

Study of Floods Risks using Remote Sensing and Geographic Information Systems: Case Study Omdurman, Sudan

Abdelrahim Elhag¹, Badria Ali², Aboalbashar Ali³

¹Abdelrahim Elhag, Department of GIS, College of Engineering, Sudan University of Science and Technology, SUDAN.

²Badria Ali, Department of RS and Photogrammetry College of Engineering, Sudan University of Science and Technology, SUDAN.

³Aboalbashar Ali, Department of Civil, College of Engineering, Sudan University of Science and Technology, SUDAN.

Abstract - Flooding in urban areas is related to many factors; the main factor of which is heavy rainfall. Large parts of the ground are covered by infrastructures such as roads and pavements. Large numbers of poor people settle and live in floodplains due to large scale urbanization and population increase.

Over the past century, Khartoum State has become an increasingly urban society. The changes in land use associated with urban development affect flooding in many ways, removing vegetation and soil, grading the land surface, and constructing drainage networks increase runoff to streams from rainfall. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams or rivers; in particular, the White Nile River.

Rapid developments in computer technology and the GIS help to process remote sensing observations from satellites in a spatial format of maps. The spatial visualization derived using RS techniques integrated with other datasets provide tremendous potential for identification of flood risk zones. The main conclusion reached at is that if the amount of rainfall in the study area exceeds a maximum of 415.5 mm, then the area is prone to floods and many buildings within the area will be destroyed.

Key Words: Rainfall, Risk, Drainage, Buildings, Contour, Omdurman Soil, Landsat Images.

1. INTRODUCTION

The frequency of major floods in many places around the world seems to be increasing^{[2] [6]}; flash floods occurred throughout the world. Climate change may be a significant driver of changes in the flood frequency which has been widely investigated^{[9] [2] [14]}. However, there are only few studies on the role of land use change in modifying river floods.

Land use change has, potentially, a very strong effect on floods as humans have drastically modified natural landscapes. Large areas have been deforested or drained, thus either increasing or decreasing soil moisture and triggering erosion. Hillslopes were modified for agricultural production, thus changing flow paths, flow

velocities, and water storage, and consequently flow connectivity and concentration times. The intensification of agricultural practices has resulted in the formation of dense soil horizons with lateral flow which may reduce and/or retard vertical infiltration in the soils, but cause an intensification of lateral mass flow besides reduced filter and buffer processes in deeper soil horizons. It is likely that hydrologically significant changes will continue in the next decades due to loss of agricultural land and forests^[16]

In all of these processes, however, the exact role of land use change in modifying river floods is still increasing.

Floods occur when large volumes of runoff flow quickly into streams and rivers. The peak discharge of a flood is influenced by many factors, including the intensity and duration of storms, the topography and geology of stream basins, vegetation, and the hydrologic conditions preceding storm events.

Land use and other human activities also influence the peak discharge of floods by modifying how it is stored on and run off the land surface into streams. In undeveloped areas such as forests and grasslands, rainfall is collected and stored on vegetation, in the soil column, or in surface depressions. When this storage capacity is filled, runoff flows slowly through soil as subsurface flow.

In contrast, urban areas, where much of the land surface is covered by roads and buildings, have less capacity to store rainfall waters. Construction of roads and buildings often involves removing vegetation, soil, and depressions from the land surface. The permeable soil is replaced by impermeable surfaces such as roads, roofs, parking lots, and sidewalks that store little water, reduce infiltration of water into the ground, and accelerate runoff to ditches and streams^[12].

Urban conditions cause drainage problems; runoff is increased by impermeable urban surfaces and, due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for storm water drainage. The poor are the most affected; they often reside in informal

settlements located on marginal land (low-lying land), riverbanks, floodplains and steep hillsides^[7].

Although these sites are vulnerable to the impacts of flooding, the benefits of living nearer sources of employment and urban services generally outweigh the disadvantages associated with flooding, which is generally perceived as a natural and seasonal event^[10]. One can distinguish four types of flooding in urban areas: localized flooding due to inadequate drainage; flooding from small streams within the buildup area; flooding from major rivers; and coastal flooding.^[4]

As pointed out before, poor communities often live in the most hazardous and unhealthy environments in urban areas^[11]. Many build their homes and grow their food on river floodplains in towns and cities. Others construct their shelters on steep, unstable hillsides, or along the foreshore on former mangrove swamps or tidal flats. People suffering these poor conditions may find their difficulties compounded by the consequences of climate change.

