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Implementation of a hydrologic model and GIS for estimating Wadi runoff in Dernah area, Al Jabal Al Akhadar, NE Libya

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ABSTRACT

This study has investigated the relationship between rainfall–runoff in Dernah area, Al Jabal Al Akhadar, NE Libya. It provides flash flood hazard warnings for ungauged basins using geographic information system (GIS). The study examined the morphometric parameters of four Wadis (Wadi Dernah, Wadi Bum Safer, Wadi Al Nagah and Wadi Bir Al Yajur) with emphasis on their implication for hydrologic processes through the integration analysis between morphometric parameters and GIS techniques. Data for this study were obtained from ASTER data for digital elevation model (DEM) with 30 m resolution, topographic map (1:50,000), geological maps (1,250,000) which were checked during the field work. About 36 morphometric parameters were measured and calculated and interlinked to produce nine effective parameters for evaluating the flash flood hazard degree of the study area. The study basins are classified according to their hazards into three groups; Basins of low hazard degree (Wadi Al Nagah and Wadi Bir Al Yajur); Basins of medium hazard degree (Wadi Dernah); Basins of high hazard degree (Bum Safer). Software (SMADA 6) is applied to generate the hydrograph of subbasins of both medium and high hazard degrees. As a result of the model applied to Wadi Dernah, rainfall events of a total of 60, 70, 90, 110 and 120 mm of return periods 5, 10, 25, 50 and 100 years produce a discharge volume of 9.1×10^6, 13.5×10^6, 22.3×10^6, 34.0×10^6 and 39.7×10^6 m^3 respectively. While in case of Wadi Bum Safer the discharge volume is 22.1×10^6, 30.5×10^6, 46.1×10^6, 65.6×10^6 and 74.8×10^6 m^3.

1. Introduction

Water shortage in the Middle East could affect human welfare and the economic activity and stability in the region. Several efforts are needed to avert the expected crisis in the Middle East region and to avoid potential conflicts in the area that might arise because of water shortages. Perhaps the most important for these activities is exploring alternative renewable water sources. The planned rationalization of water usage will be painful, given that the annual per capita availability in the Middle East fell from 3300 m^3 in 1960 to 1250 m^3 in 1996 (Gheith and Sultan, 2002). An additional decline of up to 50% is expected within the next 30 years because of rapid population growth in the area (Dervis, 1996). There is an urgent need for Libya and the surrounding arid countries to develop alternative water resources. The study area is important part of Al Jabal Al Akhdar, NE Libya (Fig. 1) which belongs to arid and semi-arid regions that is characterized by scarcity of historical and measured of hydrological data. Groundwater in the karstified Eocene and Upper Cretaceous limestone aquifers could potentially provide an alternative renewable water resource in the concerned area. Networks of minor Wadis dissect this area and collect rainfall as surface runoff in the main valleys and as groundwater in limestone aquifer.

In such regions, forecasting of flash flood events is very difficult challenge. This study tries to apply an approach to analyse the drainage basin and to determine the flash flood prone basins based on the integration between morphometric parameters and geographic information system techniques (GIS), as well as we develop a hydrologic model that simulates high-intensity rainfall, initial loses, and transmission losses into dry channel. The limited available temporal and spatial rain guage data were used to provide conservative estimates of the renewable groundwater resources of the limestone aquifers especially the Eocene one.

Flash floods can develop rapidly in the catchment without warning leaving many deaths and loss of many millions of dollars.

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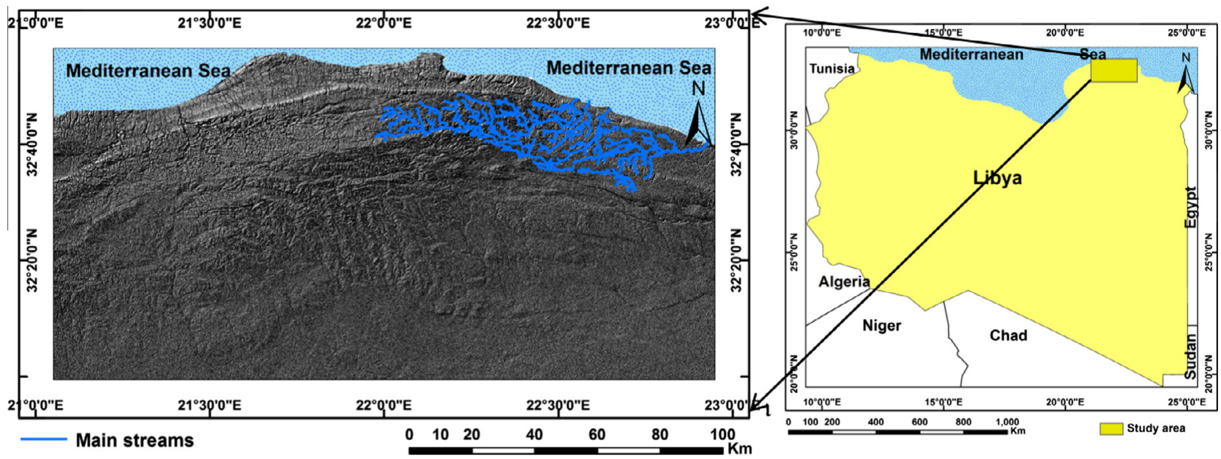

Fig. 1. Location map of the study area.

