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Resilience Techniques due to Cascading Water Effects in Informally Urbanised Hilly Terrains: A Case of Makongo and Goba—Dar es Salaam, Tanzania

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Abstract: The research was carried out in Dar es Salaam's Makongo and Goba neighbourhoods using an exploratory method covering 200 questionnaires, 100 for Goba and 100 for Makongo respectively. There were two significant issues observed: To begin, data from 2003 to 2017 reveal a large increase in urbanisation in both locations. Furthermore, urbanisation led to an increase in hard surface areas, which, according to the analysis, contributed to an increase in surface runoff, which had detrimental consequences for hilly residential settlements, resulting in downstream floods, building destruction, and loss of life and properties. Few residents were aware of water harvesting methods as a technique to deal with surface runoff, but they were not aware that they might be used to harvest water for future use. Policy to harvest, retain and use rainwater is recommended, whereby each plot owner should contain water from his/her plot by harvesting, collecting and retaining it for home use such as farming, fish ponds and other uses.

Key words: Urbanisation, floods, surface runoff, hilly terrain, water harvest.

1. Introduction

1.1 Background

Urbanisation is one of the topics that have been widely studied in urban development, especially in developing countries such as Tanzania where, in most of these countries, there is always the tendency of people to migrate from rural to urban areas. Urbanisation is caused by a variety of factors including political, social, economic, education, natural population increase, environmental degradation, and many more [1-3]. The common denominator of such causes is that there is always the tendency for people to move from one place to another for better wellbeing such as improving their income, looking for more freedom and safety, etc.

According to the United Nation's estimate from 2000, the percentage of people living in cities raised from less than 5% in 1800 to 47% in 2000 and is anticipated to reach 65% by 2030 [4]. Moreover, the study conducted by Kwasi [5] shows that urbanisation, especially in developing countries, is often accompanied by problems such as increased unemployment and poverty, poor health, poor sanitation, the growth of urban slums, and environmental degradation, all of which pose formidable challenges to city dwellers. Urbanisation, as previously stated, leads to urban concentration and the rise of large cities such as Dar es Salaam, as well as changes in land-use patterns.

According to Tarver [6], most people in Africa move to cities because they are pushed out of rural areas by factors such as poverty, environmental degradation, religious strife, political persecution, food insecurity, and a lack of basic infrastructure and services, or because they are "pulled" in by the advantages and opportunities of the city, such as education, electricity, and water. Even though urban areas in many African countries provide few job opportunities for young people, they are often drawn there by the amenities of city life.

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As big cities continue to succumb to urbanisation, their populations swell and spill over into the surrounding areas, resulting in suburbanisation. This is referred to as the growth of areas on the outskirts of major cities [7] as in the case of Makongo and Goba in Dar es Salaam. Individuals who are tired of city life, as well as the perception that urban areas are overcrowded, polluted, and dirty, are among the factors that drive people to settle in the outskirts of cities such as Dar es Salaam. Suburbanisation was also noted in America, where a study found that living in suburban areas was a sign of achieving a "good life" in the American context, where life in the city was regarded as grimy, hectic, congested, and polluted. In the contrast, life in the suburbs was regarded as cheaper, more beautiful, affordable, and exclusive with a sense of ownership [8]. According to the same study, the middle-income class was drawn to live in the purlieu due to various factors such as the availability of cheap land, low-cost building methods, and quick transportation.

A similar situation can be observed in Dar es Salaam where the outskirts of the city attract people to buy land and build settlements; however, the building process is uncoordinated due to weak governance and laxity in adherence to legal procedures. Various scholars have examined the concept of urbanisation relative to health, resources, transportation, land use, and poverty [9-13]. In these studies, there is scanty literature that integrates suburbanisation and the whole aspect of stormwater generation through hard surface runoff and cascading water effects in hilly suburbs such as Makongo and Goba in Dar es Salaam. Cascading water effects have been a typical problem of many areas in urban development, especially in cities of developing countries where development activities are uncoordinated with service and infrastructural provision. In the inner city of Dar es Salaam there is surface runoff water that flows uncontrolled during the rainy season due to lack of serviced stormwater channels while in the outskirts, the surface runoff is due to uncoordinated development of housing, infrastructure, and stormwater management.

Unnoticeably, areas of Makongo and Goba are continually growing with building development that, along with the advantages that come with it, generates hard surfaces on rooftops and paved areas which collect vast amounts of water during the rainy season. Literature shows that there is vast knowledge on the subject of urbanisation globally, regionally and locally, however, little is known in Tanzania in respect to linking urbanisation, an increase of hard surface in the neighborhoods as well as the immediate impacts to soil erosion in hilly terrains such as Makongo and Goba. Moreover, it is not known about the coping strategies which are used by the residents in these areas to deal with waters causing soil erosion in their plots and riverbanks. Thus, this study intends to investigate the pace of urbanisation of these areas, the impacts and the coping strategies employed by the urbanites in dealing with the problems that are caused by unmanaged surface runoff.

1.2 Literature Review

1.2.1 Global and Regional Context with Some Lessons from Specific Cases

The word "urbanisation" started appearing in writings in the 1800s denoting the growth and expansion of American cities particularly Los Angeles which was an early example of uncontrolled development [14]. Urbanisation was understood as a process by which towns and cities are formed and become larger as more and more people begin living and working in central areas; however, it is often perceived as a negative trend, with bad effects on quality of life and the environment [15]. It is estimated that by 2050 about 64% of the developing world and 86% of the developed world will be urbanised [16].

Urbanisation goes hand in hand with increased demand for transportation which is the second-largest sector contributing to global carbon dioxide (CO_2)

emissions from fossil fuel combustion as shown below where, 23% of global CO_2 emissions come from the transport sector, notably road transport which accounts for 73% [17].

Urbanisation in some countries such as China is criticised because it has brought hundreds of millions of people from rural locations to the bustling coastal metropolises [18] and studies are questioning whether it creates a good place for people, especially families as iterated by Kotkin and Cox [19]. Urbanisation is associated with creating an impervious surface which affects the water cycle as recapitulated by Kellner [20] who notes that "increased storm water surface runoff associated with development is the first visible sign of water cycle alteration, and often initiates a chain of events that include increased flooding, erosion, stream channel alteration, and ecological damage". This article reviews key concepts regarding the water cycle, how urbanisation affects it, and the consequences of these changes, with the view to suggesting how the problem of surface runoff could be better managed in the case study areas of Makongo and Goba.

