% stated that their households were connected to open drains that disposed of their wastewater and solid waste in the nearby streams and rivers. Further, 18% of the respondents stated that they disposed of their waste by dumping directly into the river; 16% of the respondents stated they used shallow septic tanks to dispose of their wastewater and solid waste. Seven percent (7%) of the respondents stated they used bio-digesters to generate power and organic manure as a way of handling wastewater and organic solid waste, 3% of the respondents claimed they are connected to a municipal sewer system while 3% of the respondents stated they burnt their waste especially plastic containers, clothes and other dry organic trash.

3.3 Materials that clogged the open drainage channels

Further, the study sought to determine materials that blocked the drainage channels, thus causing accumulation of storm water that resulted in flash floods. Materials that blocked drainage channels in the study area are shown in figure 1.

![Materials that blocked existing open drains](image_url)

**Figure 1:** Materials that blocked existing open drainage channels
The main material that blocked drainage channels were the old clothes at 33%, 28% of the respondents stated that plastic bags blocked the few existing open drainage channels. Further, 12% of the respondents stated that plastic containers clogged open drainage systems. Ten percent (10%) of the respondents also stated that deposits of sand debris clogged the open drains. Further, used diapers and vegetation were identified by 10% and 2% of the respondents respectively. Waste from timber and metal parts also blocked drainage channels at 1% each.

3.4 Human-induced land use and land cover changes and their effects on the rate of flooding

Table 3 shows the changes in land cover in the study area between 1998 and 2018. The four types of land cover in the study show distinct variations between 1998 and 2018. The study area has four types of land covers: Bare soil, grassland, human settlement and waterbodies. The study sought to determine the changes in each land cover and how they have impacted the occurrence of flooding events in the study area.

Table 3: Land use and land cover changes in Mukuru slum from 1998 to 2018

<table>
<thead>
<tr>
<th>Land Use/Land Cover (M²)</th>
<th>1998 (%)</th>
<th>2003 (%)</th>
<th>2008 (%)</th>
<th>2013 (%)</th>
<th>2018 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Soil</td>
<td>803140</td>
<td>25.4</td>
<td>652374</td>
<td>703140</td>
<td>645316</td>
</tr>
<tr>
<td>Grassland</td>
<td>1462223</td>
<td>46.3</td>
<td>1262223</td>
<td>40</td>
<td>454899</td>
</tr>
<tr>
<td>Settlement</td>
<td>746370</td>
<td>23.7</td>
<td>985324</td>
<td>1969282</td>
<td>2082889</td>
</tr>
<tr>
<td>Water Body</td>
<td>145154</td>
<td>4.6</td>
<td>256966</td>
<td>29566</td>
<td>45111</td>
</tr>
<tr>
<td>Total</td>
<td>3156887</td>
<td>100</td>
<td>3156887</td>
<td>100</td>
<td>3156887</td>
</tr>
</tbody>
</table>

In 1998, the area covered with bare soil was 803,140m² that further declined to 652,374m² in 2003 and then increased to 703,140m² in 2008 and declined to 645,316m² in 2013 and decreased to 593,703m² in 2018. The changes in area covered by bare soil can be stated in percentages as follows: 25.4% in 1998, 20.7% in 2003, 22.2% in 2008, 20.4% in 2013 and 18.8% in 2018.

The area covered by grassland has been declining over the years. In 1998, the area covered by grassland was 1,462,223m², in 2003 the area declined to 1,262,223m², in 2008 the area covered by grassland declined steadily to 454,899m², in 2013 the area was 383,571m² while in 2018 the area covered by grassland was 221,651m². In terms of percentage, the area covered by grassland in Mukuru slum in 1998 was 46.3%, 40% in 2003, 14.4% in 2008, 12.1% in 2013 and 7% in 2018.

Since 1998, the area covered by human settlements has been increasing from 746,370m² in 1998, 985,324m² in 2003, 1,969,282m² in 2008, 2,082,889 m² in 2013 to 2,326,414 m² in 2018. The changes
in the area covered by human settlements can further be interpreted into percentages as follows: 23.7% in 1998, 31.2% in 2003, 62.4% in 2008, 66% in 2013 and 73.7% in 2018.

The area covered by water bodies in the study area was 145,154m$^2$ in 1998, in 2003 it increased to 256,966m$^2$, in 2008 the area decreased significantly to 29,566m$^2$, in 2013 the area further decreased to 45,111m$^2$ and 15,119m$^2$ to 2018. Changes in the area covered by water bodies can further be stated in percentages as follows: 4.6% in 1998, 8.1% in 2003, 1% in 2008, 1.5% in 2013 and 0.5% in 2018.

