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Urban Areas Management in Developing Countries: Analysis of the Urban Areas Crossed with Risk of Storm Water Drains, Aswan-Egypt

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Abstract**—**One of the most risky areas in Aswan is Abouelreesh, which is suffering from flood disasters, as heavy deluge inundates urban areas causing considerable damage to buildings and infrastructure. Moreover, the main problem was the urban sprawl towards this risky area. This paper aims to identify the urban areas located in the risk areas prone to flash floods. Analyzing this phenomenon needs a lot of data to ensure satisfactory results; however, in this case the official data and field data were limited, and therefore, free sources of satellite data were used. This paper used ArcGIS tools to obtain the storm water drains network by analyzing DEM files. Additionally, historical imagery in Google Earth was studied to determine the age of each building. The last step was to overlay the urban area layer and the storm water drains layer to identify the vulnerable areas. The results of this study would be helpful to urban planners and government officials to make the disasters risk estimation and develop primary plans to recover the risky area, especially urban areas located in torrents.

Keywords**—**Risk area, DEM, storm water drains, GIS.

I. Introduction

THE world has witnessed a frightening increase in the frequency and harshness of disasters, with an average of 240 million people affected by natural disasters globally each year between 2000 and 2005. In 2007 alone, 414 natural disasters were recorded, resulting in the death of 16,847 people, injury or displacement to more than 211 million others, as well damage valued at over 74.9 US$ billion [1], [2].

In 2014, the number of reported disasters confirmed the global upward trend in natural disaster occurrence. This trend is generally driven by the rise in the number of informed hydro-meteorological disasters. Hydrological (essentially floods) and meteorological (storms) disasters are the main contributors to this pattern. In recent years, the number of reported hydrological disasters had been increasing by 7.4% annually on average [2], [3].

The number of people that have been affected by natural disasters from 1975 to 2000 sorted by revenue and disaster type is observed in Fig. 1 [4]. More than 95% of all losses, as a result of natural disasters, are in the smallest developed nations. The developed countries have the greatest number of people exposed to natural disasters. Floods are among the most destructive type of natural hazards that cause loss of human life and their properties around the world [4].

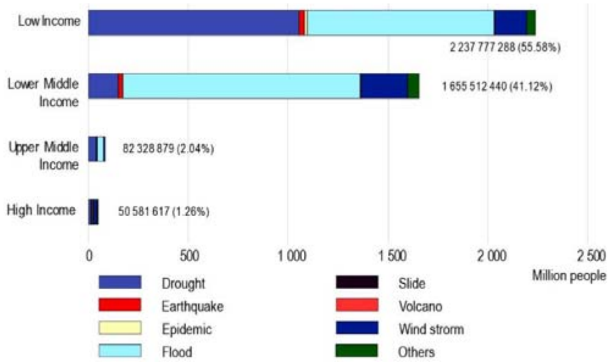

Fig. 1 World overview in the period of 1975-2000 shows the number of people affected by natural disasters categorized by income class and disaster type

A flash flood is, in brief, a sudden local flood of big volume and short period which follows within a few (usually below six) hours of heavy rainfall [5]. Flash floods are regularly characterized by powerful torrents after heavy rains that rip through river beds, urban roads, or mountain valleys, sweeping away everything before them [2], [6].

Egypt is prone to different types of disasters, for instance those resulting from natural disasters, in addition to that of environment pollution and carelessness in areas such as transportation mishaps. These crises can be separated into two types: Natural Disasters and Man-made Disasters. Fig. 2 shows a classification of the most common disasters facing Egypt [7].

Due to the failure of drainage systems in Egypt, floods in urban areas cause extensive destruction of buildings and other public infrastructure. Moreover, road flooding can limit or totally hinder the flow of traffic systems, and as a consequence, disruption to business [8]. Urbanization in flood plain areas increases the risk of flooding due to increased peak discharge and volume, and decreased time to peak [9]. Even though the occurrences of floods cannot be prevented, the negative consequences can be minimized by an integrated

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approach to flood management [10].