In the large cities of low latitude countries, it is common for much of the low-income population to live in areas at risk from flooding,^[3] and this population is most likely to be affected by factors related to climate change^[1]. Floods are natural phenomena, but damage and losses from floods are the consequences of human activities. Although climate change is driven largely by modernization and development, all human activities, including land degradation by poor farmers and grazing flocks, contribute to environmental change. However, on a per capita basis, the poor people are far more the victims of change than contributors to global warming and land degradation.

Flooding in urban areas is not just related to heavy rainfall and extreme climatic events; it is also related to changes in the built-up areas themselves. Urbanization restricts where floodwaters can go by covering large parts of the ground with roofs, roads and pavements, thus obstructing natural channels, and by building drains that ensure that water moves to rivers more rapidly than it did under natural conditions. Large-scale urbanization and population increases have led to large numbers of people, especially the poor, settling and living in floodplains in and around urban areas^[15].

As people crowd into cities, human impacts on urban land surfaces and drainage intensify. Even moderate storms now produce quite high flows in rivers because of surface runoff from hard surfaces and drains. Water flowing through a series of culverts and concrete channels cannot adjust to changes in the frequency of heavy rain, as natural streams do. They are often obstructed by silt and urban

debris, particularly when houses are built close to the channels. Such situations frequently arise when poor people build on low-lying floodplains, over swamps or above the tidewater level on the coast^[8]. The effects of climate change are superimposed on these people-driven local land surface modifications.

Over the past century, Khartoum State has become an increasingly urban society. The changes in land use associated with urban development affect flooding in many ways, removing vegetation and soil, grading the land surface, and constructing drainage networks increase runoff to streams from rainfall. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams or rivers; in particular, the White Nile River.

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. Information about stream flow and how it is affected by land use can help communities reduce their current and future vulnerability to floods.

2. REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

Remote sensing is a technique, which made it possible to obtain and distribute information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircrafts or satellites. The spectral bands used by these sensors cover the whole range between visible and microwaves. Rapid developments in computer technology and the Geographical Information Systems (GIS) help to process Remote Sensing (RS) observations from satellites in a spatial format of maps. The spatial visualization of information derived from RS techniques with other datasets provides tremendous potential for identification, monitoring and assessment of floods^[5].

3. DATA AND METHODOLOGY

3.1 The Study Area

The study area is the locality of Omdurman, bounded by latitude 16° 39' 52.6"N (Upper), 15° 54' 45.1" N (Lower) and longitude 31° 49' 46.4"N (Upper), 32° 36' 31.9"N (Lower), on the western bank of the River Nile and its tributary, the White Nile, comprising a total area of approximately 8203.936km². It is linked with the two main cities, Khartoum and Khartoum North, by the White Nile, El Ingaz, Shambat, and Halfayat El Mulook bridges respectively (see Figure 1). Omdurman features a hot desert climate, with only the months of July and August seeing significant precipitation averaging little over 155 millimeters per year. Expansive soil is mainly composed of sedimentary rocks such as shell, clay stone,

lime stone, and rich in magnesium (see Figure 2). The geological units (Figure 3) in the study area are mainly composed of superficial deposits, volcanic rocks, cretaceous sedimentary rocks and basement complex. The surface of the locality is characterized by gently rolling terrain and the end of the water discharge is generally the Nile River ^{[13] [17]} (Figure 3).

The Agricultural (cultivated and non- cultivated) area totaled one million fedans. The registered part of this area is almost 954000 fedans. Land cover refers to the physical surface of the earth, including various combinations of vegetation types, soils, exposed rocks and water bodies as well as anthropogenic elements (Figure 4).

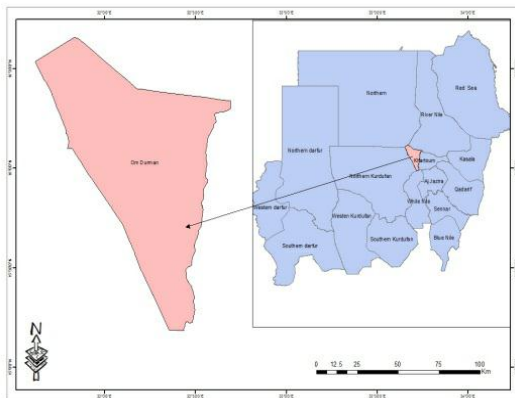


Fig -1: Study Area (Omdurman Locality)

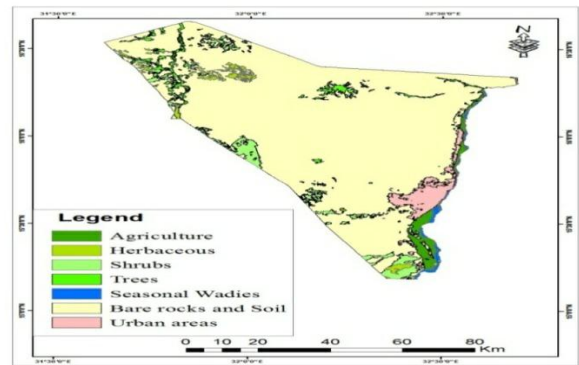


Fig - 4: Land Cover of Omdurman Locality

3.2 Data Sources:

Landsat imagery (TM and ETM) available from www.earthexplorer.USGS.gov repository were used to determine the drainage system and buildings within the study area. The characteristics of the Imageries is shown in Table (1)

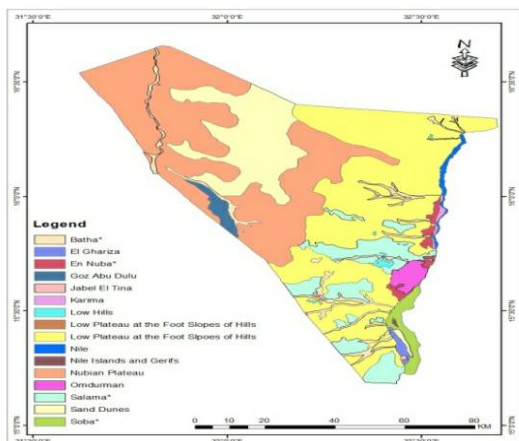


Fig -2: Soil Map of Omdurman Locality

Table -1: Characteristics of the Imageries used

Date	Sensor	Resolution (meter)
10/6/1988	TM	30
10/6/1994	TM	30
7/6/2000	ETM	30
8/6/2007	ETM	30
12/6/2013	OLI	30

Rainfall data for the years 1988, 1994, 2000, 2007 and 2013 were obtained from National Metrological Authority (Sudan) as shown in Chart (1)

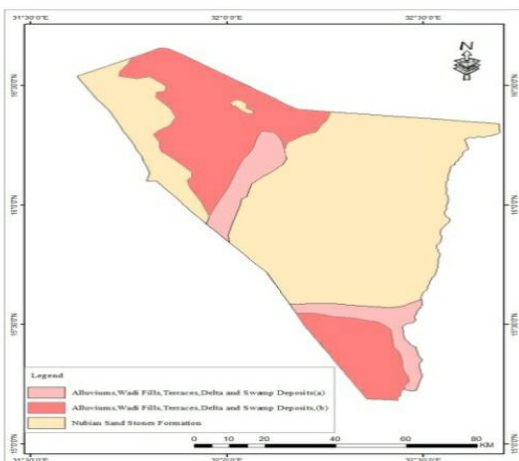


Fig -3: Geological Map of Omdurman Locality

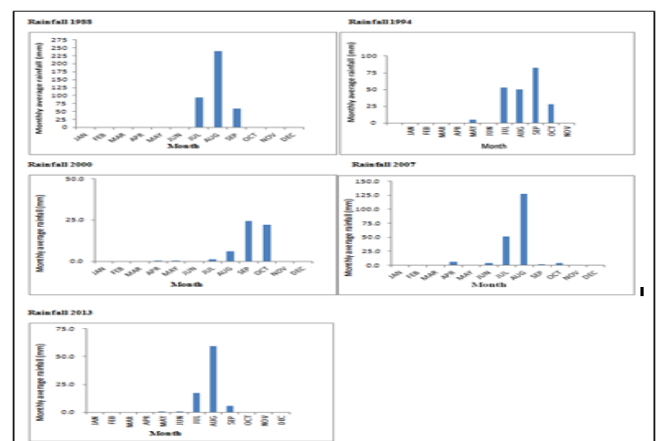


Chart - 1: Rainfall Data for the years 1988, 1994, 2000, 2007 and 2013

Digital Elevation Model was obtained from the Shuttle Radar Topography Mission, (SRTM), available at 30 meters resolution. The Paz and Collischonn (2007) approach was applied to eliminate sinks form the SRTM data and to obtain the local drain direction network.

3.3 Data processing:

The software used for data processing is the Arc Map version 10.3 and Excel 2010 following the step below:

- Open ARCGIS.
- Choose Catalog.
- Create file.
- Import Personal Geodatabase.
- From Feature Dataset and Feature class.
- Choose Projection, Zone and Datum (in this paper, the Universal Transverse Mercator (UTM) Projection, Zone 36 and World Geodetic System (WGS84) were used).
- Form Polygon of drainage and buildings.

The results of combining out these steps are shown in figures 6, 7, 8, and 9.

The tributaries of rivers and buildings within the study area for different years (1988, 1994, 2000, 2007, and 2013) were identified from satellite images and the results are as those shown in figures 6, 7, 8, and 9.

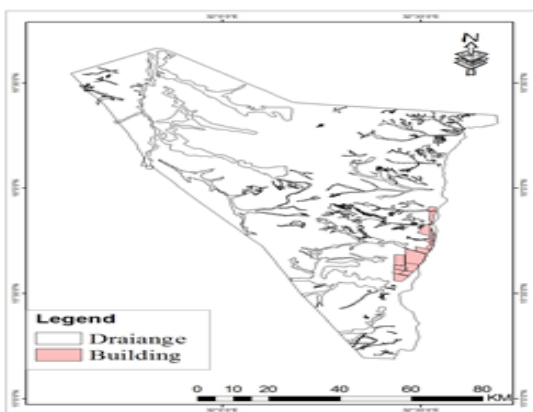


Fig - 5: Buildings and Drainage 1988

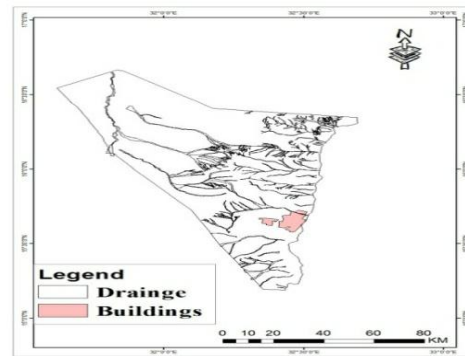


Fig - 6: Buildings and Drainage 1994

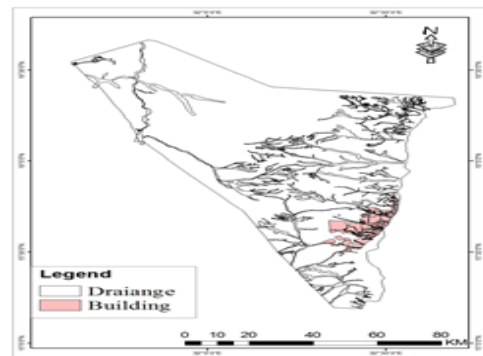


Fig - 7: Buildings and Drainage 2000



Fig - 8: Buildings and Drainage 2007

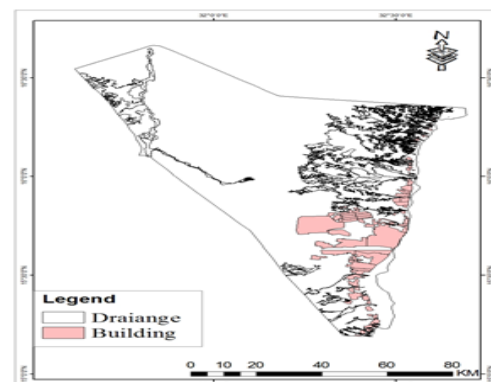


Fig - 9: Buildings and Drainage 2013

4. Results and Analysis

1. From satellite images, the tributaries of rivers and buildings within the study area for different years (1988, 1994, 2000, 2007, 2013 and 2018) are identified as shown in Figure (5, 6, 7, 8, and 9).
2. Layers created in the previous section were placed on top of each other to see the size of the impact. It is found that the buildings are not affected by the floods or rain water coming from the tributaries for the same year. This is an indication that the buildings are not affected by floods or rainwaters coming from these tributaries ; they are rather affected directly by rainfall, the magnitudes of which are shown in chart (1)
3. When the 2018 buildings were placed with the contour map of the study area, it is found that some buildings were located in low areas prone to floods as shown in Figure (10).
4. When the buildings layer for the year 2018 was overlapped with the tributaries of 1988, it is found that some buildings are constructed inside the banks of the tributaries, as shown in Figure (11).
5. When the three layers, mentioned in 2,3, and 4 above are place together and overlapped, it is found that if the rainfall rate in coming year exceeds the rainfall of 1988 (A year of drastic destruction of buildings in the study area as a result of heavy rainwater , then the study area is exposed to floods risk and the buildings there in will be at risk for vast areas within the locality, as shown in Figure (12)

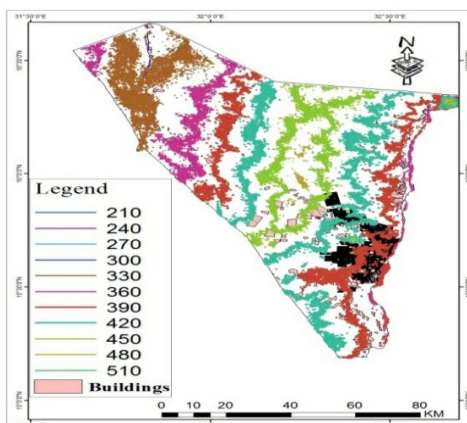


Fig -10: 2018 Buildings and Contour Map

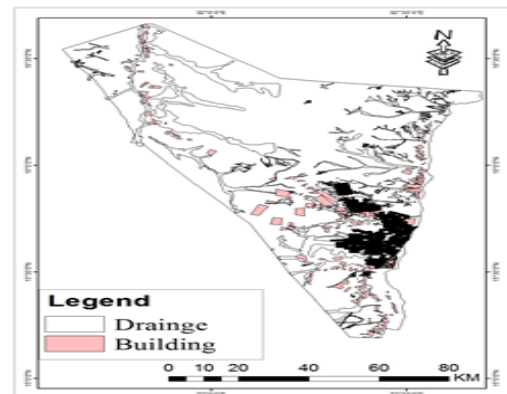


Fig - 11: Buildings 2018 and Drainage1988

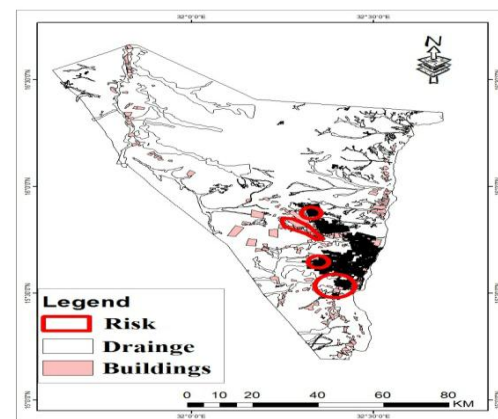


Fig -12: Risk map of Omdurman Locality

5. CONCLUSIONS

1. In general, this study concluded that it is possible to identify areas affected or may be affected by water bodies (drainages, streams) and natural rainfall with the help of RS, GIS and DEM.
2. Also, construction and buildings constructed in low areas can easily be identified to additions areas that can be most affected in the future can also be identified.
3. The most important conclusion reached at is that areas within the locality of Omdurman are at risk to be floods if the rain water exceeds 415.5 mm.

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