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Assessing Flash Floods Prone Regions at Wadi basins in Aswan, Egypt

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Synopsis

It is well known that flash floods are very devastating for human life and their properties. The main target of this paper is to investigate and determine the prone urbanized regions along the River Nile, Aswan, Egypt relying on numerical simulation and field survey. Recent flash floods impacts in Egypt were discussed showing the real effects on both wadi residences and urbanized regions. Investigation and exploring the prone urbanized regions and agriculture lands for flash floods threat at some wadi basins in Egypt were conducted based on the field survey and rainfall-runoff modelling. The GSMaP precipitation was used for simulation of flash floods at the target wadi basins. The simulation has been successfully carried out for several flash foods events. Inundation maps showing the affected regions (urbanized and agricultural) due to flash floods were developed. Consequently, proper mitigation strategies should be considered based on this study to re-manage or re-allocate the urbanized regions in order to avert flash floods. Further applications would be more effective considering the risk disaster mapping based on several important criteria.

Keywords: Flash Floods, Wadi Basins, Rainfall-Runoff-Inundation Model, Nile River urbanized regions, Egypt

1. Introduction

Flash floods consequences are not only an environmental issue but also an economic, since they may cause damages to urbanized regions and agricultural areas and may even result in loss of human lives (Merz et al. 2010). Delineation of the prone regions for flash floods and design of control facilities are subjects of continued and increasing importance at wadis along the Nile River, Aswan Egypt. Identification and management of flood hazards on such regions have become important issues for the decision makers and especially for Aswan governorate. The management of flash floods and determination of prone regions are critically important due to two reasons: 1) residential development on hill slopes and outlets of wadies in Aswan city has expanded recently and continues to grow rapidly, 2) lacking of previous studies addressing flood hazard assessment due to the infrequent occurrence of rainfall and absence of well-defined watercourses.

In general, most of low-lying urban centres are flood-prone areas which consequently needs assessment and management by using the advanced techniques. The increase of flash floods and their destructive results worldwide require an ongoing enhancement on identification and mapping of flood hazard (Kundzewicz and Kaczmare 2000; Ebert et al. 2009).

Several studies have been conducted on Wadi flash floods to understand behaviors and

characteristics (Saber, 2010, Saber et al., 2015) and water management and harvesting (Abdel-Fattah et al., 2014). Water management and mitigation strategies by using rainfall-runoff models in arid regions is highly recommended (Kantoush, et al., 2011, Sumi, et al., 2013). Consequently, Abdel-Fattah et al. 2015 studied and compared different mitigation scenarios for better management and risk reduction at Wadi Samail, Oman. Thus, mapping the prone regions of flash floods based on field survey and hydrological modeling is still needed in these regions.

In the present study, we have tried to explore and identify the disposed regions for flash floods in this arid regions throughout the following three steps: 1) Field observations to investigate the actual situation for the prone regions for the flash floods impacts, 2) Topographical analysis for the DEM using GIS, 3) Numerical analysis using hydrological models. The main purpose of this study is to assess and investigate the prone urbanized regions for the flash floods threats along the river Nile. Aswan city was selected for filed investigation and classification of urban and agricultural lands. Also, both of Wadi Abu-Shieh, and Wadi Abu-Subiera, in Egypt were selected for numerical simulation using an integrated approach including field investigation, remote sensing, GIS, and rainfall runoff hydrological models and topographical analysis.

2. Recent Flash floods Impacts in Egypt

It was observed from the previous flash floods that flash floods become more frequent especially after 2010 in Egypt. It has been affected by several recent flash floods such as 1994 (Fig. 1), 2010 (Fig. 2), 2014 (Fig. 3), 2015 (Fig. 4), and 2016 (Fig. 5). The flash floods spatial coverages exhibit high variability which hinder the forecasting and also the preparedness for their risk and impacts. In this section, the spatial impacts, resulting damages and mortality are addressed. Throughout mapping the prone regions for flash floods at some affected wadis, we could able to understand how much the impacts of flash floods on the urbanized and agriculture lands, especially at the downstream regions of wadi basins in Egypt. This emphasize the