Further, the study sought to determine human-induced changes in the LULC in the area using high-resolution satellite images between 1998 and 2018 with a five-year interval. Changes in LULC in the study area were mapped using high-resolution satellite images, as shown in figures 2, 3, 4, 5 and 6.

![Figure 2: LULC in Mukuru slum in 1998](image-url)
Figure 3: LULC in Mukuru slum in 2003

Figure 4: LULC in Mukuru slum in 2008
Figure 5: LULC in Mukuru slum in 2013

Figure 6: LULC in Mukuru slum in 2018

4. DISCUSSIONS
The study has indicated that unsustainable human activities have been the main causes of floods occurrence in Mukuru slum. Some of the residents in the area disposed of the waste in the existing open drainage channels that drain away storm water during the rainy seasons. Improper waste
management practices in the study area resulted in clogging of the existing open drainage channels. Blockage of the existing open drains due to poor waste disposal resulted in disruption of storm water flow that caused its stagnation resulting to flash flooding. Further, solid waste disposed of improperly in the area was carried by floodwaters, thus accelerating the damages to property by floods. Floodwater that contained a huge amount of waste resulted in massive destruction of infrastructure, especially housing structures that were built using cheap old rusty iron sheets. The waste also made it difficult for the residents and the disaster response teams to access the area as they blocked roads and paths after flooding.

Poor and unsustainable methods of waste disposal result in the improper discharge of wastewater from households. Generation of high amount of wastewater accelerates the occurrence of flash floods, especially during the rainy seasons as there is also high volume of storm water generated According to Alam et al. (2011), in Bangalore City, waste disposal in the existing open drains makes them narrow, thus making the accumulation of sewer and floodwaters that caused flooding especially during the rainy seasons. In developing countries, the issue of waste management in urban areas has been a persistent problem over the years. Poor disposal of waste near watercourses and drainage channels in cities reduced the capacity of the river and storm water flow, leading to an accumulation of water that results in flooding (Jha et al., 2012).

Uncontrolled and unsustainable human activities were also highlighted by the respondents as factors that have accelerated the occurrence of floods in Mukuru slum. Uncontrolled development practices in the study area include building houses above drainage systems, construction of poor drainage channels and clogging of the existing narrow open drains. Majority of the study area dwellers have constructed housing structures above the existing open drainage channels, thus blocking the flow of storm water. Construction of houses near existing storm water drainage channels led to the accumulation of surface run-off and river overflows that resulted to flash floods in the area. Some of the residents also invaded the riparian reserve along River Nairobi to set up housing structures and small-scale urban horticultural farms that affected the flow of the river. During the wet seasons, low-lying areas within the slum experienced flash floods from the river overflows due to disrupted stream flow caused by human encroachment of the riverbanks.

The encroachment in the riverbanks and wetlands by the study area residents led to the massive clearing of vegetation in these fragile ecosystems. Vegetation along the riverbank and wetlands helps to reduce the flow of storm water by accelerating infiltration. The destruction of vegetation near waterbodies in Mukuru slum led to increased flow and accumulation of surface run-off that resulted in massive flooding. During the rainy seasons, the overflowing river forced its way through the houses, especially in Sinai, Mukuru and Gatope villages resulting in floods occurrence. Rapid and uncontrolled urban expansion and failure to adhere to development plans led to the expansion of Mukuru slum in potential flood zones such as riparian reserves with Nairobi River. The growth of the slum in riparian zones exposed many residents to the floods. Urban informal settlements are usually not included in the urban development plans. The omission of urban slums from urban development plans denies the residents access to basic services such as proper housing thus encouraging them to residents encroach flood-prone areas to set up houses.

High urban populations in the study area have forced the slum dwellers to encroach the riparian reserve and even areas set aside for drainage channels to construct houses so as to meet the housing needs. According to Pickett et al. (2013), the expansion of cities has led to the conversion of wetlands, forests and river basins into built-up land. The findings of this study that uncontrolled development and clearing vegetation along riverbanks and wetlands concurs with Pickett et al. (2013) study that
stated narrowing river basins and constructing houses above drainage channels led to increased flooding in Bangalore city. Kumar & Jayakumar (2018) stated that the encroachment of river basin around River Krishna to either set up human settlements or start agricultural activities led to hydrological alteration of the area causing the river overflows to accumulate during the rainy seasons thus resulting to flash flooding.

