CASE STUDY

Integration of Remote Sensing and GIS for modelling surface run-off:

Case studyof Marbeea-Alshareef, SharqElneel, Sudan.

Abstract:

This study investigates severity of floods influencing Marbeea-Alshareef, SharqElneel, Sudan. The hydrological and topographical models of the area were integrated to point out the causes of the floods in the study area, along with adaptive and mitigation measures needed to avert these hazards. The integration was based on the digital elevation model. Data processing and analysis were carried out using QGIS hydrological modules and Google Earth on-line GIS facilities. Findings proved the study area is directly affected by small catchment area (182 km2) and indirectly by a large one (1386 km2). The core drivers of flooding events could be attributed to man-made features (highway and irrigation canal) and the low topography of the study area. Floods in the area can only be mitigated by establishing an efficient drainage network in the man-made features. Integration of topographical and hydrological models is important for pointing out the core drivers of flooding events.

Key words: Floods, catchment area, irrigation canal, highway, topographical model, hydrological model.

1. Introduction.

Water is very important for life and rain-water represents an important water source world-wide in general and rural areas in particular. However, most of the world areas are affected by surface run-off floods. Most of the countries are affected by these surface run-off flooding disasters, especially in the under-developed areas. Typical examples are the Sudan floods in 2007, 2013, 2014 and 2016, [1], [2], [3], [4]. Bangladesh, 1987, 88, 89, 93, 98 and 2000, [5]. Somalia November, 2019 [6]. Pakistan July, 2022 [7] etc. "The observed increase of direct flood damage over the last decades may be caused by changes in the meteorological drivers of floods, or by changing land-use patterns and socio-economic developments" (F. Elmer et al., 2012). However, for the study area the flood damage is mainly caused by the accumulation of highway and irrigation canal backing-up water in the low study area. Usually this water remains stagnant for days depending on the volume of the surface run-off water. In the floods of 2013 the water level reached the second buildings level in some parts of the area.

However, the effort made in this paper is devoted to the role of integrating remote sensing data with geographical information system facilities for mitigating, floods disasters effects in affected areas and providing preventive measures for new developed areas.The investigation was based on the integration of the geographical and hydrological models of the study area

to point out the main causes of the run-off floods and suggest solutions for existing problems and preventive measures for newly developed areas.

1.1The study area.

The study area lies in SharqElneel locality, Khartoum state, Sudan. It is a residential area called Marbeea-Alshareef and bounded by an agricultural area in the north direction, an irrigation canal in the west direction and a highway in the south west direction. In the east and south east directions the area is bounded by residential areas running in the direction opposite to the natural drainage direction.The natural drainage of the study area runs from the north east to the south west towards the Blue Nile River.Some drainage elements are constructed along the highway. The location of the study area and its main topographical and man-made features are presented in figure 1.

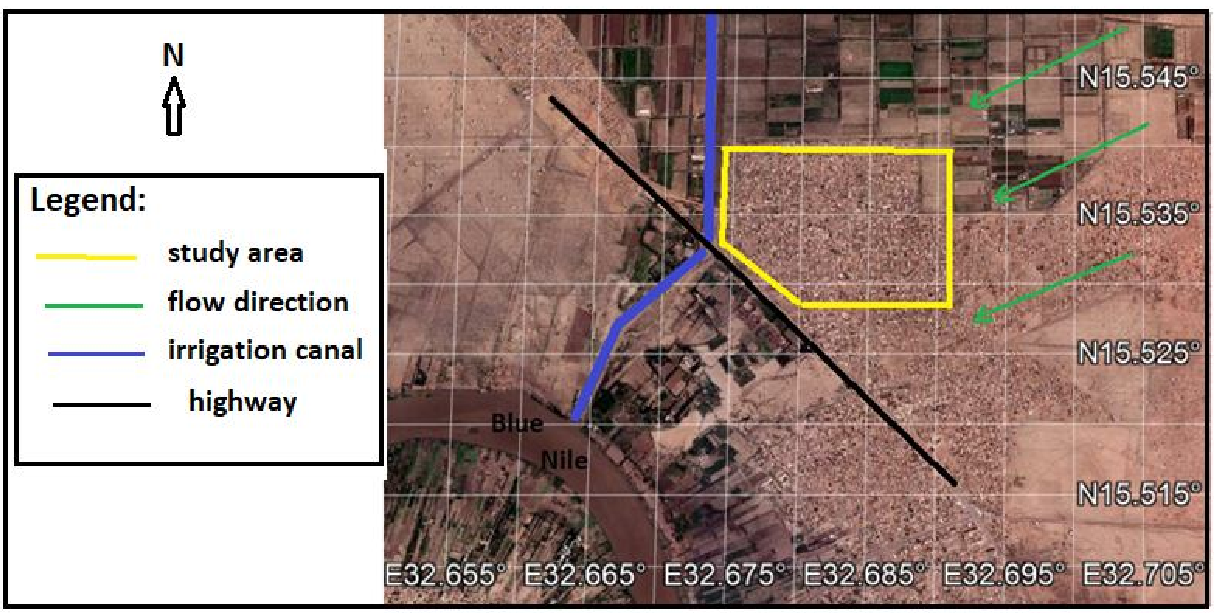


Fig 1: The study.