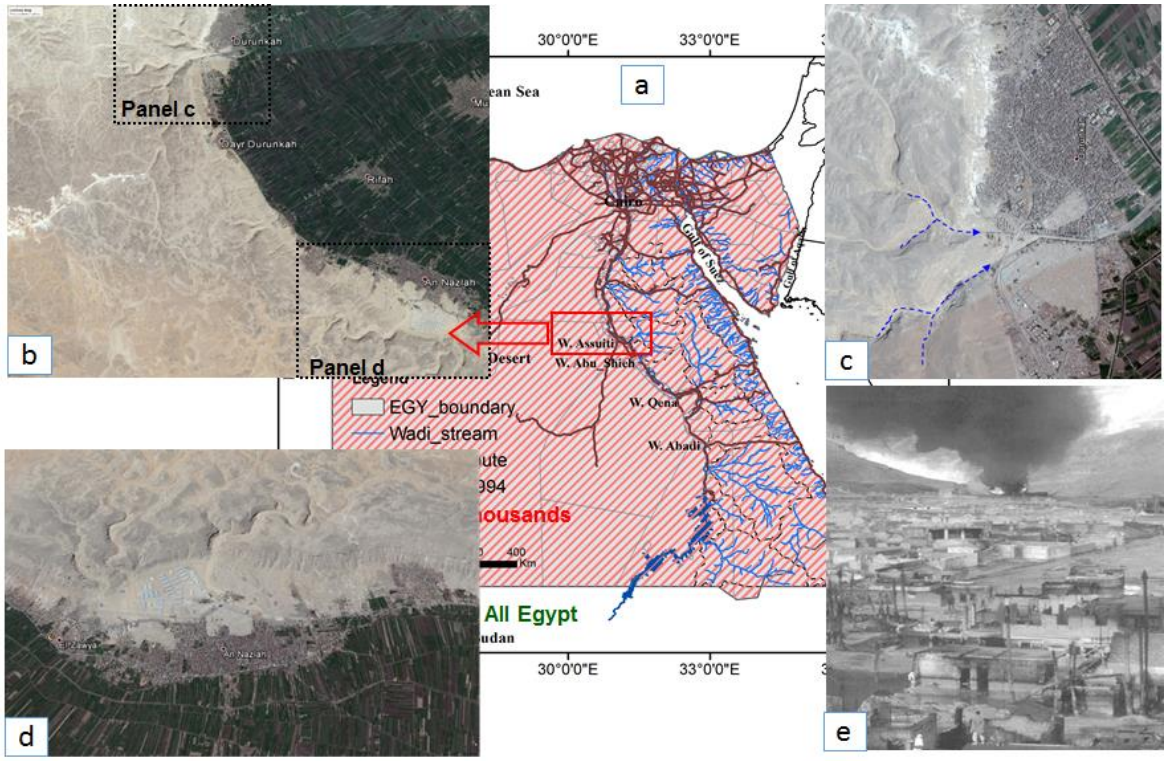


Fig. 1 Flash flood event of Nov. 1994 hit all Egypt (a), Google photo showing the locations of some cities (b) at wadi outlets along the River Nile, such as Drunka village (c), and An Nazlah village (d), Assiut City, oil storage tanks burst into flames (e) leading to huge number of fatalities (IDNDR-DIRDN, 1996).

importance of studying flash floods at wadi system in Egypt as well as showing the hidden and unknown devastating impacts on the society and environment. Some recent flash floods are explained as follow:

2.1 Flash flood of Nov. 1994

Heavy rainfall storm have been affecting most of the Egyptian cities along the River Nile (Fig. 1), resulting in a great damage in infrastructures, hosing, agriculture lands. About 1000 deeds and thousands of people affected from the flash floods. Many historical and archaeological sites have been affected by this flash flood such as Valley of the Kings, Valley of queens (Luxor). Thousands of houses and agricultures lands were destroyed. For instance, Drunka village in Assiut city (Fig. 1c), the city's population is about 45938 based on 2006 estimates. Almost most of the city was affected by the flash floods, leading to that most of the city left their damaged houses to Assiut city, the nearest location. The city is located at the outlet of many wadis at the western desert along the River Nile (Fig. 1a, b, c). The management and good planning to protect the city is still missing in these regions.

