Develop a Model in ArcGIS to Observe Areas Where Floods Occur

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Abstract

The rains are heavy in year 2019 which led to open the dams for both Turkey and Iran. This high level of water caused flooding in Iraq's border villages. For the purpose of finding solutions to reduce the impact of the floods, there should have been control of the movement and flow of water, indeed there was surveillance by satellite images for example a "satellite sentinel 2". But these images may not cover the entire study area or the images are for extended periods of time. Therefore, in this research, we integrated spatial images through development flowchart using the model method with program ArcGIS, through this work a clear video was obtained for the flow of water for different periods, possibility to find appropriate solutions to address flood situations by the authorities. The paper information derived proved to be essential and valuable for flood management plan and rehabilitation.

Keywords: Dams, Flash Floods, and Sentinel 2.

تطوير نموذج في برنامج ArcGIS لمراقبة المناطق التي تحدث فيها الفيضانات

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الخلاصـة

نظرا لان الأمطار كانت غزيرة عام 2019 مما أدى إلى فتح السدود في كل من تركيا وإيران. تسبب هذا المستوى العالي من المياه في حدوث فيضانات في القرى العراقية الحدودية. لغرض إيجاد حلول للحد من تأثير الفيضانات، كان ينبغي أن يكون هناك سيطرة على حركة وتدفق المياه، بالفعل كانت هناك مراقبة من خلال صور الأقمار الاصطناعية على سبيل المثال " القمر الاصطناعي سنتنال 2". لكن هذه الصور لا تغطي منطقة الدراسة بأكملها أو أن الصور لفترات طويلة من الزمن. لذلك، قمنا في هذا البحث بدمج الصور المكانية من خلال مخطط انسيابي للتطوير باستخدام طريقة النموذج التي تبرمج ArcGIS، ومن خلال هذا العمل تمكن من الحصول على فيديو واضح لتدفق المياه لفترات مختلفة مما اعطى فكرة إيجاد الحلول المناسبة لمعالجة حالات الفيضانات من قبل السلطات. أثبتت المعلومات الورقية المستمدة أنها ضرورية وقيمة لخطة إدارة الفيضانات وإعادة التأهيل.

الكلمات المفتاحية: السدود، السيول وسنتنل 2.

Introduction

Flash-floods are among the most frequent and devastating types of natural disasters around the world (Brivio, *et al*., 2002); (Diakakis, *et al*., 2016); (Jonkman & Kelman, 2005); (Psomiadis, 2016), with severe outcomes including:

a) Losses in human and animal life؛

b) Destruction of agricultural crops and loss of soil؛

c) Infrastructure damages, communications, and transport networks؛

(d) Transportation of the sediment and pollutant.

In particular, it is evaluated that floods produce about 40% of the damage result from all types of natural disasters (Ologunorisa & Abawua, 2005). Flood is known as a hydrologist phenomenon that occurs as a result of the accumulation or increase of water that is flooding the earth, the result of heavy rainfall or increasing the volume of water in a watercourse. This causes water to reach its natural limits. Flooding causes much damage to life and property. As a result of the difficulty of controlling them, the most prominent of these are the damage caused by transportation, industrial and agricultural buildings and installations, livestock, utilities and population, in addition to many economic difficulties. Water is a natural resource essential to the continuation of life and the necessities of economic and social activities for humans, as it is a scarce resource characterized by irregularity, both temporal and spatial. But climate change and global warming are major causes of floods and floods in different countries of the world. Climate change has become one of the main topics of scientific research in recent studies, after it has been a major factor in the occurrence of floods, landslides, earthquakes, volcanoes and other geological phenomena. In this study, the areas in which the floods occurred in the Sharqat area were observed through satellite images of Sentinel 2 with integrated flowchart using the GIS model method. In addition to find appropriate solutions to address flood situations.