Further, the study sought to determine the methods of waste disposal in Mukuru slum and how they affected the occurrence of floods. The use of open drains to dispose of wastewater and solid waste materials exacerbated the occurrence of floods. Open drains experienced blockages during the rainy seasons, thus resulting in massive stagnation of storm water that resulted to flash floods. Open drains used in the study area are shallow and not well maintained; thus, they cannot handle the massive discharge of storm water hence accelerating the occurrence of floods. Unsustainable waste disposal practices such as dumping waste in the open rains and failure to maintain them is a major contributing factor to occurrence of floods in Mukuru slum.

Some of the study area residents store human excreta in plastic tanks and use handcarts to transport them to nearby rivers and streams and dump directly. Dumping of solid waste in the river disrupts its flow, thus making it easier for overflows to cause flash floods in low-lying areas when the river bursts its banks. Some of the materials, such as human excreta that are dumped in the river contain disease-causing pathogens. When flash floods occurred, they were carried by floodwater into the households accelerating effects of floods such as the outbreak of waterborne diseases. A few number of study area residents that do not reside near rivers or streams constructed shallow septic tanks in open spaces within their homesteads that helped them to manage their waste. During flooding scenarios, wastewater from the shallow septic tanks and storm water combined and caused massive flash floods that lasted several days before draining.

Few study area residents that reside near the Industrial Area are connected to the municipal sewer system. During the rainy seasons, the municipal sewer system experienced bursts, thus spilling wastewater that combined with storm water to cause flash floods. During flooding scenarios, the high number of respondents that experienced blockage of the waste disposal methods they used depicted that the challenges of waste disposal are a severe problem. Further, the respondents stated that poor waste disposal practices in the area would further accelerate the challenges of floods as it results in stagnation of storm water. Cases of open drainage blockage used to dispose of wastewater in the area mostly occurred during the rainy seasons.

The study also aimed to determine the materials that clogged the existing open drains in the area. Old and ragged clothes were disposed and dumped in the open drainage channels by a significant number of the residents. The high number of old clothes that blocked existing open drainage channels was attributed to the fact that there was a high generation of old clothes as the price of second-hand clothes is was low in the urban slum. Old clothes that cannot be reused or resold into the second-hand market were dumped in the open drains, thus leading to accumulation of stagnant water. Despite the ban of plastic bags in the country, the plastic bags were being used in the area in secrecy and disposed of in the open drains when the residents were done using them.

Plastic containers that could be recycled were disposed of in the open drainage channels that caused severe clogging. Disposal of plastic containers in the open drains resulted in the accumulation of storm water that led to severe flash flooding in Mukuru slum. Due to siltation in the area as a result of the decline of vegetation cover and unsustainable human activities like excavating bare soil during construction, there was an accumulation of deposits of sand in the open drainage channels. Soil debris from excavation and construction activities clogged the storm water drainage channels. Blockage of
open drainage channels by deposits of sand and soil debris disrupted the flow of wastewater that led to the accumulation of storm water. Accumulation of storm water further led to the occurrence of floods, especially in households situated near the drainage channels. Improper disposal of baby diapers was also highlighted as a factor that blocked the open drainage channels. The fact that baby diapers cannot be recycled led to increased disposal of diapers in the open drainage channels that caused accumulation of storm water. The vegetation mainly from weeds that grow around the homesteads was also disposed of in the open drains when the study area dwellers cleared them. Further, the remains of timber after the construction of housing structures and metal parts were identified as other materials that blocked the open drains. The low number of waste from timber and metal parts that blocked the open drainage channels is mainly because some of the study area residents collect them and resell them to small-scale industries that operate within Nairobi City County. Timber and metal parts that remained uncollected for resale were disposed in the few existing open drainage channels, thus disrupting the ability of the open drains to discharge the storm water that accumulated and resulted in floods.

Rapid urbanization and increased human settlements within Nairobi City County has caused changes in the LUCC that have triggered increased flooding risks. According to the high-resolution satellite images, it was observed that increased human settlements over the years affected the distribution of other land cover: bare soil, grassland and water bodies. The increase of human settlements in the study area led to a decline of the area covered by bare soil, waterbody and grassland. The decline of the area covered by grassland was due to human activities such as the establishment of new settlements due to the expansion of the City. Grass and other vegetation help in the infiltration of storm water. Thus, the decline of the area covered by grass led to a high volume of surface runoff that has led to massive flooding. The draining of wetlands and encroachment of riparian reserves to set up new houses by the slum residents led to the decline of the area covered by water bodies. Waterbodies are buffer zones that reduce the intensity of floodwater as they help in the infiltration and reduce its flow. The destruction of these fragile ecosystems led to increased surface runoff that has caused increased floods. The increase of area covered by bare soil in 2008 can be attributed to the clearing of grassland and draining of water bodies before establishing human settlements. In the study area, the area covered by bare soil, led to increased siltation that affected the open drainage channels. Sand and soil debris from the bare soil had clogged the open drains making them narrow, thus affecting their ability to discharge storm water and floodwater.

Further, changes of the area covered by bare soil, grassland and water bodies due to an increase of human settlements led to an increase of surface temperatures that caused the occurrence of urban heat islands within the study area. Increase of surface temperature due to urban heat islands in the study area increased the rate of evapotranspiration within the city. The high rate of evapotranspiration resulted in high condensation rate and fierce formation of rainfall. Further, high rate of evapotranspiration led to Nairobi city to receive a sporadic and high amount of rainfall. The occurrence of the prolonged and high amount of rainfall in Nairobi City contributed to river overflows and the generation of a large volume of surface runoff that resulted in the occurrence of flooding extremes in Mukuru slum. The increase of human settlements in the study area can be attributed to diminishing housing opportunities within estates and areas within Nairobi City. The ever-increasing rural-urban migration in the Nairobi is causing large numbers of people to settle in informal urban settlements as they provide opportunities for the unemployed at a lower price. The increase of human settlements in
Mukuru slum led to a significant number of the residents to drain waterbodies and transform the area covered by grassland and bare soil into human settlements by setting up houses. The area covered by human settlements in the study area has been on the rise since 1998 up to 2018. The growth of human settlements in Mukuru slum has led to an increased rate of floods occurrence as houses are built in a low-lying areas that are potential to flooding, along watercourses and near storm water drainage channels.

LULC has a strong impact on the occurrence of flooding hazards as humanity has been involved in the heavy modification of the natural landscapes. Changes in the LULC that included increased urbanization, massive deforestation and intensive cultivation usually resulted in an increased rate of flooding (Heggie, 2016). Changes in LULC contributed to low soil infiltration capacity, a decline of vegetation cover, low rate of soil porosity, thus causing accumulation of stormwater that resulted in flash floods. According to Chotpantarat & Boonkaewwan (2018), changes in LULC has been the major factor that led to disruptions of the river and storm water flow, thus causing floods occurrence in many urban centers in Thailand. Changes in LULC led to the decline of infiltration rate and in turn resulted to the increased volume of surface runoff especially in the low-lying parts of Yom River Basin in the Northern part of Thailand (Chotpantarat & Boonkaewwan, 2018). According to Baker (2012), destruction of forest and grasslands in the low-lying areas in the East African cities left the areas without any buffer zones. The destruction of flood buffer zones continues to expose East African urban centers especially, informal settlements to flooding extremes.

5. CONCLUSIONS

Unsustainable human practices such as improper disposal of waste led to blockage of the existing open drainage channels that drain away stormwater, thus leading to stagnation of water. Stagnation of storm water caused floods and accelerated impacts of flooding such as waterborne diseases outbreaks. The study area residents improperly disposed of waste such as old clothes, plastic containers, plastic bags, diapers and wood that blocked the open drainage channels. Changes in LULC in the study area between 1998 and 2018 as shown in the high-resolution satellite images indicated that there were increased human settlements. Increased human settlements led to the decline of the area covered by grassland, bare soil and water bodies. The loss of vegetation in the area led to increased surface runoff that caused floods as the rate of infiltration was low. The losses of grassland and water bodies, which are buffer zones, reduced the ability of the area to withstand the destructive force of floods.

To address human activities that triggered flooding in Mukuru slum, the study recommended that slum upgrading initiatives such as demolition of housing structures that blocked open drains and those constructed along the riparian zones. Demolition of houses set up above drainage channels and along the river basins must be conducted by Nairobi City County Government (NCCG). The NCCG in collaboration with international institutions like World Bank, European Union, UK Aid and US Aid can provide financial resources to community based organization (CBOs) to set up sustainable communal waste management plants. Communal waste management plants will help in waste recycling and adequate waste collection thus reducing the amount of waste disposed in the open drainage channels that hinder flow of storm water.

CONFLICT OF INTEREST

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.”
REFERENCES