Many cities locating along the River Nile are cited at the outlets of wadi basins. One more example is An Nazlah Village, Assiut (Fig. 1d) is also occurred at the downstream of several wadis at the Western Desert. Based on the report prepared by Nazmi (2009) about the flash flood disasters in Egypt, focusing on the case of one of the affected villages "Durunka" in Assiut. Some of flash floods list were recorded. 1994 flash flood was one the greatest floods in Egypt affected many regions, the estimated damage was stated as: About 13165 acres of agriculture lands have been affected. Totally damaged houses, schools, other infrastructures about 3227, and partially damaged buildings were about 2827. In addition to the flash floods impacts, oil tanks in the desert near to the city was burst into flames which in turn increased the fatalities of this flash floods events (Fig. 1e).

2.2 Flash floods (17-18 January, 2010)

A great number of houses in four regions in Egypt (North Sinai, South Sinai, Red Sea and Aswan) have been severely affected by this flash

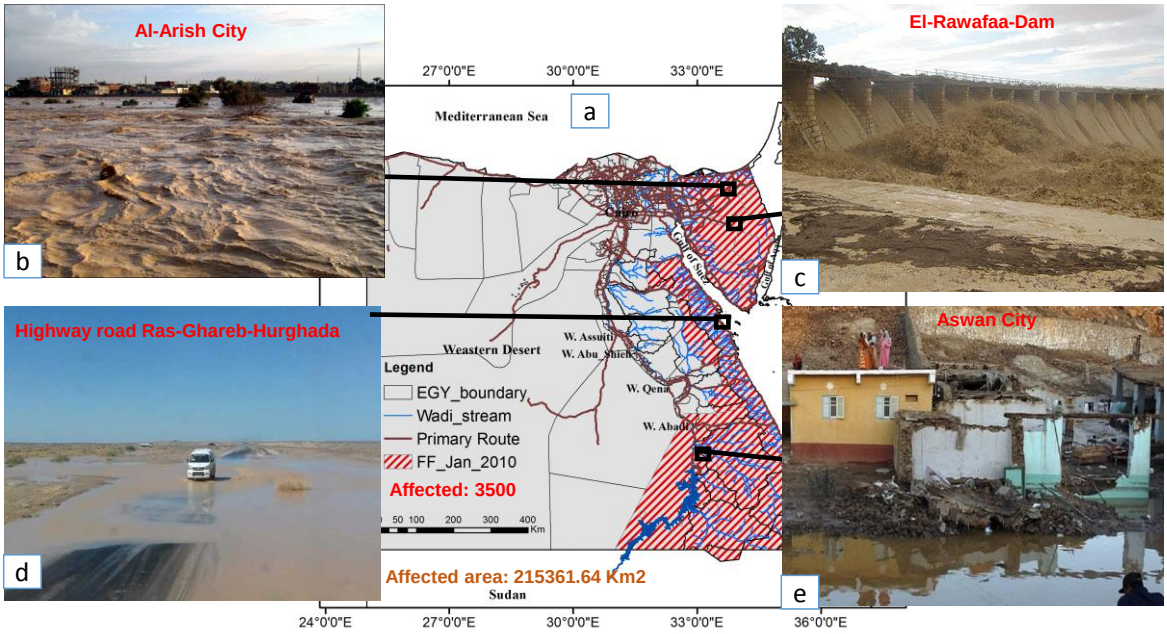


Fig. 2 Flash flood event of Jan. 2010 affecting Red Sea coast and Sinai (a), Inundation of the flash floods at Al-Arish City, Sinai (b), Overflow at EL-Rawafaa Dam in Sinia (c), Impacts on the Highway road of Ras-Ghareb-Hurghada, Red Sea Coast (d), Affected urbanized houses at Aswan City (e).

flood (Fig. 2a). At least, 3,500 people (500 families) have been affected or are homeless (http://reliefweb.int/sites/reliefweb.int/files/resources/33345A0C57264C3F852576B2005FFC64-Full_Report.pdf), CHF 257,914 (USD 246,525 or EUR 175,360) has been allocated from the Federation's Disaster Relief Emergency Fund (DREF) to support the Egyptian Red Crescent Society (Egyptian RC) in delivering immediate assistance to some 3,500 beneficiaries. The flash floods water reached to El-Rawafaa Dam (along Wadi El-Arish, Sinai) was greater than the dam capacity, thus the water overflowed to the downstream causing human lives losses and properties damage (Fig. 2b, c, and d) and some villages in Aswan city were also affected by the same event (Fig. 2e). About 3,500 persons (500 households) have been evacuated and many people become homeless.