Materials and Methods

Methodology

In this research we used two methods to determine the areas were affected by the floods during this period according to analysis and process satellite images in as the following:

1 .The Normalized Difference Water Index (NDWI) :

It is an index can be used the algorithm of spectrum reflectance from satellite images and ،

2 .Flow Water Model:

This method can be indicted the waters slopes in study area from the contour images as shown in Figure.(1)

The Study Area

The studied area is situated between two sections (35° 31' 40", 35° 29' 10") and linear (43°13' 20" and 43° ' 15" E) as shown in Figure (2). It is surrounded by hills from several sides, from the south is bordered by the hills of Khattouka, from the west bordered by beautiful hills and from the north by the hills of the Garnaf with the presence of other scattered hills (Aljazaary and Jamal, 2018). It is located at the feet of the mountains within the semi-mountainous region and is characterized by the scope of the long and narrow asymmetrical bends of the mountains of Makhoul. Al-Sharqat is a district of Salah Al-Din province in 1987 where it was previously a district of Ninawa province, to be the north and west of the province of Ninawa and the south of the city of Baiji and the eastern province of Kirkuk and Erbil. The Al-Sharqat city was built on the remains of

the historic city of Ashur, with its municipal borders to the north, the village of Huraira, the Tigris River to the east, and the village of Sabkha to the south.

Climate Study Area

The climate of Saladin province is 90% of the annual rainfall between November and April, and the concentration is in the amount of rain during the winter months, from December to March, and the other six months are dry and hot especially in June and August. And Tews. There are such climatic characteristics where rainfall is low and temperatures are high. Some parts of the province can be considered desert areas where soil and vegetation lose their moisture from rainwater quickly due to high evaporation rates. The province of Salah Al-Din from the provinces of the major climate changes in Iraq.

Data Used

The data used in this study are the Sentinels 2, data which they have become available thanks to the policy of open data from Space Agency ESA. Generally, for flood mapping, two at least images of remotely sensed data are required: one image acquired pre-flood event and the other acquired post-flood occurrence. Two images of Sentinel 2 data sets were downloaded from ESA's Open-access-hub (https://scihub.copernicus.eu/) at 18 Nov, 2018 and 28Nov. 2018, to cover all the study area as seen in Figure (3).