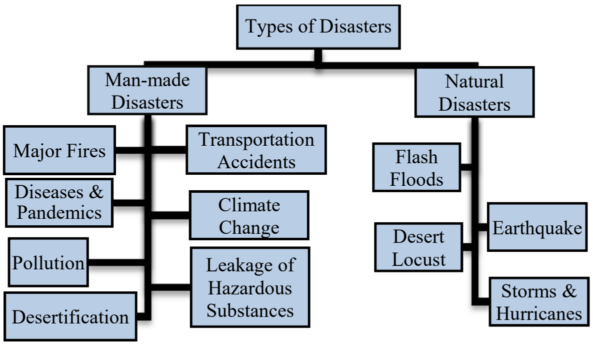

Fig. 2 The most common types of man-made and natural disasters occurring in Egypt

Surface water flooding describes the combined flooding in urban areas during heavy rainfall. As such, it includes pluvial flooding, sewer flooding, flooding from small open-channel and culverted urban watercourses, as well as overland flows from groundwater springs [11]. The presence of large sealed surfaces in urban areas (such as buildings, roads, and car parks) raises the volume of surface water runoff [12], [13]. Another element of exposure in the context of flooding is housing type. Houses with the lowermost floor at or under ground level are further exposed than dwellings located on upper floors, and inhabitants and their properties may be more meaningfully affected [14]. Construction in floodplains, canal straightening, building of dams, and construction activity creating resistant surfaces such as transport infrastructure and housing areas are samples of urbanization that increases the risk of river floods in small watershed areas and minor river networks [15].

During the last two decades, Remote Sensing (RS) has played an important role in the fields of hydrology and water resources management [16]. Geographic Information System (GIS) on the other hand has also been used extensively to model surface water [17], particularly flood and associated damage [18], [19]. RS technology, laterally with the GIS has become a main tool for torrent mapping and flood risk assessment [9], [10], [20]. RS application is however, considered imperative for third world countries because it is difficult for government to update their database frequently with the ground observation techniques because of the time and cost associated with traditional methods [4]. The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) presents a valuable source of important hydraulic or hydrologic information for large flood plains, when high precision datasets are not available [21]. Therefore, the SRTM DEM 30 m × 30 m resolution is used to define the stream network and disaggregate the watershed into a series of interconnected sub basins [9].

DEMs are an important source of information in GIS applications. It has been widely used for modeling surface hydrology including the automatic delineation of catchment areas, erosion modeling or automatic drainage network extraction [22]. Delineation of drainage network for catchments is very important for partitioning sub-basin and the application of a spread hydrologic model. Several available algorithms automatically extract stream network segments and related sub-watersheds from a DEM, which is a kind of spatial data set, which reflects topography of a river basin [23].

Similar to the hydrologic tool in ArcGIS, the Preprocessing Software has several functions such as determination of flow direction, flow accumulation calculation, drainage extraction and so on [23]. With the update of computer and information technology, disseminated hydrologic models become a research emphasis, in which watershed delineation based on DEM is the main step and priority [1]. Effective and accurate watershed delineation is the precondition of the following runoff, sediment and water quality modeling and credible results [24], [2].

(a) Houses destroyed by deluge

(b) Flood damaged urban areas

Fig. 3 Buildings destroyed in Abouelreesh village after flooding in 2010

Storm Water Drains, which are located in the east of River Nile at the region between Edfu and Aswan cities, are dangerous, particularly at the area of Kom Ombo and the east of Aswan. In May of 1979, the runoff spate had resulted in disrupting the rail lines, as well as affecting the centers of Edfu, Kom-Ombo and Aswan, which led to the collapse of some 200 houses. Moreover, the deluge flooding resulted in the deaths of three children killed by debris, as well as the displacement of around 300 families, in addition to the highway road network interrupted due to a vast landslide. These floods repeated in October from the same year, which led to the collapse of more than 300 buildings and damaging a

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large number of buildings. Moreover, deluge was accompanied by dust storms, thunderstorm, cyclonic rain and frequent floods in the years 1980, 1987, 2005 and 2010 [25], [26].

A severe hurricane thrashed the province of Aswan on the evening of 17th January, 2010, and was followed by half an hour of a continuous torrential downpour. The storm resulted in bringing down 50 high voltage electricity pylons, cutting power to Aswan province. After that, rains which had accumulated in the mountains turned into a torrent and swept away houses and people, leaving behind hundreds of destroyed properties. In addition, the heavy rains caused cracking in hundreds of houses, which threatened to collapse at any moment. The rains and severe storms also damage thousands of acres of agricultural lands, uprooted trees, as well as damaging tons of harvested dates which had been lying under the sun to dry. This sudden catastrophe happened at the village of Abouelreesh, which is located at a distance of five kilometers north of Aswan adjacent to the Red Sea Mountains at a length of 500 meters north-south and at a depth of 1300 meters east-west. Houses built east of the railway, and those areas on the slope of the mountain were most vulnerable to the flood deluge. The administrative authorities had been alerted to the danger of constructing any structures or buildings in this region and its surroundings because of the high storm water risk (Fig. 3).