The study area is a coastal area and receives thousands of people, so it is very important to assess the flash flood of this area to create flash flood guidance. This flash flood guidance is formulated in the flash flood mapping and potentiality of recharge areas. Flood hazard mapping is very important for the sustainable development of the water resources and for the protection from the flood hazard and drought. Rainfall and runoff data are the essential hydrological elements in the flood mapping of basin systems (El Bastawesy et al., 2013). The study area is suffering from the scarcity of data and the flood inundation maps are dependent on the topographic and geomorphic features of the study Wadis (Sen et al., 2012). Flash floods often occur in arid regions as a consequence of excessive rainfall which occasionally causing major loss of property and life (Subyani, 2009). Flood hazard mapping is needful component to appropriate land use in the flooded areas. It creates easily read, rapidly accessible chart and maps which mitigate their effect (Bapalu and Sinha, 2005). Flood hazard mapping in arid regions is an extremely important but difficult task, the main reason is the scarcity of data in arid regions.

The integration of GIS to create flood hazard maps and disaster decision support has been continually upgraded and widespread since beginning of 21st century, as a result of the increased availability of spatial databases and GIS software (Zerger and Smith, 2003; Wade et al., 2012). Several studies were cited in the literature, relating to flood hazard mapping and zonation using GIS (Sui and Maggio, 1999; Merzi and Aktas, 2000; Guzzetti and Tonelli, 2004; Sanyal and Lu, 2006; He et al., 2003; Fernadez and Lutz, 2010).

The application of geomorphological principles to flood potential or flood risk has led to a noteworthy amount of researches, attempting to identify the relationships between basin morphometric and flooding impact (Patton, 1988). Identification of drainage networks within basins or sub-basins can be achieved using traditional methods such as field observations and topographic maps, or alternatively with advanced methods using remote sensing and Digital Elevation Model (Macka, 2001; Maidment, 2002; Masoud et al., 2013; Masoud, 2014).

Numbers of studies have applied the transmission losses in similar conditions from the point of view of arid to hyper-arid environment, hydrologic characteristics and geologic setting. Savard (1997) evaluated the relationship between stream flow records and measured water levels in nearby wells in Forty mile Wash in Yucca Mountain, Nevada. Abdulrazzak and Sorman (1994) provided equations to derive transmission losses knowing inflow volume, active flow width, and antecedent soil moisture measurements.

The magnitude and frequency of recharge from ephemeral streams is dependent on the amount of water loss through infiltration into the Wadi bed as the flood wave progresses in the downstream direction. Alluvial channels usually infiltrate large volumes of flood flow. The amount of abstraction, which represents the cumulative infiltrated volume, depends on the soil profile, certain physical conditions, and rainfall and runoff characteristics. The infiltrated volume initially satisfies the soil moisture deficit and evaporation requirements, and may eventually contribute towards recharging the alluvial aquifer (Abdulrazzak and Sorman, 1988).

2. Site description

Al Jabal Al Akhdar (Green Mountain) area is a highland along the NE Libya. It is a crescent-shaped ridge attaining a height of more than 850 m a.s.l. in its central part. The northern flank consists of step-like plateaus bordered by escarpments. The southern flank dips gently towards a depression extending from Ajdabiya to Al Jaghbub, which is marked by several large sabkhas. To the east and mostly to the west, a coastal plain is well developed between the foot of the first escarpment and the sea. There are six main cities in the area; Al Abyar, Al Bayda, Al Marj, Al Qubbah, Darnah, and Shahat, and about 54 villages, in addition to scattered populations. The expected population in 2025 is estimated at 769,487 inhabitants, which considered as a pressure on the water resources of Al Jabal Al Akhdar area. The study area is located in the northern part of Al Jabal Al Akhdar area, which represents a mountain range along the northern coast of north eastern Libya, located approximately at 31°N and 23°E (Fig. 1).

The geomorphologic features of Al Jabal Al Akhdar region are largely related to tectonic events which were dominated in the area from the Upper Cretaceous to the Tertiary, and also to prevailing climatic conditions, weathering and erosion processes of the existing extensive carbonate rocks in the region (Hamad, 1999). The slope is crossed by a network of seasonal streams that flows during the rainy seasons from the north to the south to the seasonal lakes that called Balats which are flat areas represents downstream area where the surface water accumulates to evaporate.

Geologically, the exposed rocks in Al Jabal Al Akhdar consisting mainly of marine carbonate rocks ranging in age from Late Cretaceous to Quaternary (Fig. 2). Late Cretaceous outcrops are only present in northwestern parts (Dernah area). Tertiary outcrops are partially buried under widespread and thick Quaternary deposits that cover the other parts in the study area. The description of the different formations can be summarized as following: