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ASSESSMENT AND MANAGEMENT OF FLOOD RISKS AT THE CITY OF TABUK, SAUDI ARABIA

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Computer technology has recently been developed to convert maps into a computer-usable digital format and allow the simultaneous manipulation of both the geographic spatial data and related attribute data. In this context, digital elevation model (DEM), aerial photographs and aeromagnetic data sets have been analyzed and used to understand the drainage pattern and wadeis distributions around the city of Tabuk in the northern side of Saudi Arabia. This work provides basic information for preliminary flood risk assessments and flood hazard mapping. The results and analysis of this study to some extent will help planners and citizens to quickly and efficiently create and test alternative development scenarios and determine their likely impacts on future land use patterns and associated population and employment trends, thus allowing public officials to make informed planning decisions.
Key words: flooding, flood management, flood risk assessments, flood hazard, geographical information system (GIS).

Procjena i upravljanje rizicima od poplava u gradu Tabuku, Saudijska Arabija. Računalna tehnologija je nedavno razvila pretvorbu karata u računalu iskoristiv digitalni format i omogućila simultano rukovanje geografskim prostornim i srodnim podacima. U tom kontekstu analizirani su digitalni model podizanja (DEM), snimke iz zraka i aeromagnetski setovi podataka i korišteni su za razumijevanje modela odvodnje i rasporeda suhih korita oko grada Tabuk u sjevernom dijelu Saudijske Arabije. Ovaj rad pruža osnovne informacije za preliminarne procjene rizika od poplave i rasporeda poplavljenih područja. Rezultati i analiza ove studije do neke mjere pomoći će urbanistima i građanima da brzo i učinkovito stvore i testiraju alternativne razvijene scenarije te odrede vjerojatnost njihova utjecaja na buduće modele korištenja zemljišta i pripadajuće trendove stanovništva i zapošljavanja, te tako omogućiti javnim službama donošenje planiranih rješenja.
Ključne riječi: poplava, upravljanje poplavom, procjene rizika od poplava, opasnosti od poplava, geografski informacijski sustav (GIS).

INTRODUCTION

Floods are the major disaster affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems. It causes damage to lives, natural resources and environment as well as the loss of economy and health. The impact of floods has been increased due to a number of factors, with rising sea levels and increased development on flood plain.

Flash floods are caused by slow-moving weather patterns (convective systems) that generate intense rainfall over the same area. Important contributing factors include topography and soil condition: The water is concentrated into a small area without getting absorbed into the soil [1]. During such an intense episode almost all the rainfall is converted into surface runoff, and if runoff is not routed efficiently or in time, flooding occurs. A flash flood is defined when flooding occurs after a few minutes to less than six hours after the intense-rainfall event [1].

Flash floods are one of the most dangerous weather-related natural disasters in the world. Flooding is the costliest and deadliest weather-related natural disaster in the United States with nearly 9,000 confirmed deaths in the 20th century [2] and more than $2 billion in annual property damage. In fact, nearly 90% of all natural disasters in the United States involve flooding [3].

Academic work suggests that the impact of such disasters is very persistent and losses are not diminishing. Gruntfest and Handmer [4] believe that losses to flash floods will rise in the future because of climate change and increases in human activities in flash flood prone areas. Losses will increase in known high risk areas unless forecasts, warnings, and preparedness are all addressed. Losses will also increase as a result of more areas becoming hazardous through unwise or unregulated urban development that affects storm water flow, runoff relationships, and patterns of human occupancy.

Urbanization is rapidly increasing throughout the world. Flooding becomes problematic when people and property reside within areas prone to flood, commonly referred to as flood plains. Floods can occur under varying conditions and in many different environments and thus affect all cross-sections of the physical, man-made and human landscapes. Given the high spatial concentration of people in the cities, even small-scale floods may lead to a considerable damage. In extreme cases urban floods can result in disasters that set back urban development by years or even decades. During the 1998 Chinese flood, over 3,000 people died, about 15 million were made homeless and the direct property damage was estimated at US $20 billion. Another example is the historic Midwest flood of the Mississippi and Missouri rivers in the spring and summer of 1993. This flood affected nine states, damaged or destroyed more than 50,000 homes, flooded over 4 million hectares of farmland, and reduced the national soybean and corn yields by 17 and 30, respectively, from their levels in 1992. Total losses as the result of the flood ranged between US $ 15 and 20 billion, although fewer than 50 deaths were reported [5].

Floods can have a massive impact on human societies. In 2000, 37% of Asia's population lived in cities and the proportion is projected to reach more than 50% by 2025. Unfortunately, the majority of mega-cities in Asia occupy hazard-prone land. In the period 1994 to 2004 alone, Asia accounted for one-third of 1562 flood disasters. Urbanization in developing countries doubled from less than 25% in 1970 to more than 50% in 2006 [6]. Nowadays, the problem is further aggravated by low squatter settlements.

As cities and towns started growing uncontrollably, the land use pattern changed considerably, the level of settlement, drainage, the road conditions, management of solid waste etc. are not considered; nor is the location of the settlement in or near a flood plain. As a consequence of random expansion, urban hydrology is changing drastically from gradual rising discharge to a higher peak flow increasing urban flood risks and aggravating the urban environment. Under these circumstances, flood management is becoming an increasingly challenging task for urban communities and the responsible authorities to address. Unfortunately, many city authorities all over the world are not able to keep up to these challenges.

The Middle East region extends from the Arabian Gulf at the East to the Atlantic Ocean at the West. It extends over Africa and Asia. About 128 million hectares of the Arab world is dry and semi dry land (this means that 89% of the total area which amounts to 144 million hectares is dry or semi dry land). Most of this land (99 million hectares, 69% of the total area) is severely dry, with annual rainfall being less than 100 mm. The rest can be divided into two categories: (a) Semi arid land that receives about 100 to 400 mm annual rainfall. This part forms about 20% of the Arab world land; (b) The remaining 11% of the Arab world land that receives more than 400 mm annual rainfall and is outside the arid and semi arid zones. This can be summarized as in Table 1 [7].

Table 1. The Arab World land categorized according to Rainfall
Tablica 1. Arapsko tlo kategorizirano prema Rainfallu

Type of land	Annual rainfall (mm)	Area in million of hectares	Percantage of total area
Dry	< 100	99	69
Semi dry	100 - 400	29	20
Non dry	> 400	16	11
Total		144	100

The region encompasses variable topographic features varying from plane deserts to mountains to river valleys. A wide range of natural hazards are present, including drought, floods, sand dunes movement, landslides, human and animal diseases, pests, earthquakes, and urban and forest fires. Recurrent drought and floods in particular have the most severe impacts on people’s lives. Mountainous regions and their adjacent valleys suffer from unpredicted flash floods, which create massive soil erosion, land sliding and destruction to any human settlements established in their natural conduits. Flash floods can happen once every 25 to 50 years.

People may forget all about it during the long periods of drought. Desertification and drought are the most significant and recurrent climate-related hazard. Due to climate change and human-induced factors, the areas affected by drought and desertification are expanding.

Saudi Arabia is one of the driest countries of the world. Lying astride the tropic of cancer, its climate is dominated by sub-tropical anticyclones throughout the year. The northern part of the country receives some precipitation from temperate latitude low pressure systems that pass along the Mediterranean and the south gets some rain in spring and summer on the line of the Sudanese low pressure system. This rainfall is enhanced along the mountains adjacent to the Red Sea and into Yemen where up to 500 mm/year can be received. In general, amounts are low with between 100 to 200 mm/year in northern areas but dropping below 100 mm/year for most of the central and southern areas. Riyadh, the capital, has a mean annual total of 104 mm falling mainly between January and April.

Heavy wind and rains affected parts of Egypt, the Gaza Strip, occupied Palestine and Jordan on 18 January 2010, sweeping away homes, knocking out power lines and cutting roads. Torrential rains in Egypt claimed the lives of 12 people, leaving many injured and hundreds displaced by rain-induced flooding in the Sinai Peninsula, the Red Sea port of Hurghada and Aswan Governorate in southern Egypt.

A great number of houses in four regions in Egypt (North Sinai, South Sinai, Red Sea and Aswan) were severely hit by these flash floods. Some 3,500 persons (500 households) were evacuated. At least, 3,500 people (500 families) were affected or were homeless in the flash floods that happened in January 2010. Many people have lost their crops and Cattle but they were recompense by the Egyptian government through the donation account they have established for the Egyptian flash floods.

Flash Floods frequently cause loss of life, property damage and destruction. In this context, several methods have been proposed to simulate several flash flood events in the target basin. One such example is by the comparison of Global Satellite Mapping of Precipitation (GSMaP) with the monitored data of Global Precipitation Climatology Center (GPCC) at wadi basins of the Nile River in Egypt. It is founded that the GSMaP has a systematic seasonal bias as over-estimated or underestimated. Hydro-BEAM (Hydrological River Basin Environmental Assessment Model) linking with the corrected GSMaP precipitation is used to simulate several flash flood events in the target basin. The simulation has been successfully carried out indicating that the proposed model can be used to predict the flash floods in such areas. The behaviors of flash floods have been depicted revealing that the warning time of flash floods is very short. GSMaP precipitation can be reasonably used with Hydro-BEAM to predict the flash floods at wadi system.

A major risk has been illustrated by the tragic case of Bab el-Wad commune that provoked seven hundred of victims in Algeria. In November 2001, a sudden massive augmentation of rainwater's runoff caused the flood in Wed Koriche. The basin morphology and the uncontrolled urbani-zation have been the reasons of damages over seven kilometers causing economic disturbance and propagation of many infectious diseases. Aroua and Azzag study aims to pinpoint the impact of the urban development of Algiers agglomeration on the flood's risk and to demonstrate the role of urban planning process in improving security, comfort and health conditions for its inhabitants. The result reveals a number of insufficiencies in term of town arrange-ment. Such context calls obviously for some urgent measures integrating the question of water's risks in the strategy of the urban planning process.

A recent study of flood impacts was conducted on north of Iran by Rahimi [8]. According to their study, more than 170000 people in the country have annually been influenced by flood events and 242 people have lost their lives from 1950 till now. Also, average annual financial damages caused by flood events have been estimated about 220 million dollars (1980 billion RLS) which is 12.5 of total national budget in 1963 and is 15.2 of water division in that year. This data indicates increasing trend in flood event frequency as well as incurred life and financial losses in Iran.

A study on modeling flash floods in Wadi Hudain catchment in Southern Egypt by El Bastawesy [9] presents a new approach to modeling flash floodsin dryland catchments by integrating remote sensing and digital elevation model (DEM) data in a geographical information system (GIS). This discriminates parts of a catchment affected by a recent flood event from unaffected parts, using a time series of Landsat images. The SRTM3 DEM was used to derive flow direction, flow length, active channel cross-sectional areas and slope. Runoff patterns resulting from different flood events are quite variable; however the southern part of the catchment appears to have experienced more floods during the period of study (1984 to 2000), because the bedrock hill slopes in this area are more effective at runoff production than other parts of the catchment which are underlain by unconsolidated quaternary sands and gravels.

A study on the flash flood hazards and their environmental impacts on the development Shuni Tourism Center, aims to study the flash flood hazards and their environmental impacts on the development of the Red Sea coastal plain based on the rainfall records, landsat (TM) image, topographic, geologic maps and field observation. The studied four hydrographic basins focused their morphometric analysis in terms of linear, areal and relief characteristics; site analysis and site planning are estimated. Protection means are discussed in order to minimize the negative impacts on the natural resources as well as the proposed infrastructures that are supposed to be constructed [10].

Dawod [11] highlights the capability of GIS for quantifying and mapping the flood characteristics in the city of Makkah, Saudi Arabia. The GIS-based curve number (CN) flood estimation methodology incorporates many input datasets including land use, geological, metrological, soil, and a Digital Elevation Model (DEM). Results show that the main factors affecting the total flood volumes are the catchment area; the basin stream length, and the peak discharge. The runoff depth using a 50-years return period, range from 128.1 to 193.9 mm while the peak discharge vary from 1063 to 4489 m^3/s. The total flood volume is expected to reach 172.97 million cubic meters. The advantages of the developed methodology are precision, cost-effective, digital outputs, and its ability to be re-run in other conditions. The attained results should be utilized in governmental planning in Makkah City, and that approach should be applied to all other cities in Saudi Arabia.

A study on determination of flash floods in WesternArabian Peninsula conducted by Sirdas, and Şen [12] presents a combination of isohyetal map, kinematic wave, and rational methods for estimating flash flood synthetic hydrographs in arid regions. These techniques are combined for the calculations of time of concentration and synthetic flood hydrograph. This empirical approach relates flood peaks to the average temporal and areal intensities of storm rainfalls. Hydrograph peaks yield practically reliable estimations of the observed flood magnitudes from individual storms. It is observed that the time of concentration of the floods is a function of the catchment size, slope, geology, soil types, and topography. In addition, it is influenced by rainfall intensity, duration and distribution.

The large and often devastating impact floods have on human lives is of great concern in flood studies. Rahman [13] suggested a Monte Carlo simulation technique to derive flood frequency curves. Yang and Yu [14] proposed a probability-based rainfall-forecasting model to predict rainfall and, consequently, water flow, in advance. Todini [15] developed an integrated model for flood management and planning. The model attempts to locate areas at risk and estimates the potential flood impact.

Dutta [16] suggested an integrated mathematical model for the simulation of flood inundation and estimation of loss. Correia [17] introduced an approach that couples hydrologic and hydraulic models with GIS to determine affected areas for different flood scenarios and to assess the subsequent damage. Consuegra and Joerin [18] described an integrated application of GIS and hydraulic modeling for flood mapping in flat areas. Lanza and Siccardi

[19] discussed the role of GIS as a tool in assessing flood hazard.

Ghoneim [20] investigated the flash flood potential in the wadi El-Alam, on the Red Sea coast of Egypt. Many important basin characteristics and morphometric parameters were defined from a digital elevation model (DEM). The range of hydrograph characteristics was estimated and the flood-vulnerable sites along the Idfu-Marsa Alam road identified.

Flash floods in Saudi Arabia are observed as a yearly disaster with high magnitude of influence. A study on an assessment of flood hazard in Jeddah region was carried out by Mashael Al Saud [21] when the city, has witnessed severe flood event in November 2009. The flooded water and sediments (torrents) invaded the urban areas killing 122 people and more than 350 were missing. The study aims to identify the zones subjected to flood and then inducing the influencing factors at different levels of effect.

For this purpose, space techniques were utilized, with a focus on IKONOS satellite images, which are characterized by high resolution in identifying terrain features. In addition Geographic Information System (GIS) was also used to support space techniques. Thus, damaged areas and the mechanism of flooding process were recognized and targeted for mitigation or stricter floodplain management practices.

FLOOD MANAGEMENT

Flood management is a broad spectrum of water resources activities aimed at reducing the potentially harmful impact of floods on people, the environment and the economies of the affected regions [22]. Flood management processes can be divided into three stages: The planning stage, the flood emergency management stage, and the post-flood recovery stage [23].

During the planning stage, different alternative measures (structural and non-structural) are analyzed and compared for possible implementation in order to reduce flood damages in the region. The analysis of alternative measures involves project formulation for each measure, understanding the advantages and disadvantages of alternative project arrangements, the evaluation of positive and negative project impact, and the relative comparison of alternative measures.

Flood-risk assessment is an important component in the planning stage. Assessing flood-risk plays a crucial role in helping decision- makers to take appropriate measures that alleviate and reduce the adverse impact of floods. Since structural measures are often insufficient to reduce the Flood-risk to the required level, non-structural measures play a relevant role; these often consist of precautionary actions taken in real time, thus requiring sufficiently early flood forecasting [24].

Flash flood is increasingly common due to; land degradation, increasing climate variability, and settlement patterns. During the past two decades, major floods in 2000 to 2010 have caused significant loss of life and property in Saudi Arabia. Large-scale flooding is limited to the lowland areas of the country; however, intense rainfall causes flooding of settlements in a number of basins, particularly the Jeddah, Riyadh, Makkah, Tabuk and other areas of the kingdom. The main reason is human intervention.

As cities and towns started growing uncontrollably, the land use pattern changed drastically with more area got impervious due to constructions, carpeted roads etc. This results in change of urban hydrology from gradual rising discharge to quicker and higher peak flow. Flash floods are common in most parts of the country, especially when rains occur following prolonged dry spells continually causing property damages.

A Digital Elevation Model (DEM), or more correctly a Land Surface Model (LSM) is one of the most useful sources of information for spatial modeling and monitoring, with applications as diverse as: Environment and earth science, e.g. catchment dynamics and the prediction of soil properties; Engineering, e.g. highway construction and wind turbine location optimization military, e.g. land surface visualization, and; entertainment, e.g. landscape simulation in computer games [25].

Within the extensive flood assessment literature, linking GIS and the distributed hydrological model to flood assessment is well documented. This section highlights some features concerning the practical use of constructing a distributed hydrological modeling system incorporating remotely sensed data and digitized geographic information as well as conventional hydrological inputs. For a general overview of distributed hydrological models, we refer to, amongst others [26,27]. More specific literature concerning the computation of hydrologically sound grid-based DEM from contour lines can be found in Lu [28], Dowding [29], Gamache [30], Chaplot [31], and Fisher and Tate [32].

METHODOLOGY

The current study was carried out for the city of Tabuk and designed to investigate the potential to flood risks and to determine the areas affected by floods. To achieve the aforementioned objectives, the following methods were adopted. Digital Elevation Model (DEM), aerial photographs and aeromagnetic data sets have been extensively used and analyzed. ESRI ArcGIS® software components were used to generate sets of digital maps for the study area. Generated maps from digital elevation model include drainage lines, sub-catchments, and contour lines.

DEM map

The term "DEM" (Digital Elevation Model) can refer either to a specific elevation file format or to gridded elevation data in general. Some people use "DTM" (Digital Terrain Model) as the more general term. Digital elevation model (DEM) data files are digital representations of cartographic information in a raster form. DEMs consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. These digital cartographic/geographic data files are produced by the U.S. Geological Survey (USGS) as part of the National Mapping Program (Source: USGS).

Tremendous growth in the telecommunication and engineering industries has created a greater demand for terrain data. This data will allow engineers to plan and manage all infrastructure growth with the accuracy required by new spatial applications. Other primary applications include mobile communication, terrain visualization, cartographic analysis, slope analysis, and environmental modeling. DEMs are used often in geographic information systems, and are the most common basis for digitally-produced relief maps. Figure 1 shows the DEM maps of the northern side where the study area is located.

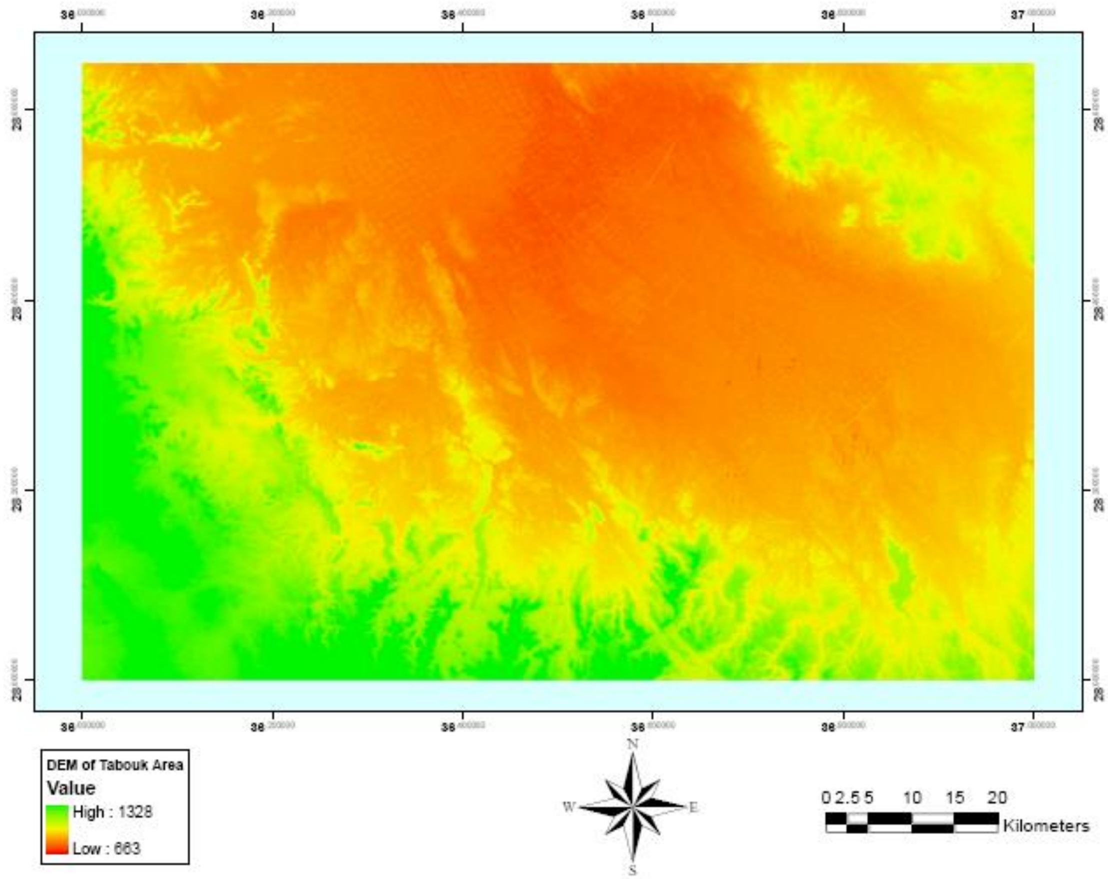

Figure 1. DEM Map of the study area
Slika 1. DEM karta istraživanog područja

Drainage pattern

The paleo-drainage mapping capability of the Shuttle Imaging Radar is evaluated by Dabbagh [33]. Drainage map of an area is a useful tool to test the lineaments in the area. The movement of water over land surfaces is an important feature governed primarily by terrain shape. The terrain shape, on the other hand, is a result of all internal and external factors that collectively shape the area. Therefore, certain characteristic drainage patterns and sudden changes in flow direction can be attributed to the fractures that are recognizable on the satellite image. Drainage networks extracted from the DEM using different thresholds are shown in Figure 2.

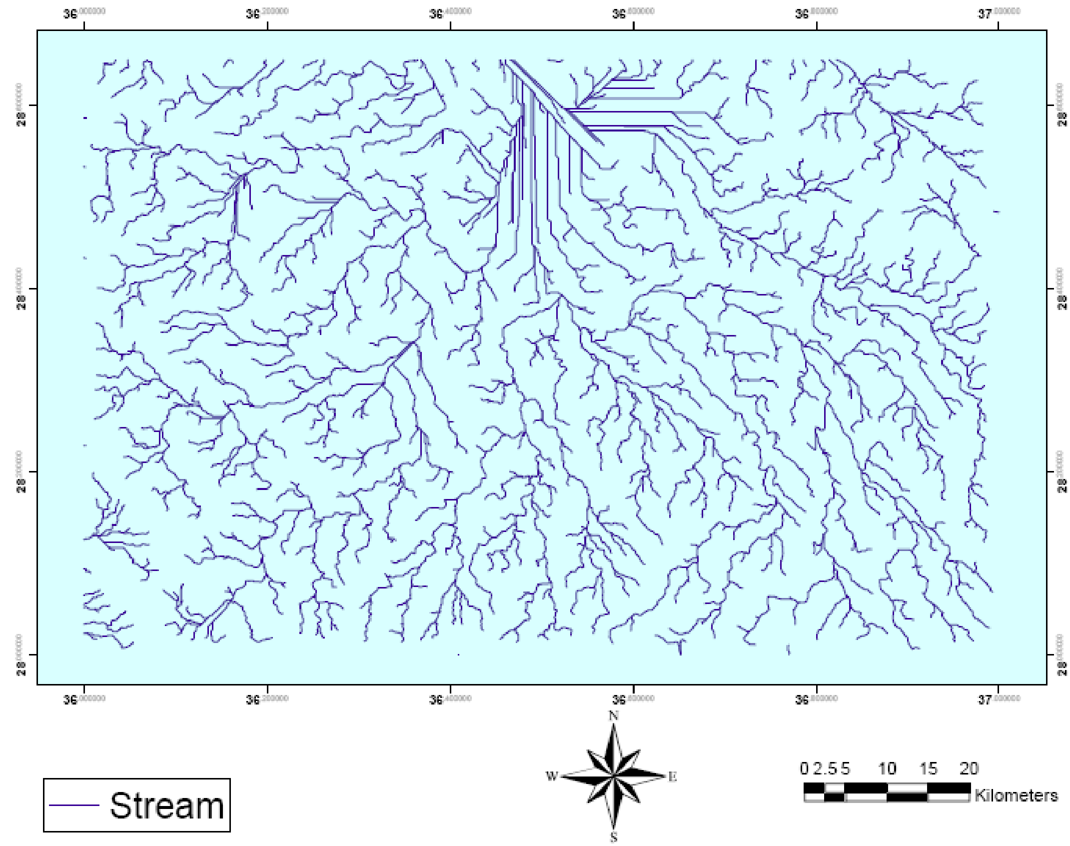

Figure 2. Drainage system of the study area
Slika 2. Sustav odvodnje istraživanog područja

Assessing drainage systems in the context of surface deformation is getting very important because they represent the witnessing of erosive and tectonic processes which may have disconnected, linearized and changed the dendritic behavior of the drainage system.

The morphology of the drainage network is clearly influenced by geological forces at different stages.

The study area features mainly two types of spatially distributed drainage patterns; major stream course changes (dendritic) and straight stream lines.

The straight stream lines patterns consists of a sudden change in the stream orientation due to the geotectonic conditions of the underlying basement rocks as shown in Figure 3. The straight stream lines patterns can be easily recognized from satellite images. The water channels thus flow through the valleys between the ridges and spurs resulting in a pattern that resembles a tree and its branches. Dendritic patterns, with channels oriented in a wide variety of directions, are commonplace in areas of nil or very slight slope, and little or no structural influence.

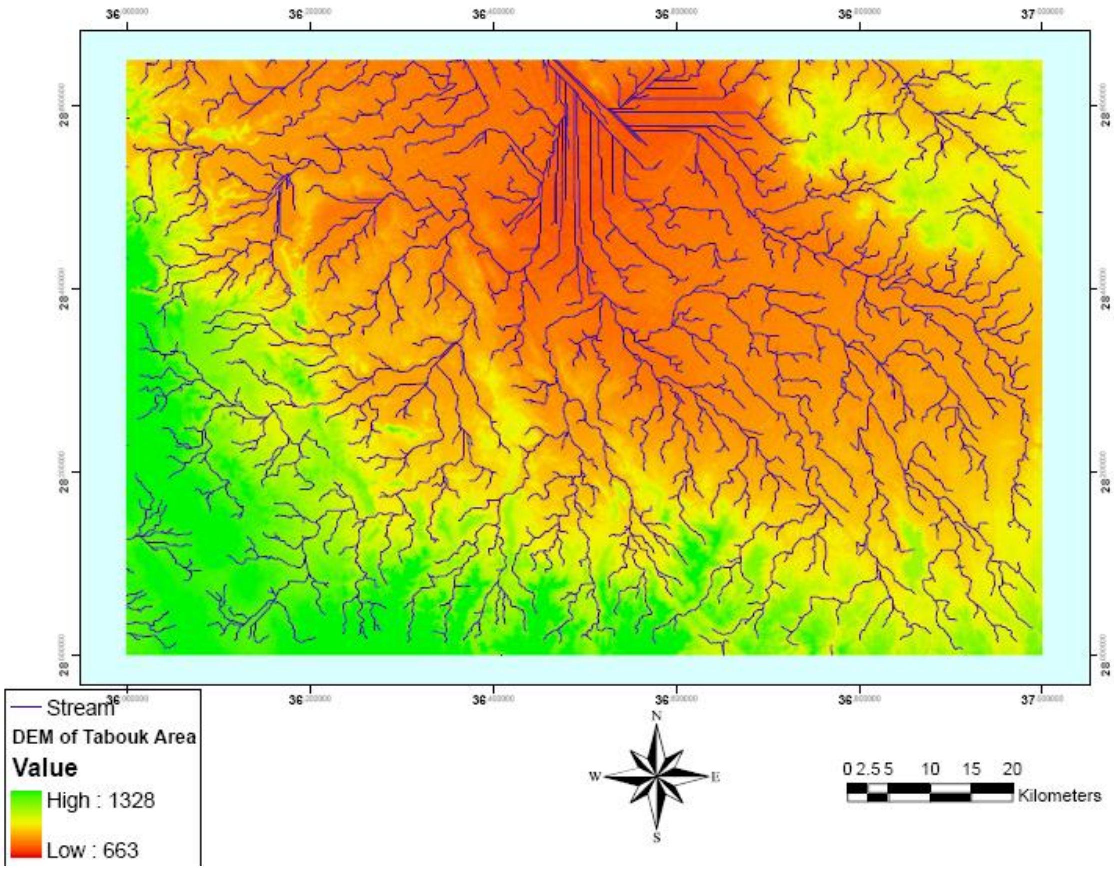

Figure 3. Drainage system combined with DEM of the study area
Slika 3. Sustav odvodnje u kombinaciji s DEM-om istraživanog područja

Flood hazard for Tabuk City

From the deduced drainage pattern, the scenario for the expected flooding directions can be easily estimated. In general there are two distinctive directions for the rainfall water, one toward the Tabouk City and the other to the east direction.

Also, by comparing the DEM and its relevant drainage pattern (Figure 3) it is easily to locate the boundaries and the wadies, valley and other lowland areas, which are considered dangerous areas during the flooding event.

More investigation for Tabuk city (Figure 4), show that the drainage pattern is helpful in determining the directions of running water and the possible locations for storing it and also, the suitable sites for dam constructions. Moreover, the decision maker can take such maps for choosing the suitable site for evacuations as shown in Figure 5.

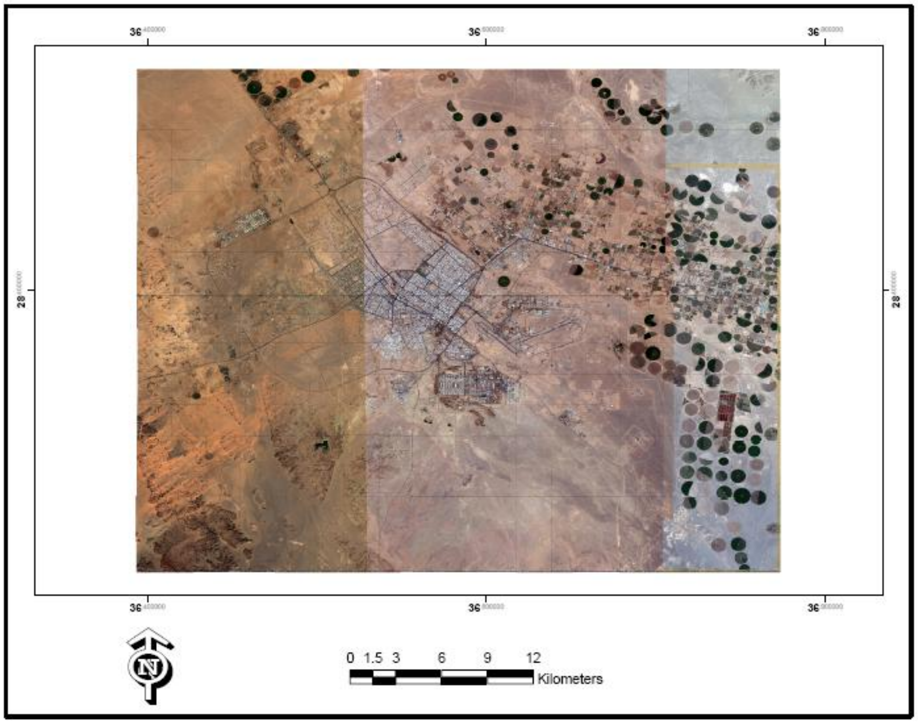

Figure 4. Aerial photo of Tabouk
Slika 4. Fotografija iz zraka Tabuka

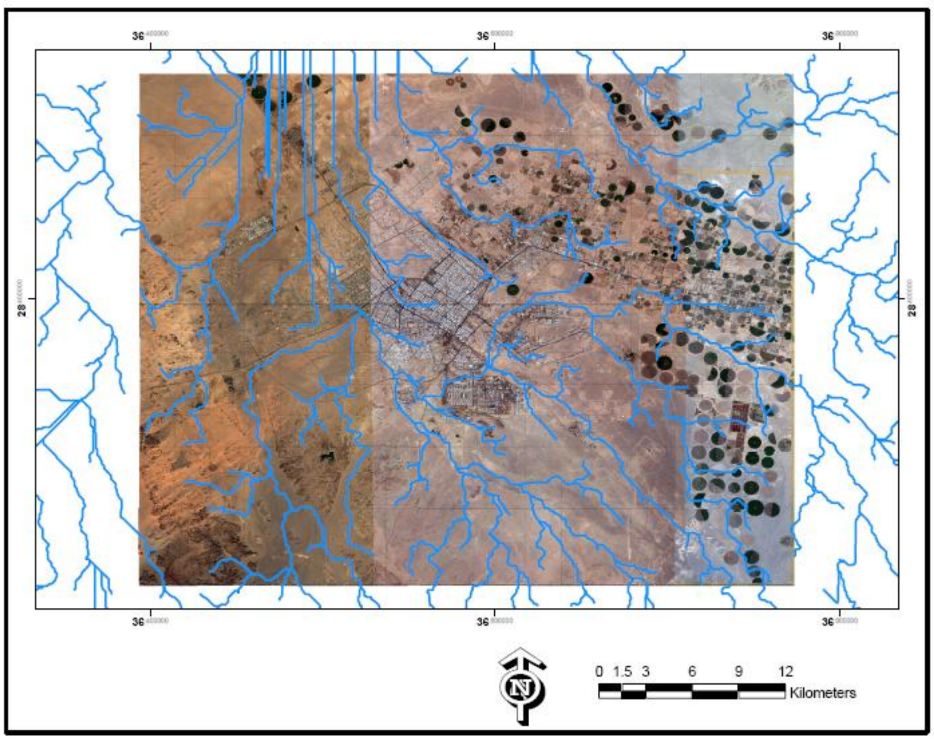

Figure 5. Drainage system of Tabuk
Slika 5. Sustav odvodnje Tabuka

RESULTS AND DISCUSSION

Data entry is the most important task of the GIS process. All the required GIS process were completed and stored as relational GIS and RS database including; data entering, scanning, layers designing, digitizing, geo-referencing, projection, and creating layouts. The application of GIS for evaluating the expected flooding hazardous in Tabuk area is very important, critical and easily done.

Utilizing different kinds of data to analyze the regional and local trends of the lineaments and drainage pattern in Tabuk area is very helpful to get a good estimation for the trends of expected flooding events and make a good scenario for the possibility of evacuation and building the protected dams. Combining the DEM and other available data sets make the process and estimating the most hazardous areas very clear and introduce a fast and reliable help for organizing rescue actions in proper time. One can visualize that the flooding susceptibility is very high in some parts of the city. Based on the SRTM DEM data, the flow accumulation and the drainage patterns provide information of the areas susceptible to flooding as shown in Figure 6.

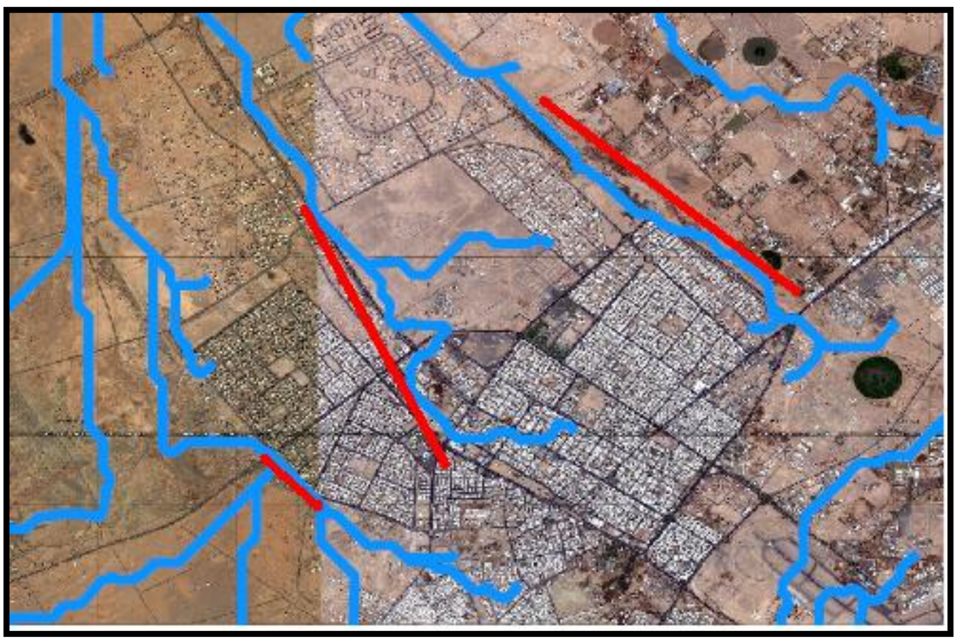

Figure 6. Expected hazardous flood location in Tabuk
Slika 6. Očekivano opasno poplavno područje u Tabuku

It was lined out previously that extreme precipitation events lead to floods in large part of the city. Figure 6 shows (red lines) the possible locations of hazardous flood in Tabuk city which had very good agreement with the actual floods as shown in Figure 7.

Therefore, flow occurring is mostly through many residential neighborhoods towards the western and southern parts of the city and thus making these neighborhoods prone to accumulation. These neighborhoods can hence be regarded as flood sensitive zones.

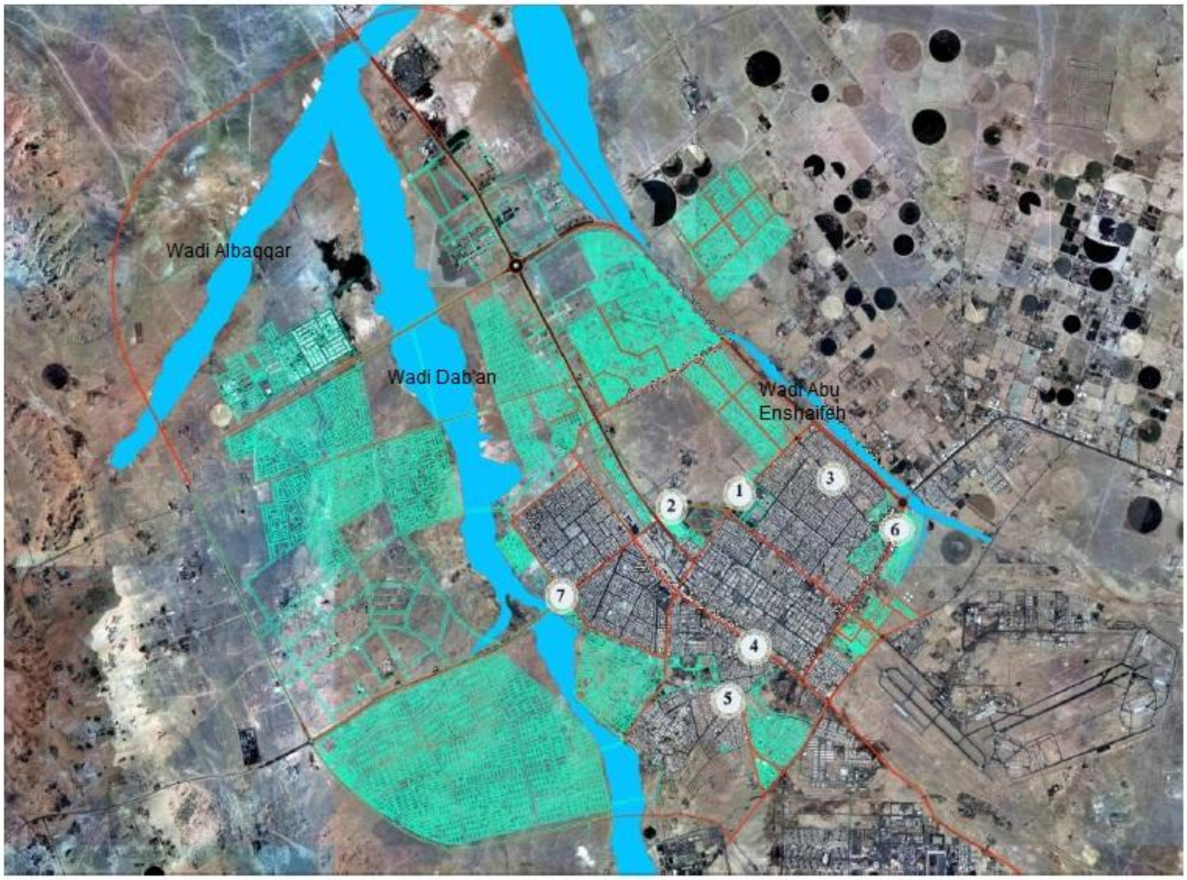

Figure 7. Actual hazardous flood location in Tabuk
Slika 7. Stvarno opasno poplavno mjesto u Tabuku

The need of protecting existing built-up stock in flood-prone areas against flood disasters is recognized. A rigorous flood disaster reduction approach would consider measures such as restricting new development or activities in the flood plain, removal of certain physical structures from the floodway and controlling land use practices within the basin. Moreover, a holistic catchment planning approach for adaptation to floods is required. Reducing flood losses must be considered using the basin as the basic planning unit. To this end, an active cooperation between local/regional authorities and water authorities is a priority.

This cooperation has to be made effective through a legal framework that embeds natural hazards in the spatial planning process.

The main outcomes of the approach presented can be summarized in two aspects. First, it facilitates ex-ante flood risk mapping as a consequence of urban development. Other factors, such as changes in the frequency and magnitude of extreme floods could also be incorporated. Second, it can assist realistic assessment of spatial planning practices synergized with spatial and technical measures for flood mitigation.

CONCLUSION

In recent years, GIS remote-sensing methods have been increasingly recognized as a means of obtaining crucial geo-scientific data for both regional and site-specific investigations. They provide a synoptic perspective that cannot be achieved by traditional field studies. In the present study, various thematic maps, namely, drainage, lineament, lithology, slope and land use have been generated using satellite images. All these techniques are efficient tools to define topography and morphological changes. Analysis of produced maps emphasized the use of Digital Elevation Models (DEM) whenever unavailable data are needed. Generated results and maps would assist engineers, decision makers and city officials to analyze and manage flood hazards, and also to formulate remedial strategy such as evacuation, flood routing and provision of water retaining structures.

The space borne satellite remote sensing technology is found to be an effective tool to disseminate the proper information in near real time basis. The results obtained from this study are illustrated in Figures 7. The methodology described in this study and the results offer several practical applications; that are of substantial interests to planners, land developers, design engineers and general public. This can also provide the basis for floodplain management programs. The following are some of the potential applications:

1. Design of flood control structures: Can be used to determine suitability of building flood control structures for prevention purposes (that is, embankment, detention ponds).
2. Design of other structures: Can provide valuable information for the design of hydraulic structures like weirs and bridges and culverts.
3. Non-structural measure to risk reduction strategy: Can provide the basis for the planning of non-structural measures for flood protection. Measures like floodplain zoning, demarcation. This can also help in the planning of the evacuation and relief routes and storing of the emergency flood relief materials and equipments.

Problems of urban hydrology may prove to be quite severe as a consequence of random expansion. However, urban hydrology is changing drastically from gradual rising discharge to a higher peak flow increasing urban flood risks and aggravating the urban environment. Under these circumstances, flood management is becoming an increasingly challenging task for urban communities and the responsible authorities to address. GIS and remote sensing techniques may be prove to be a very useful tool in analyzing situations such as the one described above.

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