(a) Roads destroyed by flood waters

(b) Buildings destroyed by flood waters

Fig. 4 Roads and buildings affected by torrents in Egypt.

Due to the lack of other available areas, people have been forced to build their houses in this region and settle there. The damage caused by the 2010-hurricane was not severe, as there were not many residences there at that time [27]. Around 20,000 people were living in this region. The torrents that resulted from the disaster caused in the complete demolition of about 25 houses and partial demolition of about 50 homes. Most of the demolished homes were built from stone and mortar clay.

Away from the city of Aswan, Abu Spirh village is located about 15 kilometers to the north, then eastward about 4 kilometers, and inhabited by tribes called Ababdh. This village has a population of approximately 3000 people. Assessing the total damage caused by the hurricane confirmed that 10 houses were completely destroyed, while about 30 were damaged, along with large tracts of agricultural land and the uprooting of many trees (see Fig. 4) [26].

This paper aims to identify risk areas which are prone to deluge from storm water drain networks then overlay this layer with the urban area layer to classify those urban areas belonging to one of two groups, the at risk area and the safe area.

II. Study area

The study area (Northern Abouelreesh village) is located in the city of Aswan in southern Egypt, which lies between longitude 32°52'E to 32°55'E and latitude 24°10'N to 24°14'N. Limiting the study area to the east of the mountain and from the west was agricultural areas and River Nile (Fig. 5).

Fig. 5 Location of the study area in Egypt

The official total area of urban spaces in the village of northern Abouelreesh is approximately 453.01 acres in 2010. This area includes the roads and pathways and urban spaces with area estimated to be 106.11 acres, while the area for land space (private property) is about 67.33 acres. Also, this area includes desert land with an area of approximately 126.25 acres and farmland of about (4.73) acres. From around 9,896 inhabitants in 1986, the population of the village was rose to around 12,206 in 1996, and to 13,189 by 2006, representing an annual growth rate of 2.12% for the period 1986/1996, which fell to 0.78% per annum in the period 1996/2006. The average of growth rate was 1.45% per annum in the period 1986/2006. The total population of the village in 2010 was 14,202, which consisted of 3,204 families and an average family size is about 4.16 people [27].

III. Methodology

GIS is widely used to support water quantity and quality studies. GIS and DEM can been used to perform watershed delineation and Storm Water Drains at points in areas of interest. This paper presents the methodology that used DEM files to identify a Storm Water Drain network. As a result, Storm Water Drains can been delineated quickly and with consistent time response, regardless of the DEM size.

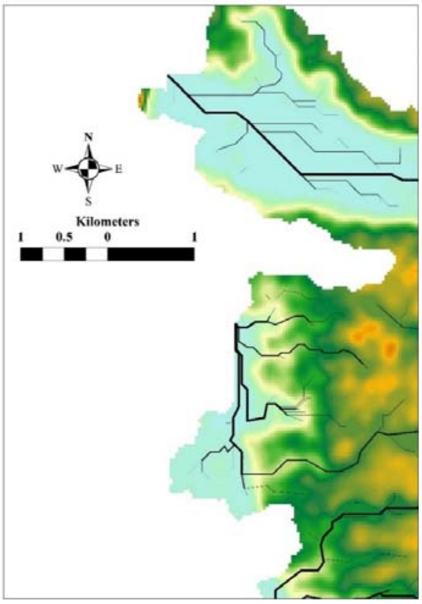


Fig. 6 DEM file and water streams

The research methodology attempted to determine the urban areas under risk and was conducted in two steps. Firstly, the risky areas were identified based on the storm water drains network. DEM files were used to delineate the storm water drains network. In the case study area, different analysis tools in hydrology toolbox in Arc GIS were exploited (Fig. 6). Secondly, the detailed master plan of the study area was updated by Google Earth. These maps determined the approximate periods for buildings that have been constructed by observing changes during the display of historical images [28].

Storm water drains can be delineated in GIS by initiating the flow direction and number of upper stream points for keeping all grid point in DEM files. Once the watershed is delineated, it can then be used to crop out data from added layers (e.g. land cover, area, etc.) that are valuable in hydrology [2], [29]. As shown in Fig. 7, we will use the spatial analyst extension in ArcGIS in the following steps.