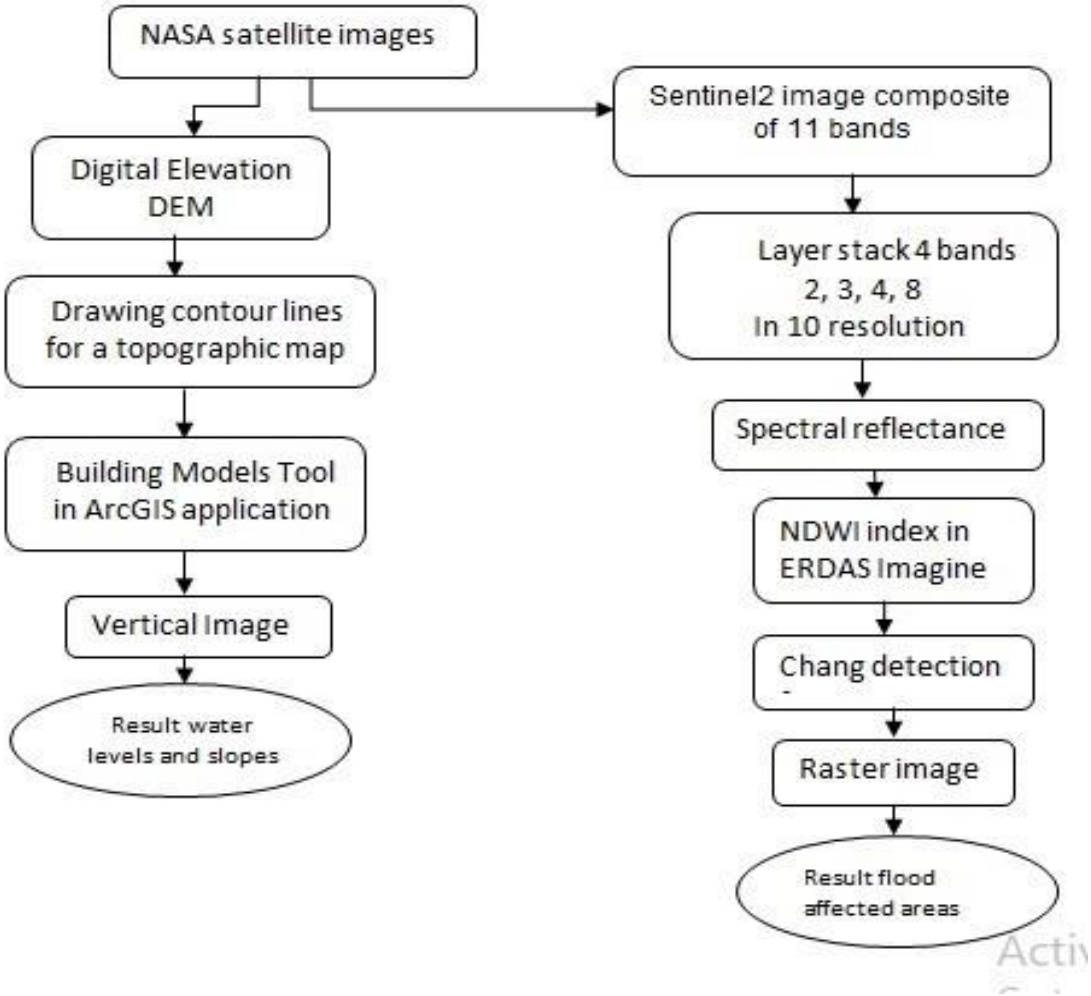

Figure (1) Flow Chart of Flow Water Model.

Figure (2) Location of the Study Area.

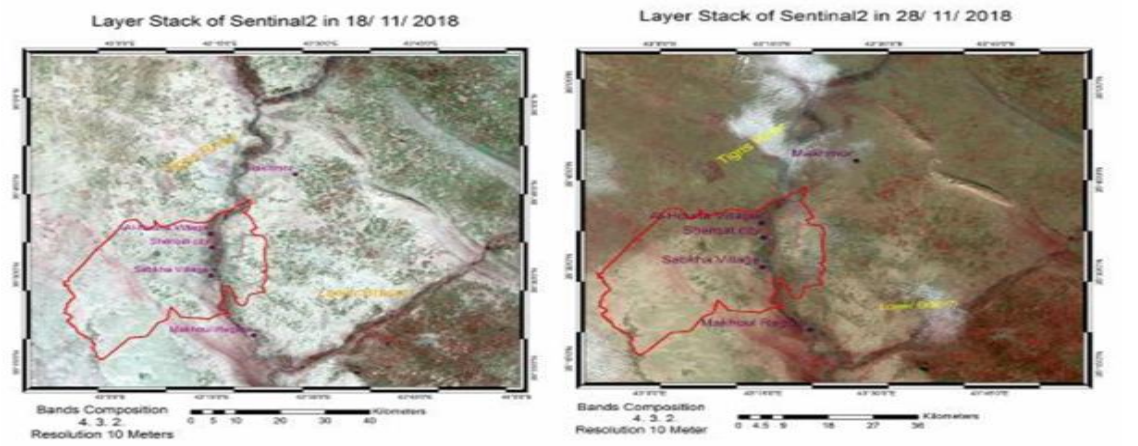

Figure (3) Satellite Images of the Sharqat Region on 28\11\2018, 18/11/20118.

Data-Processing

The data of the Remote sensing are major sources for analyzing environmental processes in local and global scale. These data are used to find change detection in recent decades compared with old decades. Remote sensing data (Such as Landsat Data, Sentinel Data, etc.) are very useful for visualization, classification and analysis of the area. Sentinel 2 data having 12 bands depending on its wavelength (Blue, Green, Red, Infrared, and Thermal Bands). Sentinel2 data's bands, wavelength & their resolution are given below in Table (1). The preprocessing step of the Sentinel 2 images included converting the values of the Digital Number into Top-of-Atmosphere reflectance and then into surface reflection. The basic processing step concerned the calculation of the Normalized Difference Water Index (NDWI) to enhance and extract open