Kellner [20] continues to contend that impervious surface and urban drainage systems increase surface runoff into the receiving streams and rivers which in the end create a larger volume and velocity, washing along stream banks and causing erosion. This is very similar to what has happened in Makongo and Goba where according to this study, several plots have been consumed by water due to the expansion of river banks.

A study by Brown and Vivas [21] has affirmed that in the course of urbanisation, the changes in land use associated with urban development affect flooding in many ways. The author continues to assert that removing vegetation and soil, grading the land surface, and constructing drainage networks increase runoff from rainfall. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams. This is noted in the two rivers within the study area. Also, changes to stream channels during urban development can limit their capacity to convey floodwaters. Roads and buildings constructed in flood-prone areas are exposed to increased flood hazards, including inundation and erosion, as new development continues [21]. Information about streamflow and how it is affected by land use can help communities reduce their current and future vulnerability to floods.

1.2.2 Regional and National Context with Policy Derivation

Singh [22] linked unplanned urbanisation and flooding in cities especially in South-East Asian countries, ascertaining that as the urban sprawl of rapid urbanisation expands outwards and upwards, it provides ready opportunities for hazards such as floods, storms, and earthquakes to wreak havoc. Dar es Salaam is characterised by 75% of its urbanites living in unplanned settlements; these are exposed to urban floods with the corresponding impacts on infrastructure, housing and properties, and the lives of the inhabitants. Due to this situation, Wahlstrom [23] argues that there must be an all-out push to increase knowledge and expertise that will enable countries and communities to build more robust urban environments. The situation in Makongo and Goba neighbourhoods calls for an urgent need to examine the pace of growth and possible means to build with minimum surface water generation to curb flooding and erosion.

A study by Hooijer et al. [24] has pointed out that water retention areas and land-use adaptations far upstream may be useful in lowering the frequency of floods in small basins. This can be applied in areas such as Makongo and Goba due to their terrain, by harvesting rainwater and minimising surface run-off in each residential house as well as constructing rainwater retention structures at strategic points, to minimise the effects of floods downstream.

1.2.3 Resilience in the Context of the Study

The term resilience in this study is used as a concept that has been defined by other scholars in arts, literature, law, psychology and engineering [25, 26].

The use of the concept has soared to the top of the development agenda due to the current increase of natural disaster-related studies around the globe [27]. In the ecological study, the term is used to understand and explain the different trajectories of ecological systems as they seek equilibrium [26, 28, 29]. It goes further by saying that ecological conceptualizations of resilience largely focus on the capacity of a system to absorb changes but still maintain its core function [30].

Holling [31] describes resilience as a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables. The term is also used in the urban setting to explain the need to reshape existing urban systems and make them able to accept a certain level of disturbance while maintaining the status quo, and is defined as the ability to "withstand a large disturbance without, in the end, changing, disintegrating, or becoming permanently damaged; to return to normal quickly; and to distort less in the face of such stresses" [32].

In the case of Makongo and Goba, the concept is used to explain or investigate how the people in the two communities have been using various means to return to normal during the disturbances from the cascading water effects in their communities. Resilience techniques are the means/tools that the communities use to overcome the effects of the disturbance, especially during rainy seasons. It is defined as knowing which components constitute the resilience of a system depending on the nature of the threat(s) (resilience to what?), the unit of analysis (resilience for whom?) and the context of the internal social dynamics of the system. It thus implies that the study areas have threats from cascading waters that result from surface runoffs from roofs and hard landscapes. It further implies that the communities undergo resilience to erosion around buildings, plots and driveways by applying various means.

It is further claimed that the term is seen by development actors as a valuable conceptual tool in understanding how people respond and adapt to the many changing shocks and stresses that affect livelihood outcomes [33-35]. In Makongo and Goba settlements, residents respond by using various means to cope with the cascading water effects.

2. Theoretical and Conceptual Framework

Different works of literature show that urbanisation is caused by three major factors: natural growth of urban population, migration of population, and reclassification of rural to urban [36]. Literature goes further to elaborate these three aspects in terms of their contributing factors where for example natural growth of urban population is explained as the difference between the number of births and deaths in a population or simply the difference between birth rate and death rate.

Migration of population is a well-known phenomenon where people tend to move from rural to urban areas in search of green pastures, particularly in developing countries where there are unbalanced services and amenities in rural areas than is the case in the urban areas. Reclassification of rural to urban is simply defined by Keddie and Joseph [37] as a tendency where urban boundaries are expanded to rural areas.

The study of Makongo and Goba is theorised by the three aspects mentioned earlier; however, it is more concerned with the implications of urbanisation. Studies show that urbanisation has four major implications including an increase in pollution (water, land, air, noise), increase in activities (construction, agriculture, commercial and social), demand on resources (water, land, food, and energy), and increase in population-based on natural factors.

All these consequences are interlinked in settlements; for example, the increase of population leads to pressure on resources, pollution, and an increase in socioeconomic activities that leads to pollution and demand for resources. The study of

Makongo and Goba deals with pressure on land where land has been developed but the issue of surface runoff water has not been properly addressed. Moreover, the study considers the increase in activities on land, increase in population, and pollution as other factors connected with the construction of buildings. Due to such an increase, residents in the study area have taken initiatives to cope with the situation (resilience techniques), particularly the issue of surface runoff water which causes multiple effects in the neighbourhoods such as plant and soil erosion, floods downstream and roadside destruction.

Conceptually (Fig. 1), the study in Makongo and Goba investigates urbanisation in the two neighborhoods through literature review, Google mapping, physical verification, life experiences and interviews of which the factors of urbanisation were deduced. The increase of surface runoff due to the increase of the built environment (increase of hard landscape, increase of roof cover and excessive use of paving materials) was considered as the immediate effect of the urbanisation as far as the built environment is concerned. This was achieved through observation, measurements, interviews and photographs.

Due to the increase of hard surfaces (roof covers, hard landscape and use of concrete paving construction), there was an increase of the cascading waters in the hilly terrains which caused soil erosion around buildings, plots and roadsides thus making the place accessible, particularly during the rainy season. This was an immediate/micro effect which was documented through the narratives from the residents who have lived in the neighborhoods for several years, interviews, observation and measurements. Again, there was a macro/city level effect of the same that caused surging of waters in the downstream which cause floods (erosion of plots near the river banks, demolition of buildings and the destruction of lives and properties) which was documented through observation, interviews and life stories from the residents who were in the neighborhoods for more than ten years.

Finally, the study focused (main discourse) on the micro effects and the resilience techniques which the residents apply to cope with the situation (coping strategies) which include water harvesting and storing for landscape use (water retention), use of sandbags as temporary measures to reduce erosion around the buildings, change from concrete paving to porous paving materials and construction of drainage systems along roadsides.