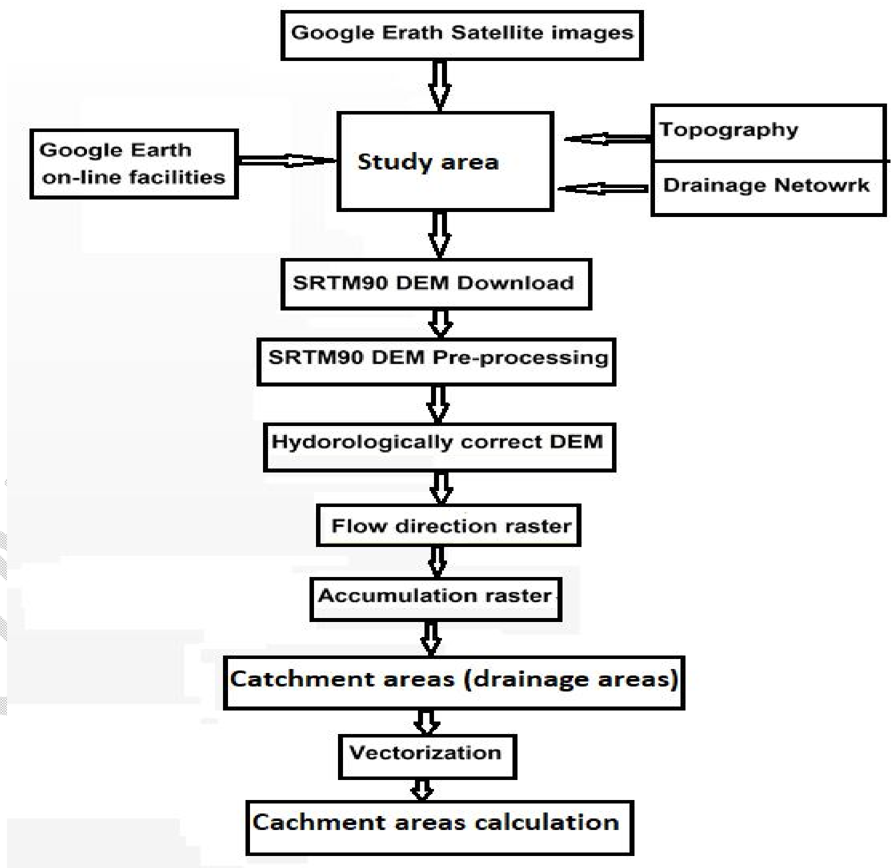
1.2Research objectives.

The primary purpose of this study was to address the research question on why the study area is highly susceptible to floods, compared to other areas in the entire residential area.

2. Methodology.

The research methodology used in the investigation was as follows:

1- The main man-made and natural features in the area were identified using Google Earth photos and on-line GIS facilities (geographical model of the area)
2- The hydrological model of the area was formed using its SRTM90 digital elevation model [9]and the hydrological modules in QGIS application program, version 3.22.1 [10].
3- The main catchment draining areas affecting the study area were identified and their geometric information was derived (Flow chart 1).
4- The topographical and hydrological models parameters were integrated to answer the research question.



Flow chart 1: Data processing and derivation of the catchment areas.

3. Data analysis.

Data analysis was based on the integration of the hydrological and topographical models parameters in the study area. The topographical models parameters are the natural and man-made features, topography and general slope of the area and drainage elements. These parameters were derived using Google Earth on-line GIS facilities. The hydrological model parameters are the catchment areas locations, their flow direction and areas. The catchment areas were calculated using the QGIS "Calculate geometry plugin" [11], which is based on the method of area calculation by boundary coordinates [12].

4. Results.

The hydrological model of the area demonstrated that there are two catchment areas in the vicinity of the study area, small area (182 km^2) and large area (1386 km^2). However, Figure 2 demonstrated that the study area (red) is directly affected by the small catchment area, which is not capable of causing the severe damage experienced in the years 2013, and 2016. However, though the large catchment area is not directly affecting the study area, but it is not far from it and suspected. This catchment area run-offis passing the irrigation canal (IC) first on its way to the Blue Nile which the natural drainage out let for the whole area. To reach the Blue Nile this catchment area run-offshould also pass the highway (HW). The very important question is that, is it possible for this large volume of water to pass through the irrigation canal and the highway. The answer to this question requires an investigation of the drainage elements associated with these features.

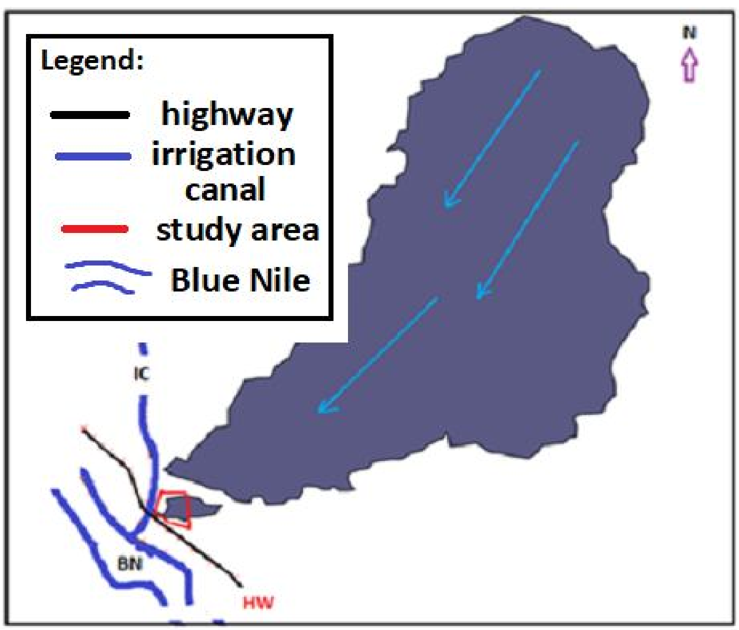


Fig2: The catchment areas affecting the study area (solid blue).

4.1Highway and irrigation canal drainage elements.

Figure 3, clearly demonstrated that the large catchment area run-off will be blocked by the irrigation canal, back-up and flow parallel to the canal through the study area (yellow) on its way to the Blue Nile, causing flood crises. The situation even get worse when the running water blocked by the highway with an embankment 2.7 meters high, with a very limited drainage elements which are not capable of passing this large volume of water.

The draining elements in the area were explored using Google Earth on-line GIS facilities. Three elements were identified in the highway (marked red H). One large culvert (27x5 meters) and two small culverts (7x3 meters). There are no draining elements in the irrigation canal and it is surrounded by agricultural areas and has an embankment three meters high approximately (Figure 3).

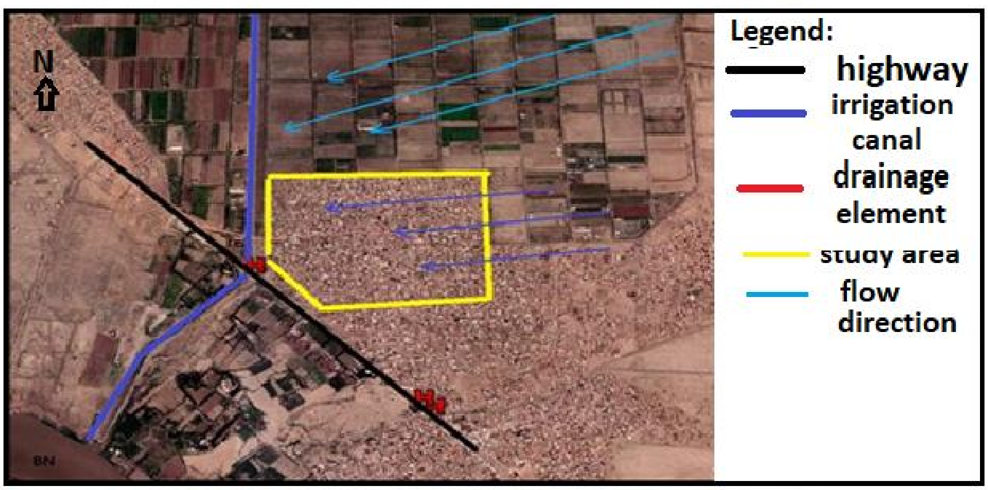


Fig 3: The drainage elements in the study area.

5. Discussions.

The result is that the run-off water blocked by the irrigation canal and the highway will back-up and accumulate in the low areas. As demonstrated by Figure 4, the study area (yellow) is the lowest area in the investigated area. This explained why the study area was the most severely affected by floods in 2007, 2013, 2014 and 2016.Normally, these floods cause a serious damage in the study area, in the form of fully and partially damaged houses and properties and losses of lives [13], [14].However, the investigation clearly demonstrated that the floods in the study area are mainly attributed to the man-made features and to some extent to the low topography of the area. Though the study area is

low compared to areas in its vicinity, it will not be severely affected by surface run-off if the irrigation canal and the highway are not present. In the absence of these features the surface run-off will follow the natural drainage course to the Blue Nile and the study area will be subjected to the small catchment area only.

Fig 4: Google Earth topographic data of the study area.

5.1Demonstration of the irrigation canal and highway effects.

The large culvert was located in the highway at its intersection with the canal (Figure-3). Figure 5, demonstrated the strong effect of these two man-made features on the study area. As mentioned before the surface run-off from the large catchment area hits the canal and back-up following the natural drainage course in the direction of the Blue Nile. The bulk of this water runs by the side of the canal creating a very wide (30-40 m) and deep (2-3 m) water course by erosion. This water hits the highway and accumulate due to the lack of an efficient drainage network. The result is that the water back-up again and accumulate in the low areas. As demonstrated in Figure 4, the study area is the lowest area in the vicinity. Thus it was severely affected in all of the past floods.

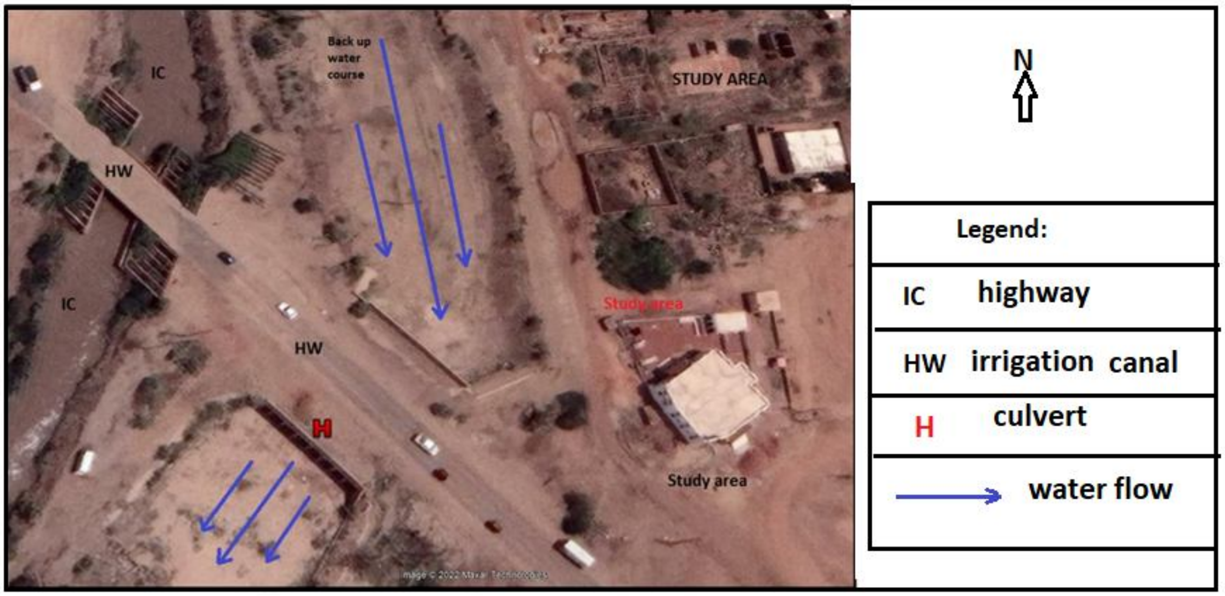


Fig 5: The effect of the irrigation canal and highway.

6. Conclusions.

The results obtained and the discussions made in this investigation demonstrated that the severe floods affecting the study area are attributed mainly to the two man-made features (highway and canal). If these are not present the study area will be affected by the small catchment area only and the large catchment area run-off will follow its natural drainage course to the Blue Nile. This clearly indicated that whenever, there is a heavy rain in the area the study area will be flooded. . Floods in the area can only be mitigated by establishing an efficient drainage network in the man-made features. The investigation also, demonstrated that the integration of remote sensing and GIS can play an important role in the surface run-off flooding disasters.Findings demonstrated the importance of integrating topographical and hydrological models to point out the core drivers of flooding events. Government and non-government organizations are making an appreciated effort related to flooding disasters world-wide. However, this effort is mainly in the form of relief aids. It is high time to devote some of this effort to investigations related to pointing out the core drivers of these flooding events and the preventive measures. This can be applied to the existing affected areas to mitigate floods and newly developed areas to provide floods preventive measures.

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