water features. Xu, (2006) described the NDWI results as the most reliable index in the water extraction from the satellite imagery. For an analysis of the Normal Difference Water Index (NDWI), only four bands are used (NIR – SWIR) and can enhance water information efficiency in most cases. The NDWI is a remote sensing-based indicator is computed using the green band (Sentinels 2 Band 3) and the near infrared band (NIR – Sentinels 2 Band 8) reflectance's. NDWI was proposed by (McFeeters, 1996) to improve water-related features for landscapes. This NDWI indicator utilizes both the near infrared (NIR) and short-wave infrared (SWIR) bands by the following equation:

$$\mathrm{NDWI} = \frac{\mathrm{NIR} - \mathrm{SWIR}}{\mathrm{NIR} + \mathrm{SWIR}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

For Sentinel2 data,

$$\mathrm{NDWI} = \frac{\mathrm{Band8} - \mathrm{Band11}}{\mathrm{Band8} + \mathrm{Band\ 11}} \quad \ldots\ldots\ldots (2)$$

But the result from (1 and 2) equations appear to be of poor quality. Pure water does not reflect NIR nor SWIR. The NDW equation has been modified by (Zhao and Chen, 2005). It utilizes SWIR and Green bands.

$$\mathrm{NDWI} = \frac{\mathrm{Green} - \mathrm{SWIR}}{\mathrm{Green} + \mathrm{SWIR}} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

For Sentinel 2 data,

$$\mathrm{NDWI} = \frac{\mathrm{B3} - \mathrm{B11}}{\mathrm{B3} + \mathrm{B11}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The NDWI values are between -1 to 1. In general, the NDWI values for water bodies is greater than 0.1. The vegetation cover has smaller values which easily distinguish water bodies from vegetation. The building features with positive values fall between 0- 0.2.

Flood Inundation

The topography is an essential factor for hydrological models to simulate flooding and runoff. One of the most obvious factors controlling streamflow is the gradient, or slope, of the river channel. The definition of Flood inundation is the accumulated level index overflowing the banks of the main river. Flood obviously refers to the depth produced by flood on the banks of -a river and can be described as an indicator of an accumulated level. Flooding maps are intended to build mitigation scenarios and response planning. The real computation of flood inundation needs a data set consisting of DEM, flow-direction, and network of the river. DEM simplifies mapping flooding depth over landscapes (Verdin, 2016). Flood inundation was determined based on DEM and by use ARCSCENE v.10.5 with use model builder in ArcGIS v.10.5 as show in Figure (4). Once the river depth is defined by the application of the software or directly determined by the user, the corresponding submerged area is calculated utilizing the DEM. The DEM concept is based on work by (De Roo, *et al*., 2007; Nobre, *et al*., 2011). DEM is a version of the DEM input that is processing to produce height values that are expressing by the elevation over the river. Inundation maps can be used for (Verdin, 2016):

1. Readiness, the scenarios of " What-if."
2. Linking timely response to real-time scale and prediction information.
3. Recovery–damages estimation.
4. Planning and Mitigation for analysis of the flood risk.
5. Ecological and Environmental Estimations - identification of wetlands, and cleanup of hazardous spills.

Table (1) Sentinel 2 Data's Bands, Wavelength & their Resolution.

Sentinel-2 Radiometric and Spatial Resolutions			
Band Number	Central Wavelength (nm)	Bandwidth (nm)	Spatial Resolution (m)
1	443	20	60
2	490	65	10
3	560	35	10
4	665	30	10
5	705	15	20
6	740	15	20
7	783	20	20
8	842	115	10
8a	865	20	20
9	945	20	60
10	1375	30	60
11	1610	90	20
12	2190	180	20

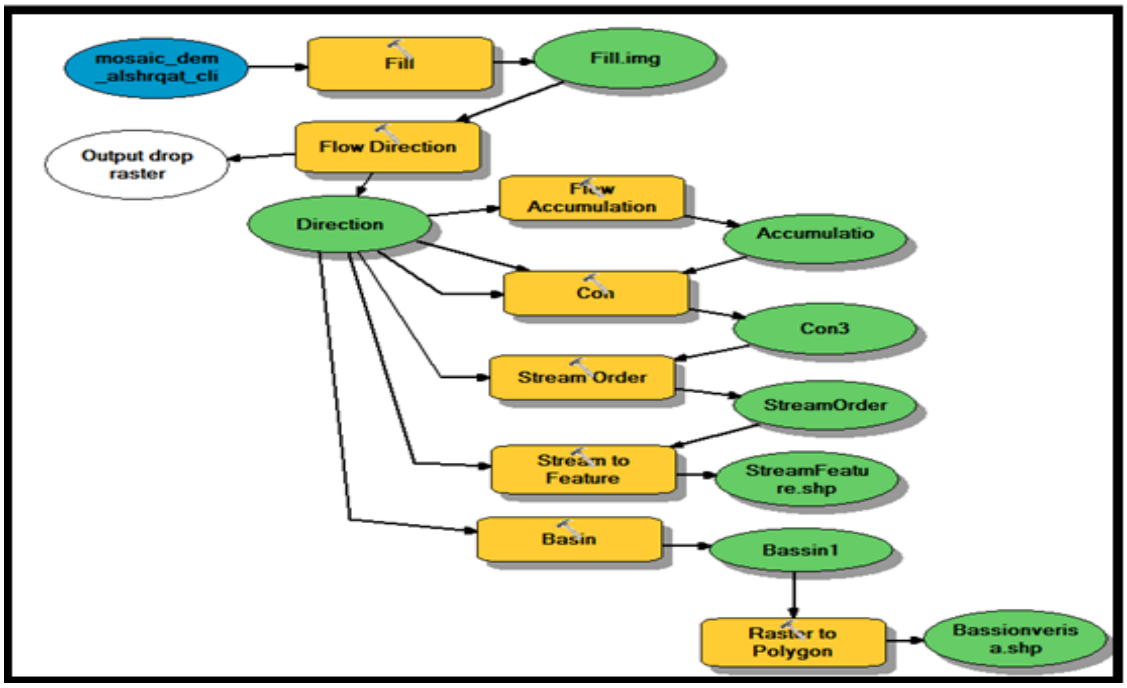

Figure (4) Process Flow Chart by Model Builder in ArcGIS.

Results and Discussion

The Sharqat area was subjected to flood in November 2018, therefore this study implements to observed flood stream in this area by using Sentinel 2 images and processing approach by ArcGIS model tools. The final results illustrated that the water body's surface has a low reflection with little reflection within the visible part of the electromagnetic spectrum. The liquid nature of water has a higher reflectance in the blue band spectrum (0.4-0.5μm) than less reflection in the green (0.5-0.6μm) and red (0.6-0.7μm) bands spectrum. Clear waters have a greater reflection in the blue band than turbid waters. Therefore, the water appears blue. While there is no water reflection within the NIR range and beyond, as seen in Figure (5).

The outcomes reveal that the NDWI presented the highest accuracy results to extract the water-surface. We have been able to obtain an integrated picture of the flood control process, also a video that shows the flow of water through the integration of satellite images. This facilitating the monitoring of water flow and flood control by used NDWI, finding appropriate solutions and preventing recurrence. The spectral reflectance curve helps to understand the NDWI index. The curves of the spectral reflection explain the relations between the electromagnetic spectrum (The Distribution of Continuity of Radiant Energies Plotted as Either a Role of Frequency or Wavelength) and the percentage associated with the reflection of any particular material. They are plotted as a chart representing the wavelengths in the horizontal axis and the percentage of reflection in the form of the vertical axis, as illustrated in Figure (6). This curve will support imagine the NDWI equation. The flood inundation application consists of the derivation of river networks as shown in Figure (7), from the DEM input, which consisting of interconnected segments of the streams and the development of stream cross-sections for every stream segment. Based on flood water extent results of flood inundation, can mapping probably the area that can be submerged by water of the river as seen in Figure (8). The flooded-areas are direct related to the inundation area near the river. Consequently, it is clear that potential floods - denotes depth due to flooding of river banks and can be defined as accumulated level - an indicator. The flood caused to inundation the south areas of the study area because this area was a lower level than the north aras. Moreover, the slope of the study area was increased from upper to lower of the area as shown in Figure (8) from stage 4 to stage 6. This flood led to damage the regions which were near and beside the Tigris River. There are many streams in the area that can be used to draining the flood water into the river.

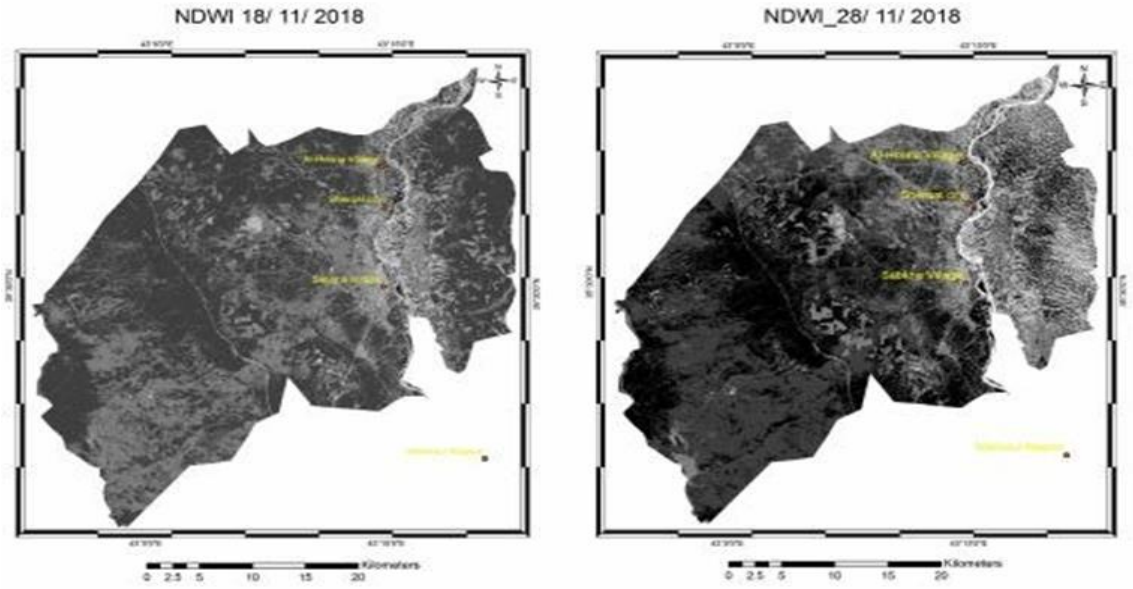

Figure (5) NDWI for Study Area 18/11/2018 before Flood and 28/11/2018 after Flood.

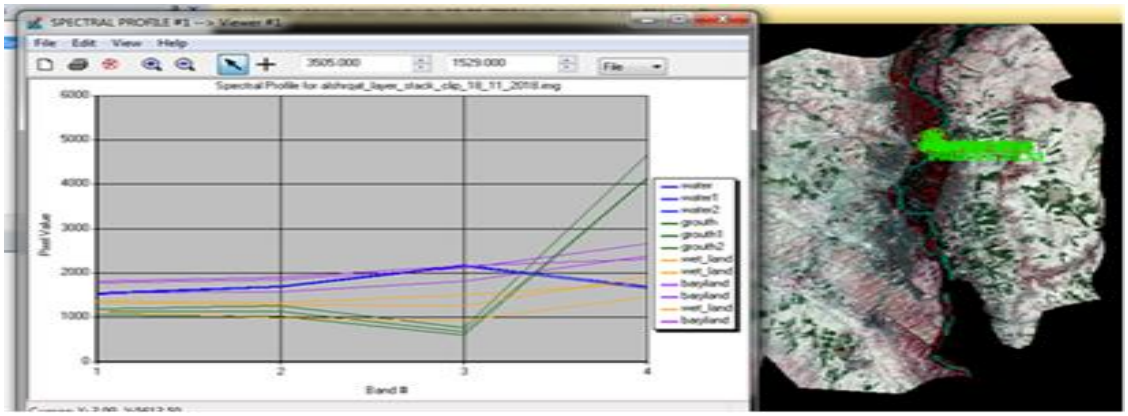

Figure (6) Spectral Reflectance Curve.

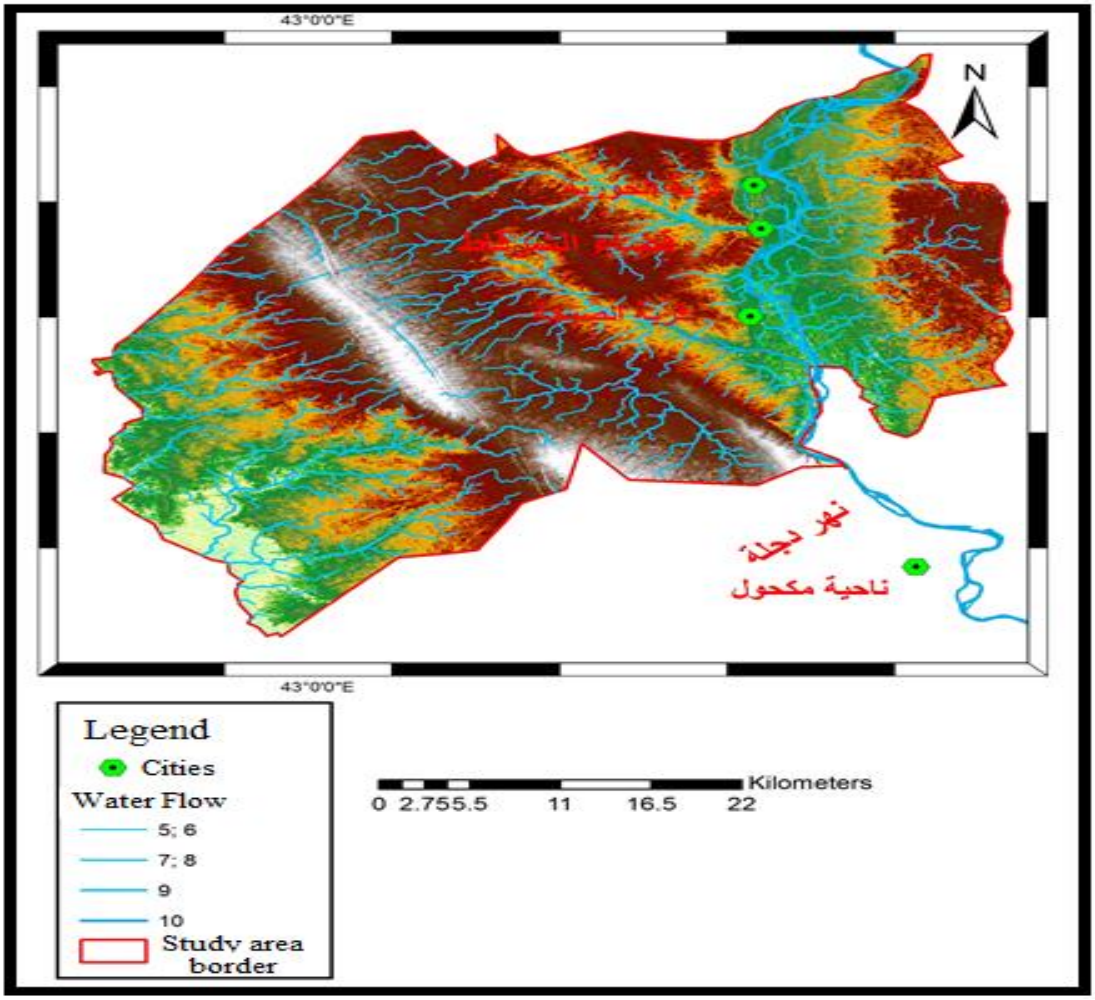

Figure (7) Area of Water Flow.

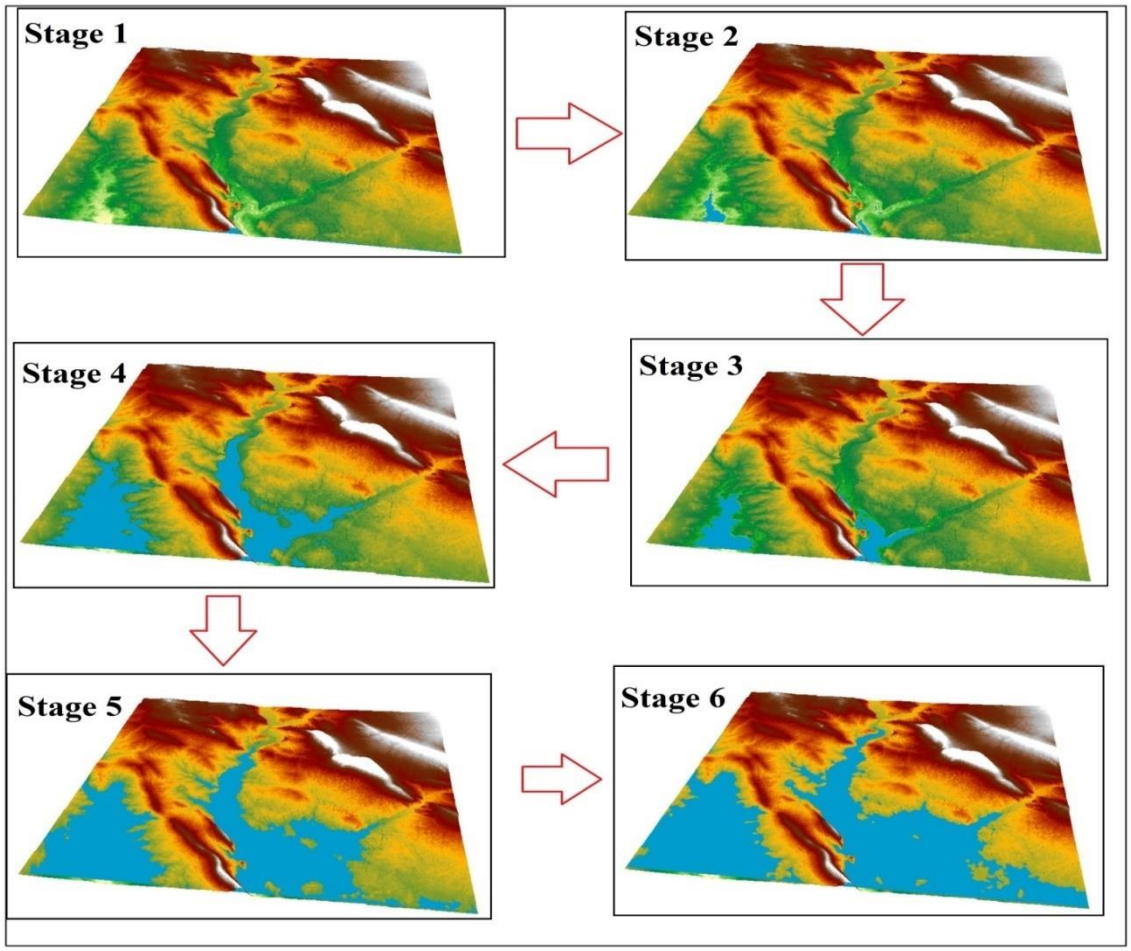

Figure (8) Stages of Flood Inundation.

Conclusions

1− Overall, the NDWI gave the most accurate outcomes in estimating changes in surface water and monitoring flood events.

2- The NDWI needs to apply a threshold for every time for surface water extraction, then subtracting the statistics to assess surface water changes.

3- The outcomes showed an intense increasing trend in the water surface area in the 28 November 2018 due to high rainfall.

4- The geographic information system (GIS) including satellite images is an effective way to interpret and analyze a wide flood risk assessment. Satellite images are also necessary to analyze flood disasters.

5- The patterns of the flood inundation could be utilized in conjunction with extra information to representing patterns of the settlement, transport network, and land-use, land-cover LULC to assess the susceptibility of lands along rivers and streams to flood occasions and to aid in planning and mitigating negative flood impacts.

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