After conducting the analysis using the hydrology toolbox, the Storm Water Drains network that affected the case study area was determined. During the rains, the Storm Water Drains are the riskiest among all areas which means that the urban areas located in the path of Storm Water Drains will be at high risk from excess rain waters.

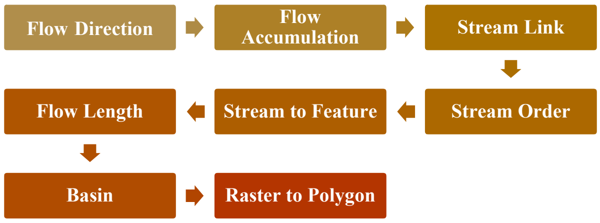


Fig. 7 The steps to get watershed and water streams from DEM file [30]

IV. Results and Discussion

ArcGIS was used to match between storm water drains (risky area) and the layer of urban area. The urban area can be divided into two groups. The first one intersected with storm water drains that are under risk of flooding and is called the risky area. The second one also intersected with storm water drains but is considered safe from excessive rain water, it called safe area (Fig. 8).

The risky area group comprises of about 4.79% of the total urban areas in 2001. The area increased to 9.76% and 14.26% in 2005, 2009, respectively. Finally, it decreased again to 11.70% in 2013, which is the highest percentage of urban areas located in risky areas, as shown in Table I.

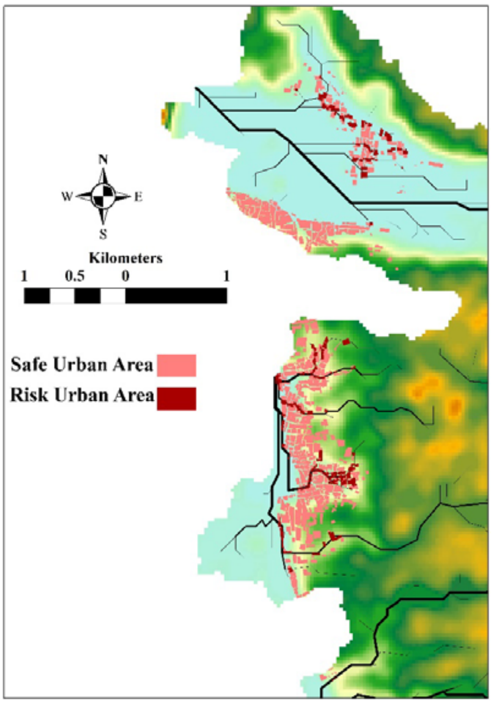


Fig. 8 Relationship between risk area and urban area

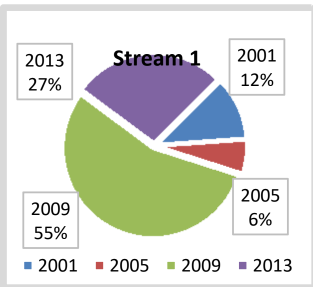
Urban areas in the risk area were distributed according to three categories based on the storm water drains name, as shown in Table II. In the risk area, urban area allocated in the second drain was the biggest category, occupying 8.9 ha or about 62.96 % of the total risk area. The second value was the urban area located in first drain and occupied 5.23 ha or about 36.83%, while urban areas in the third watershed were the smallest category in the risk area.

TABLE I
URBAN DISTRIBUTION IN RISKY AND SAFELY AREAS

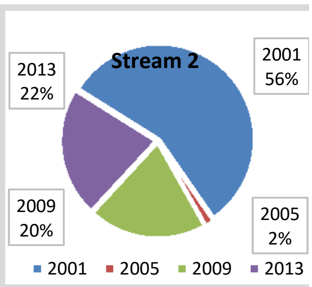
Urban Area	2001		2005		2009		2013		Total Year	
	(%)	ha	(%)	ha	(%)	ha	(%)	ha	(%)	ha
Crossed with Drains	4.79	5.65	9.76	0.45	14.26	4.69	11.70	3.41	7.69	14.20
Non-Crossed with Drains	95.21	112.38	90.24	4.16	85.74	28.20	88.30	25.74	92.31	170.48
Total Urban Area	100	118.03	100	4.61	100	32.89	100	29.15	100	184.58

TABLE II
DISTRIBUTION OF URBAN RISK AREA

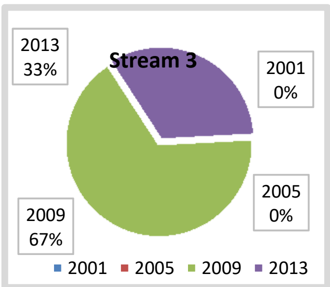
Urban Area	2001	2005	2009	2013	Total Year
Stream 1	0.59	0.32	2.88	1.44	5.23
Stream 2	5.05	0.13	1.79	1.97	8.94
Stream 3	0	0	0.02	0.01	0.03
Total risk Area	5.64	0.45	4.69	3.42	14.20



(a) Urbanization in stream 1



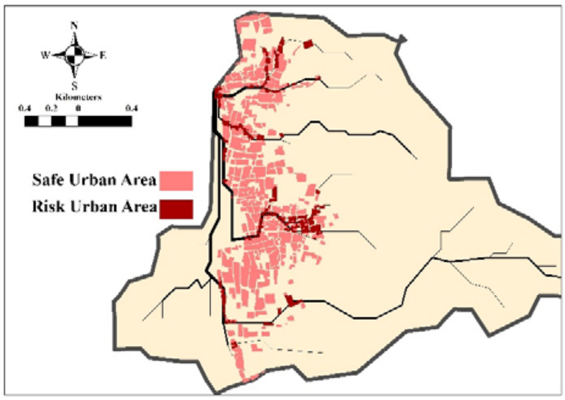
(b) Urbanization in stream 2



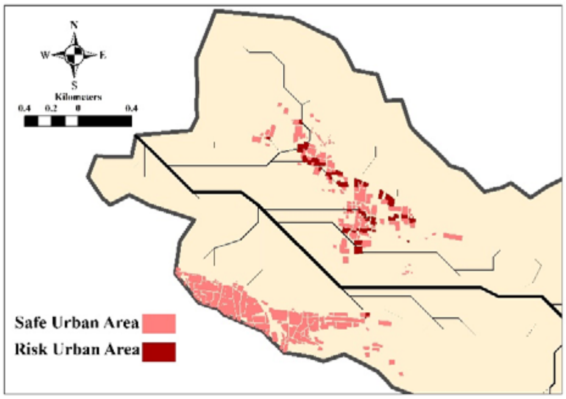
(c) Urbanization in stream 3

Fig. 9 Percentage of urbanization by years

Fig. 9 shows the percentage of urbanization for each year of the study period. In stream 1 it can be observed that the biggest percentage of urban area was built in 2009 and consists of about 55%, while the smallest urban area built in stream 1 was 6% in 2005. The percentage of urban area totally changed in stream 2, from the highest level of urbanization (56%) occurring in 2001, to the smallest percentage of urban area built (2%) in 2005. The situation in stream 3 was very different; here, the urbanization happened in only two periods: 33% of the urban area was built in 2013 while 67% at risk urban area was built in 2009.



(a) Urban area crossed by stream 1



(b) Urban area crossed by stream 2

(c) Urban area crossed by stream 3

Fig. 10 Location of buildings that crossover the storm water drain

V. Conclusion

After studying urban growth in Abouelreesh village in each of the following years 2001, 2005, 2009 and 2013, all urban areas were assessed to determine the ratio in each of the safe areas and at-risk areas. The results of the study found that Abouelreesh village has seen rapid development in high-risk areas; that is, urban areas in high at-risk areas consisted of 5.95 ha in 2001, rising to 10.79 ha in 2013. This situation threatens the future development of the village. On the other side, the government should develop a plan to manage the risk in these risky areas with the provision of alternatives for the population to avoid construction in unsafe areas.

The availability of residential land is one of the most important factors that attracts urban growth into certain areas. This factor can explain why the average area of buildings in the study area increased into risky areas more than the safe areas, as shown in Fig. 10, where the characteristics of the land available in the designated risky areas have an easy terrain and covers vast areas.

Urban growth in risky areas took place not only because of people's need for bigger houses, there was also a very important reason related to government policies that encouraged people to build in high-risk areas by providing them with services.

Some of the towns and villages in Aswan Province are exposing to the risk of natural disasters. The urban growth in the risky areas that prone by torrents requires studying the behaviors of urbanization. In addition, the behaviors of urbanization should include the relationship between the urban areas and the risks; moreover, it is important to find solutions to protect urban structures from torrents risks and to study the causes of urban growth into risky areas and try to avoid it.

Abouelreesh village is facing the problem of the significant growth in areas at-risk of floods. Therefore, more studies are required to find solutions in order to redirect the urbanization toward safer areas. These studies will provide the means to manage the risks of storm water drains in the village.

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