2.1 The Study Area

The study areas Makongo with a population of about 44,000 people [38] and Goba (42,000) (Fig. 2) are among new neighbourhoods in Dar es Salaam which started around the year 2000; however, they have been urbanising rapidly and without proper guidance and follow-up especially on building projects. Urbanisation is a widely covered subject in the field of urban studies in developing countries mainly focusing on issues such as housing accessibility, sewerage treatment, access to clean water, access to transportation, and access to security to low and medium-income earners. However, urbanisation has brought up various challenges from urban to peri-urban areas whereby due to weak government institutions, residents in developing countries have resorted to their measures and techniques that help them live with the effects of urbanisation.

Unfortunately, the resilient techniques applied by individual ingenuities have not received noteworthy attention, thus calling for a need to investigate and document the tacit knowledge from the peri-urbanites in order to add to the literature on the linkage between informal urbanisation and its manifestation in cascading water effects, particularly in hilly residential areas. Specifically, the study will assist in creating a framework for managing cascading water effects in terrain settlements and develop a community-based policy that will help residents to deal with surface

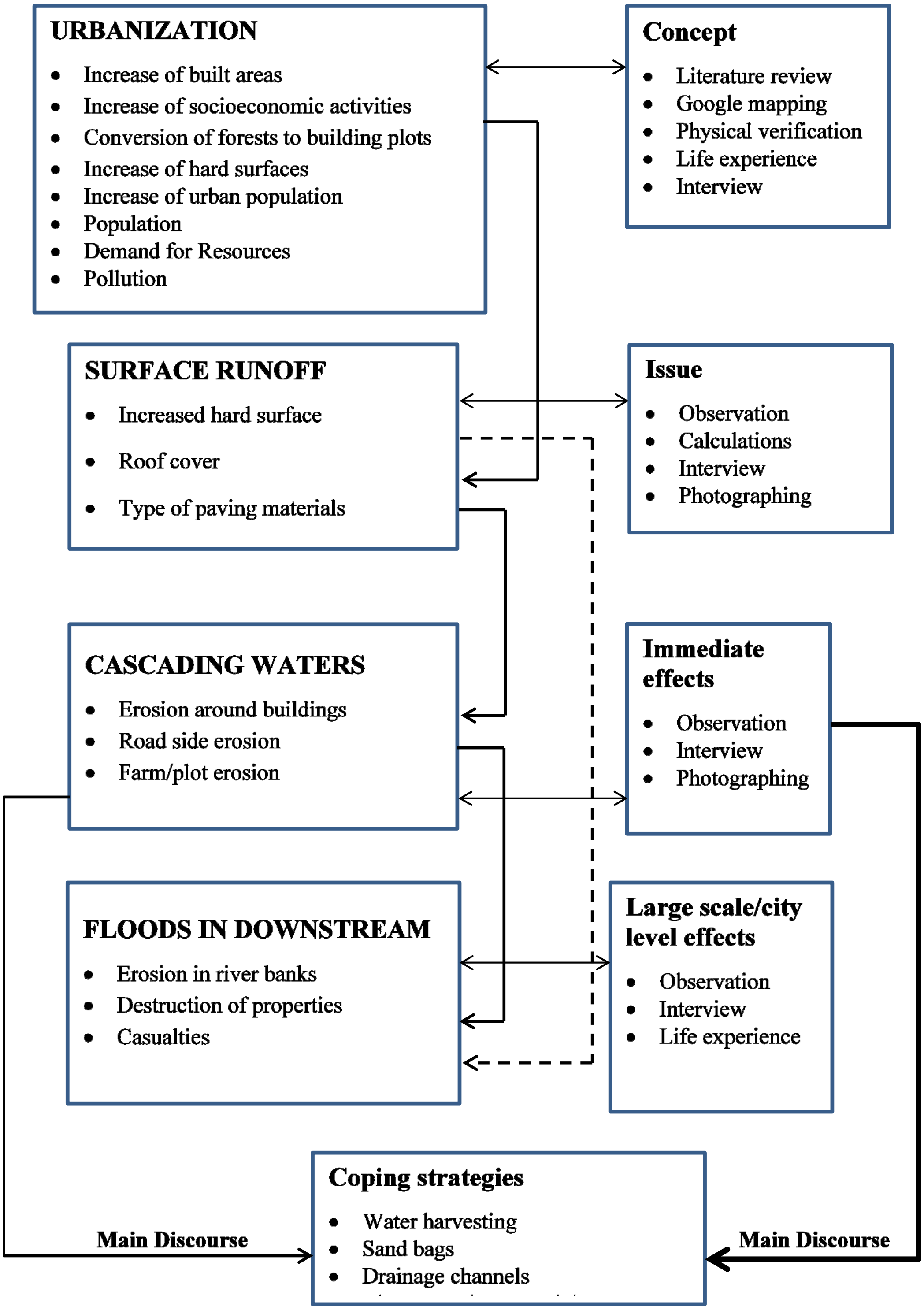

Fig. 1 Conceptual framework (urbanisation consequences and coping strategies).
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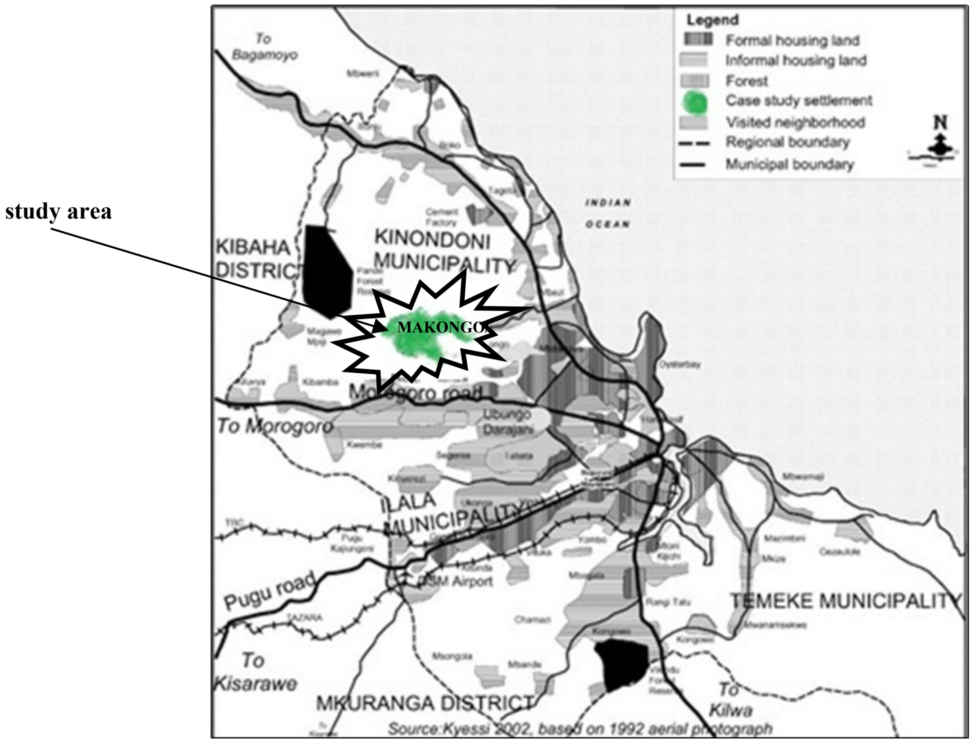

Fig. 2 The study area of Makongo and Goba.
Source: Kyessi [39] updated by the author in 2017.

runoff water during the design and construction of buildings using low technology. Moreover, the findings will be available to Ward Executive Offices, tax administrators, policymakers and civil societies so that they are in a better position to give the necessary advice.

2.2 Methodology and Research Strategy

The study was conducted in the two settlements namely Makongo and Goba located in the periphery of Dar es Salaam City. The study applied a qualitative exploratory method which was conducted through serial field observations and in-depth interviews. The settlements are relatively new and fast urbanising from the year 2000 thus, selected due to their pace of urbanisation and the nature of their terrain where, together with the development of housing, there was an increase of hard surface areas leading to the increase of surface runoff during the rainy season.

The two settlements have approximately equal size of area and population (Makongo: 43,796 people and Goba: 42,000 people) according to the 2012 census from the National Bureau of Statistics [38]. The Makongo with 43,796 people) and Goba with 42,000 people) are the total population for each entire settlement, however, it is not the entire area where the residents experience the challenges of cascading water effects. Some areas within the settlements (Makongo and Goba) are flat while others are on sloppy terrain. The study specifically focused on the sloppy terrains whose population ranges between 150 and 210 people [38].

Google Earth mapping and layering techniques were applied to deduce the trend of urbanisation of the two settlements from the year 2003 to 2017. Physical verifications (survey) to confirm the year when each building was built, location of the buildings, development of other infrastructure, and building typologies, were conducted to update the developed Google Earth Maps shown in Figs. 3 to 14.

Four research assistants, most of whom are graduate students of Architecture from Ardhi University, were employed in the study to count buildings, record physical conditions, conduct questionnaires, and interview the residents.

About 100 questionnaires for each respective settlement targeting the areas in the sloppy terrain were distributed. The questionnaires represent about 40% to 60% of the residents living in the sloppy terrains where the majority are affected by the cascading water effects. To avoid biases, the questionnaires were distributed randomly (a random sampling procedure) and used to cover a large percentage (above 50%) of the sloppy terrains. Thus, the information obtained from the questionnaires represents a good number of the population that was mostly affected by the cascading water effects.

This was followed by the field documentation on the level of surface erosion and infrastructure. Again, FGD (focus group discussion) about life stories, resident's experiences of rainfall concerning the increase of surface water runoff and erosion as well as coping strategies employed by the residents to deal with the immediate effect of the surface water runoff around the buildings, plots, and river banks downstream of the study areas was conducted. Some of the information was meant to explore the tacit knowledge from the selected resource persons (life experience-based solutions practiced by the residents).

The above empirical information from (Google Earth Mapping, questionnaire, FDG, measurements, and photographs) was triangulate [40] and statistically processed to confirm the growth of the number of buildings (urbanisation), an increase of surface areas due to paving and roofing, expansion of river banks, erosion of river banks, and plots. Moreover, with the aid from the literature support was grouped into themes which were analysed and discussed to form the findings and conclusion.

3. Results and Discussion

3.1 Urbanisation as Observed from 2003 to 2018

Areas of Makongo and Goba, like many other suburbs of Dar es Salaam, have been undergoing urbanisation from 2003 to date due to many factors including an increase of population of Dar es Salaam, rural-urban migration, availability of premium plots and availability of various higher learning institutions including Ardhi University, University of Dar es Salaam, East and Southern African Statistic Institute and Lugalo Army Barracks. Data collected from the two settlements by using Google Earth (Google Mapping) show that the two study settlements were mostly covered by greenery (bushes and shrubs) with just a few buildings (21 buildings) and roads serving the study area from four to twelve (Fig. 5). The increase of the total built-up area and the number of roads signify the subdivision of the previous large chunks of land into residential plots connected by access roads.

Another noteworthy increment was observed between 2007 and 2010 in which the built-up area increased by 30% from 11,000 km^2 to about 16,600 km^2 (Fig. 6). An increase in the built-up area in urban and suburbia has been noted to have various impacts on the environment including an increase in surface runoff [41], increase of impervious surfaces as well as a decrease in foliage and natural vegetation [41-43]. The same site showed that there was an increase in the paved surface area of about 2,700 km^2 which contributes to the creation of surface runoff. Other studies have associated the increase of paved surfaces in the built environment with a decrease of water quality, destruction of aquatic quality, reduction of groundwater charge, and alteration of the natural cycling of water [44]. The study on the same site shows that there was an increase in the number of service roads which are again used as channels of surface water runoff in the built environment as noted in the study by Enniful and Acquaye [45]. The fact that surface runoff uses roads as channels of water calls forth the need to design roads that have structures to lead away water, to minimise the effects of runoff.

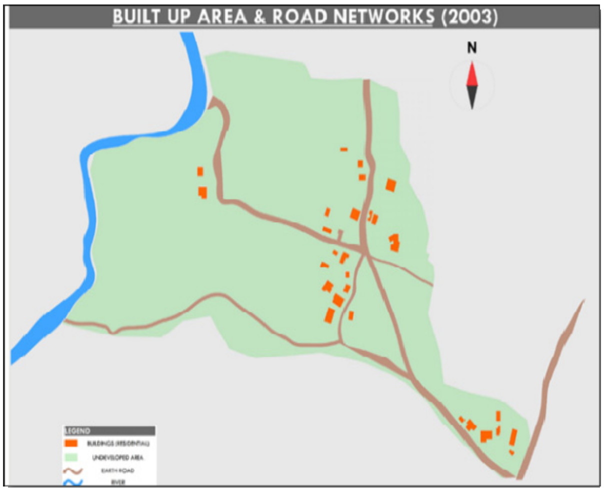

Fig. 3 Existing buildings and road networks in 2003.
Source: Author.

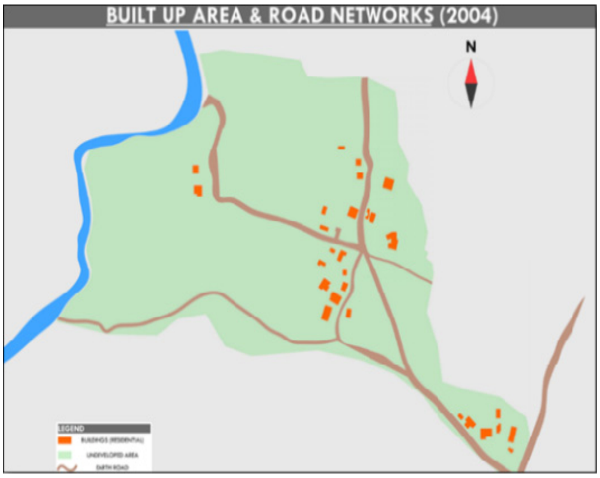

Fig. 4 Existing buildings and road networks in 2004.
Source: Author.

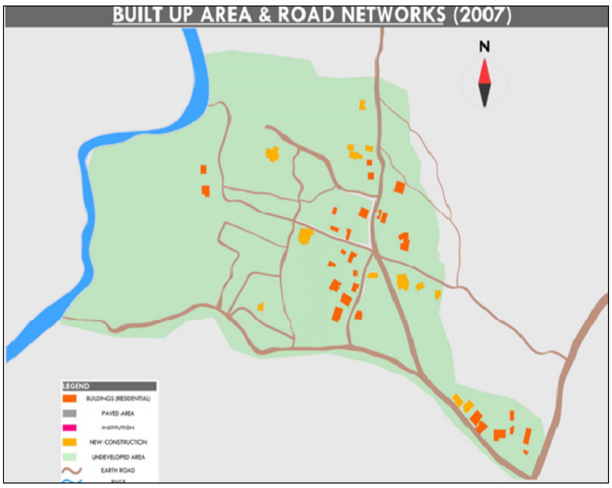

Fig. 5 Existing buildings and road networks in 2007.
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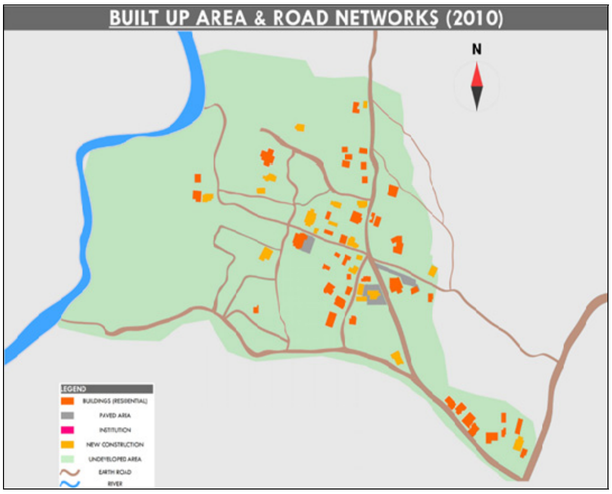

Fig. 6 Existing buildings and road networks in 2010.
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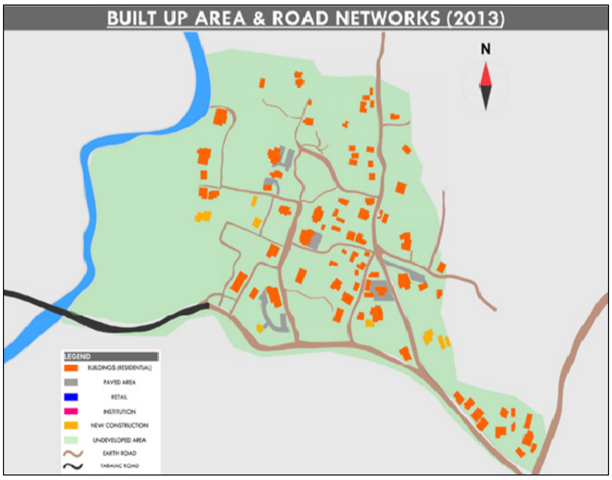

Fig. 7 Existing buildings and road networks in 2013.
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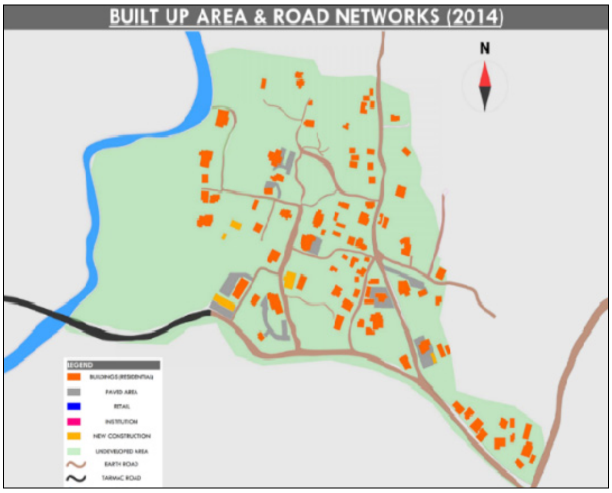

Fig. 8 Existing buildings and road networks in 2014.
Source: Author.

This was followed by another significant increase within a short period between 2010 and 2012 where the paved area increased to about 4,000 m^2 while the total built-up area increased from 16,660 km^2 to about 23,000 km^2 (Fig. 7). Built-up areas were noted also in the following years 2013 to 2014 (31,238 m^2), 2014 to 2016 (32,500 m^2); 2015 to 2016 (32,260 m^2); 2016 to 2017 (38,260 m^2) (Figs. 8 and 9) whereas the paved area increased to 8,500 m^2 (Fig. 6). This implies that from 2003 to 2017 there was an increase of the built-up area from 11,000 m^2 to 38,260 m^2, which is about a 348% increase (Fig. 9). This is a significant increase of pressure inland which definitely if not properly managed may lead to various consequences in the neighbourhood.

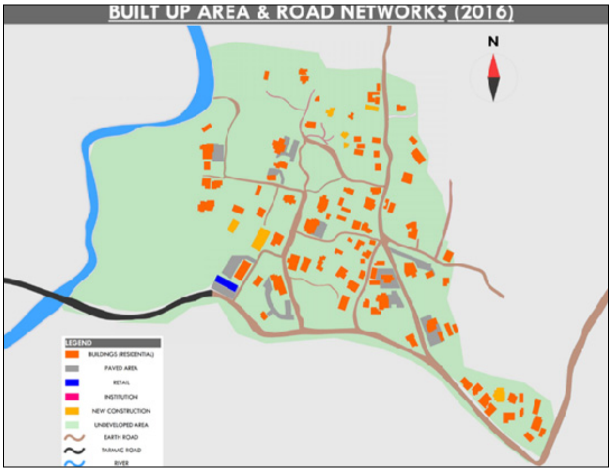

Fig. 9 Existing buildings and road networks in 2016.
Source: Author.

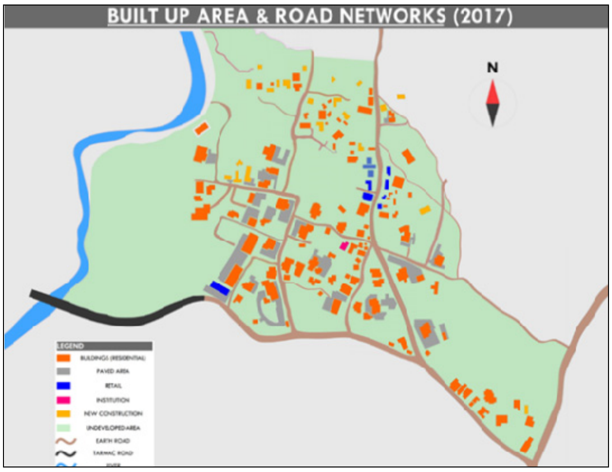

Fig. 10 Existing buildings and road networks in 2017.
Source: Author.

BUILDING TYPOLOGY		BUILT UP AREA	PAVED AREA
A1	TWO STOREY (COMMERCIAL)	-	-
A2	SINGLE STOREY (COMMERCIAL)	-	nill
B1	TWO STOREY (RESIDENTIAL)	-	-
B2	SINGLE STOREY (RESIDENTIAL)	15,231M^2	-
B3			-
C1	SINGLE STOREY (INSTITUTION)	-	-
	TOTAL AREA	15,231M^2	-

Fig. 11 Total paved area in 2003 (the site was mostly covered by vegetation within only in few buildings).
Source: Author.

BUILDING TYPOLOGY		BUILT UP AREA	PAVED AREA
A1	TWO STOREY (COMMERCIAL)	532 m^2	720m^2
A2	SINGLE STOREY (COMMERCIAL)	1,450 m^2	nill
B1	TWO STOREY (RESIDENTIAL)	4,366 m^2	5,225 m^2
B2	SINGLE STOREY (RESIDENTIAL)	7,616 m^2	12,116 m^2
B3		19,549 m^2	nill
C1	SINGLE STOREY (INSTITUTION)	187 m^2	nill
TOTAL AREA		33,700 M^2	18,061 M^2

Fig. 12 Total paved area in 2017 (showing an increment of the built area by 10%).
Source: Author.

3.2 Change of Building Typologies

In the course of urbanisation of the two settlements, it was observed that there was an increase in building typologies ranging from residential, commercial, religious, warehouses and institutional buildings (Fig. 13). Again, there was an increase in double-storey structures within the settlements (Fig. 14). Buildings, particularly residential houses, were concentrated on the elevated side of the settlements leaving the lower side with scattered buildings. Due to this arrangement, surface runoff water was left by the residents on the elevated side to run freely downhill to the settlements at the lower parts, through building alleys and roads thus causing erosion. This was confirmed in both settlements when residents were asked where they directed surface runoff water. The majority disclosed

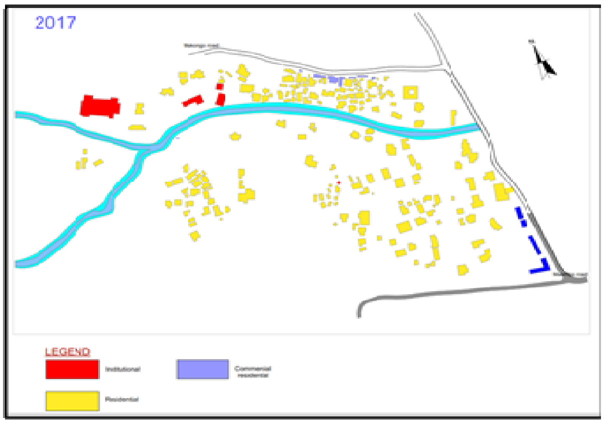

Fig. 13 Types of buildings by function in 2017.
Source: Author.

Fig. 14 Types of buildings by floors in 2017.
Source: Author.

that they were directing the water towards neighbouring settlements on the lower level; while others said that they were directing the same towards the valley (existing river). Others simply said they directed the water out of the plot but they were not able to explain what "out of the plot" meant (Fig. 15). Nevertheless, following the layout of the terrain, it implies that all waters from rooftops, surface hardscapes was following the terrain towards the river on the lower side of the Goba Settlement (Fig. 16).

3.3 Damage Caused by Surface Runoff Water

The increase of buildings in the two settlements has gone proportionally with the introduction of road networks and paved hard surfaces which altogether generate impervious surfaces leading to surface runoff. As a result, four main areas within the neighbourhoods were affected—erosion around buildings, erosion of roadsides, erosion of plots, and flooding of river banks in the existing river.

It is noted in the study by Tan-Soo et al. [46], van Noordwijk and Tanika [47], and Wahren et al. [48] that tree and forest removal is well known for raising the likelihood of floods and also, the planting of trees and forests can reduce flooding according. It continues to add that removing trees leads to soil compaction and hardening, soil erosion (especially in mountainous areas), transpiration loss, reduced infiltration and increased runoff, thereby promoting floods. The above literature affirms the situation in Makongo and Goba in the sense that more effect of cascading waters was in the built areas than those areas which remain undisturbed (with shrubs and forests) although they are next to each other.

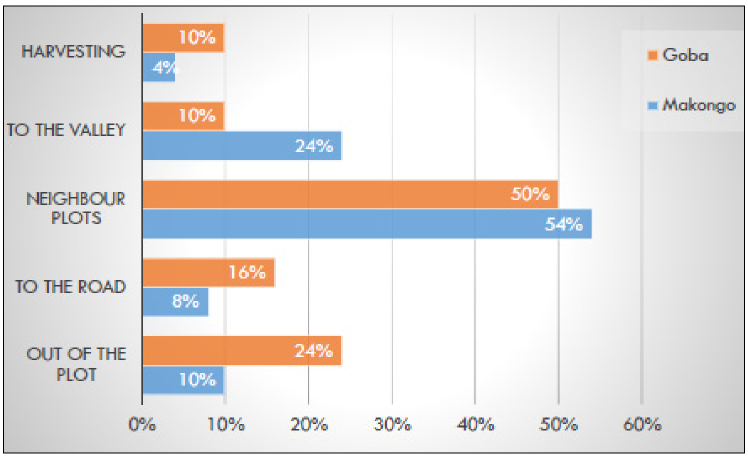

Fig. 15 How residents direct surface runoff water.
Source: Author in 2017.

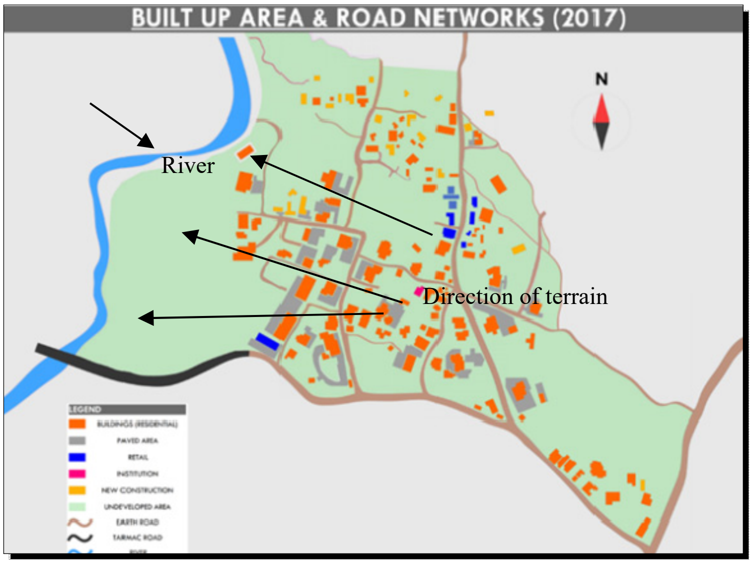

Fig. 16 How residents direct surface runoff water.
Source: Author in 2017.

Also, literature shows that climate change affects a large area including both the built (the study settlements) and the surrounding unbuilt areas near the study areas. However, there was no erosion in the undisturbed areas covered by shrubs and grass. Furthermore, the life stories from the FGD and the observation in the two areas led the authors to be convinced that the increase of the hard surfaces in the built areas contributes more to the generation of surface runoffs and their immediate effects in buildings. Combining the above findings and the literature, the authors confirmed that if it were the effect of climate change, then it would equally affect both the built and unbuilt area in terms of eroding the soil.

3.4 Erosion around Buildings

Some studies such as that of Kabanda [49] show that the trend of rainfall in Dar es Salaam has been decreasing for the past 55 years and in the period during which this study was conducted when the rainfall in Dar es Salaam according to the TMA (Tanzania Meteorological Agency), was in the minimum as compared to the years before, yet the same amount of rainfall had this continuous impact in the study area. This means that the climate change observed in Dar es Salaam may affect the amount of rain but not increase the same. The same author highlights that Dar es Salaam is found in a bimodal rainfall zone, with "long" rains centered on MAM (March to May) known in Tanzania as Masika rains, and "short" rains in OND (October to December) known as Vuli rains [49].

Most of the buildings in these settlements do not have rain gutters, so there is the random pouring of water around the buildings, which in some cases is the source of erosion around such buildings. Again, gutters in buildings keep the ground around the buildings from becoming waterlogged and ensure that rainwater does not get absorbed into the foundation where it could cause severe damage to the structure, as well as surrounding structures (Fig. 17). Thus water gutters are important in a building because they protect the building foundation, prevent erosion, protect landscaping, and prevent basement flooding. Gutters too prevent staining to the exterior of buildings, mitigate paint damage, and stop mold and mildew growth.

3.5 Erosion of Roadsides

Due to the lack of drainage channels in the two settlements, rainwater from roofs and hard surfaces normally runs along roadsides causing serious erosion (Fig. 18). Studies by various scholars [50-52]

Fig. 17 Erosion along roadside due to cascading water field study in 2018.

also noted that impermeable road surfaces are a source of rapid runoff, which increases both peak rates and volumes of runoff. This means that when water is left without proper direction, particularly when the soil is lost like the case of Makongo and Goba, it creates erosion on the channel as well. Another study from a different scholar [53] also shows that surface runoff water tends to cause roadside erosion which leads to damage of road embankments; so efforts should be made to manage freely flowing waters in the neighbourhood.

3.6 Erosion of Plots

As mentioned earlier, in Makongo and Goba, surface runoff water has consumed some plots, particularly those lying in the lower slopes of the neighbourhoods. Normally, residents in the upper slopes do allow water from their compounds to run uncontrollably to the lower plots. As the surface water accumulates in several plots it increases in volume thus causing soil erosion to plots in lower levels. When this continues for a long time, the water consumes and destroys a large part of the prime construction area. The study shows that plots have been eroded to different degrees. Some have lost a quarter of their size, others up to three quarters, and in the worst case whole plots have been washed away. The study shows that, in Makongo, a quarter of the plots were eroded by 85% while in Goba this was about 75% of the plots. Again, in the same area, it was observed that 10% of the plots had been completely consumed by water.

3.7 Flooding of River Banks

Due to the accumulation of water from different areas, the study observed that river banks overflow, particularly during the rainy season, and this has led to erosion-consuming plots and prime construction areas near the river (Fig. 19). Residents of both settlements (70% at Makongo and 66% in Goba), iterated that they had experienced an increase in the volume of rainwater flow, particularly during the rainy season.

3.8 Coping Strategies by Residents

Water harvesting, especially in areas with no proper tap water supply, is of paramount importance; but can only happen when people are aware of the advantages of harvesting rainwater. The study by Ganguly et al. [54] considers rainwater harvesting as an innovative and suitable alternative approach to a water supply that can be used by anyone as it helps to capture, divert, and store rainwater for later use especially in dry seasons.

Fig. 18 Erosion around buildings and alleys field study in 2018.

Fig. 19 Effect of flooding along the river banks consuming plots.
Source: Field Study.

Fig. 20 Using sandbags to prevent erosion around buildings.
Source: Field Study.

Residents of Makongo and Goba have devised some techniques to cope with the challenges of living in sloppy settlements, particularly in dealing with surface runoff. As shown earlier, only a few residents have rain gutters in their buildings because, as the study found out, people have little knowledge of water harvesting. Specifically, it was found that a high percentage of residents (68% at Makongo and 60% at Goba) do not know how to harvest water. Again, residents in the two settlements were eager to get the skills and techniques on how to harvest rainwater. Rainwater harvesting does not only protect buildings against surface runoff but also is a sustainable way to help to store water for other uses. Environmentally, rainwater harvesting can reduce stormwater runoff from a property, thus eliminating runoff which can reduce contamination of surface water with pesticides, sediment, metals, and fertilisers. Some of the coping strategies have been described in the following sections.

3.8.1 Use of Sandbags

It was observed in some residential houses that residents in the two settlements use sandbags to control surface runoff around buildings. Sandbags were laid along building alleys to prevent soil erosion caused by water pouring directly from the roof, or surface runoff water (Fig. 20). When some residents were asked why they used this method they associated it with the cost. One resident iterated the following: “I cannot afford any other means to protect my house against the massive water that runs around my house during the rainy season. This is cheap to me. I just direct this water away from my house to other areas.” When asked about whether she knew where this water ended, she admitted, “As long as the water goes away from my house, I do not care about where it ends. My house is safe that is all I need” (name withheld).

This kind of thinking shows that there is a lack of collective concern about surface runoff as it destroys roads, undeveloped plots, and river banks. The community has not taken up a collective strategy to address the challenge of surface runoff water. Another rather seemingly indifferent resident in Goba was asked about how he treated water from his house; he gave the following response: “Only rich individuals can help us to construct water channels. I have no money but I just need to ensure that my little resources can safeguard my property” (name withheld).

3.8.2 Concreting and Paving

In some areas at the two settlements, it was observed that some residents use concrete beds around buildings and build alleys to safeguard their buildings. This is to a large extent done by well-off residents and it lacks communal coordination because it was observed that residents who put concrete beds around their houses and compounds were not concerned with the direction of the runoff. As a result, as water cascaded, it caused soil erosion and property destruction in other plots, roadsides, and riverbanks as shown in Fig. 21.

Although the method of concreting and paving is considered a good solution by some residents in the two settlements, studies have shown that paving creates an impervious surface that prevents water from leaching into the ground and in turn creates cascading water in the lower levels of the settlements. The study shows that up until 2017, the total paved area within the built neighbourhood had increased from zero in 2003 to 18,061 m^2 in 2017, which was an increment of 18,061%. This is apart from paved areas covered with road network, indicating the significance of the amount of surface water collected or left to flow randomly in the neighbourhoods. A study by Chithra et al. [55], testified that the increase of paved areas particularly the impervious surface causes weather change, affects water quality and also affects the overall hydrological cycle in urban settings.

When a few residents were asked the consensus was: "It is the role of the government to build stormwater systems, not me. What I can do is just to ensure my house is safe and free from mud during the rainy season. I have very little concern about the water channels outside my plot." (name withheld). Again, this response reflects a lack of communal responsibility regarding common areas such as roads and undeveloped plots as well as river banks.

Fig. 21 Concreting and paving in the built areas.
Source: Field Survey, 2019.

When the residents were asked whether they pay any attention to the type of paving materials used in their buildings one of them asked: "… I only need to take water out of my plot. I have slippery muddy soil. Do you know that this is black cotton soil? It is very bad when it gets into contact with water. So, I make sure that rainwater has no chance of permeating the pavers" (name withheld).

From the findings, it is apparent that there is a lack of awareness on the type of pervious materials which ought to be used to balance underground water. A study by Barnes et al. [56] raised concern about the threats on the quality of natural and built environments (stormwater runoff, reduced water quality, higher maximum summer temperatures, degraded and destroyed aquatic and terrestrial habitats, and the diminished aesthetic appeal of streams and landscapes) and these were caused by growth and spread of impervious surfaces due to urbanisation. Disregarding these facts, residents in Makongo and Goba do not have a specific type of paving materials that are receptive to the environment. This implies that although the case in Makongo and Goba cannot be directly compared to the just mentioned study, there is the need to raise awareness on the dynamics of paving in the residential neighbourhood.

4. Conclusion and Policy Recommendations

4.1 Conclusion

The study was geared towards investigating the pace of urbanisation in the two areas of Makongo and Goba in order to unveil its impacts in terms of the increased hard surface and roof coverage which fuel the surface runoff water and soil erosion in the area. To identify the coping strategies employed by the residents in dealing with the problems that are caused by unmanaged surface runoff. Finally, to recommend a policy that can be applied to deal with the surface runoff.

The study through the data from 2003 to 2017 shows that there has been a significant increase of built-up area (18,000% increase) contributed by built and paved areas within a short period that was accompanied by the construction of paved surfaces and increase of roof surface areas which have impeded the natural leaching of water in the soil, and instead it has led to accumulation and build-up of surface runoff water. Again, urbanisation is accompanied by clearing of areas surrounding the plots thus exposing it to direct impinging rainfall which facilitates the easy movement of soil causing erosion. The study demonstrated various effects of surface runoff water such as erosion around the perimeters of the buildings, erosion of roadsides, erosion of plots and finally the increase of water down the stream that led to erosion of plots and plants near river banks.

The study highlighted several coping strategies applied by the residents including the use of sandbags, use of both concrete and blocks to pave their courtyards, use of water harvest and landscape techniques. Finally, the study recommends establishing a local policy that can be adhered to by residents to minimize the effects of surface runoff including harvesting, storing and recycling of rainwater.

4.2 Policy Recommendations and Implications

The literature review has shown that proper rain-water harvesting techniques can be used to deal with surface runoff in the built environment. The case of Makongo and Goba is a good study where, with sufficient awareness, residents can use well-informed water harvesting methods to reduce the amount of surface runoff. Not only that, the residents can apply various landscape designs and strategies to reduce the surface runoff water that affects the neighboring plots as well as the river downstream.

The study recommends that a policy to harvest, retain and re-use rainwater should be enforced by all residents in Makongo and Goba, whereby each plot owner should contain water from his/her plot by harvesting, collecting and retaining it for home use such as farming, watering plants, filling fish ponds and other uses. In this way, surface runoff water will be controlled and likewise its accompanying effects such as erosion, and erosion of river banks downstream. The policy framework needs to be participatory, involving residents, local ward leaders and individual building developers. In the event residents want to pave the surroundings of their buildings, proper technical advice should be given to minimise the impacts of hard surfaces in residential neighbourhoods.

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