2.3 Flash floods (March and May, 2014)

Many cities have been affected by this flash flood event such as Taba in Sinai, Wadi Abu-Shieha, Sohag, Aswan and Kom ombo along the River Nile (Fig. 3a). Wadi AbuShiha one of the most important wadis in the eastern desert, however it was suffering from many flash floods. It is characterized by occurring many sub basins (Fig. 3b) are flowing at the downstream region while there are many urbanized areas and agricultural reclamation projects. The downstream delta of the wadi is very large and has many new urbanization and agricultural reclamations started from 2001, the extension of agriculture lands increased to cover much larger area in front of the outlet of the wadi which is prone for the flash floods. Due to the importance of this developed wadi delta, the government established three mitigation dams (Fig. 3c), the first and the second one was established on 2009, then they started to establish the third one in 2015 (Fig. 3), especially after the failure of dam no. 1 two times during the flash floods of 2014 and 2015 (Fig. 3d, e, and f).

2.4 Flash floods (3-4 Nov. 2015)

Flash flood event of Nov. 2015 hit many regions over the country such as Wadi El-Natrun in Beheira, North Sinai, and Alexandria (Fig. 4a and b)

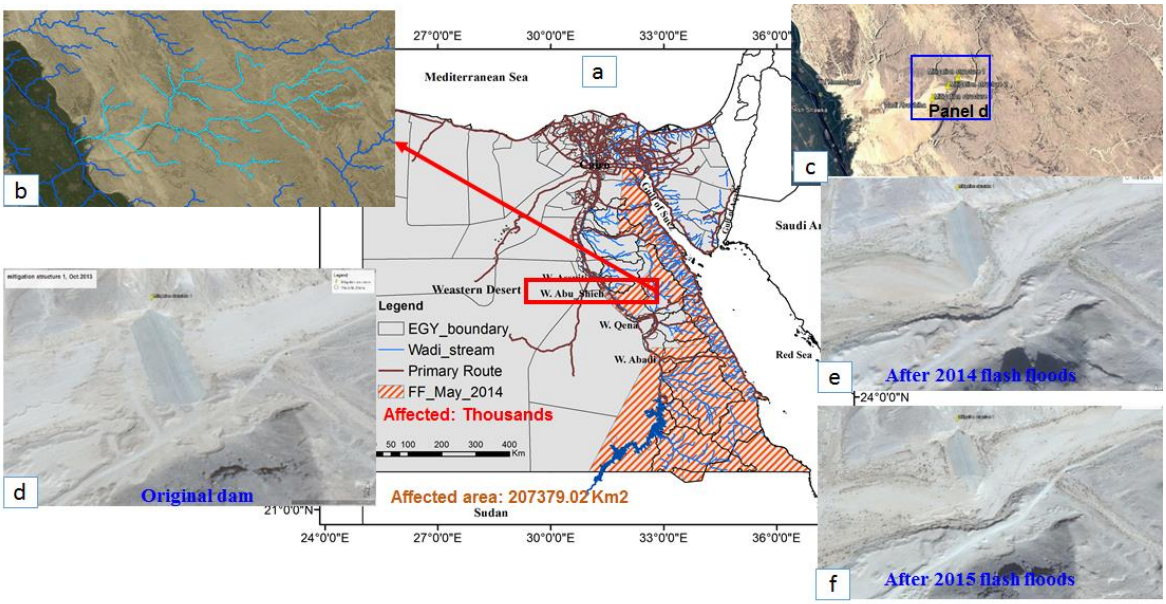


Fig. 3 Flash flood event of March and May 2014 affecting Red Sea coast and some River Nile cities (a), The location of Wadi Abu-Shieha along the River Nile showing the stream networks (b), and the occurred mitigation dam structures (c), the original structure mitigation dam (d), dam failure after March and May 2014 flash floods (e), increasing the damage after flash flood of Nov. 2015 (f).

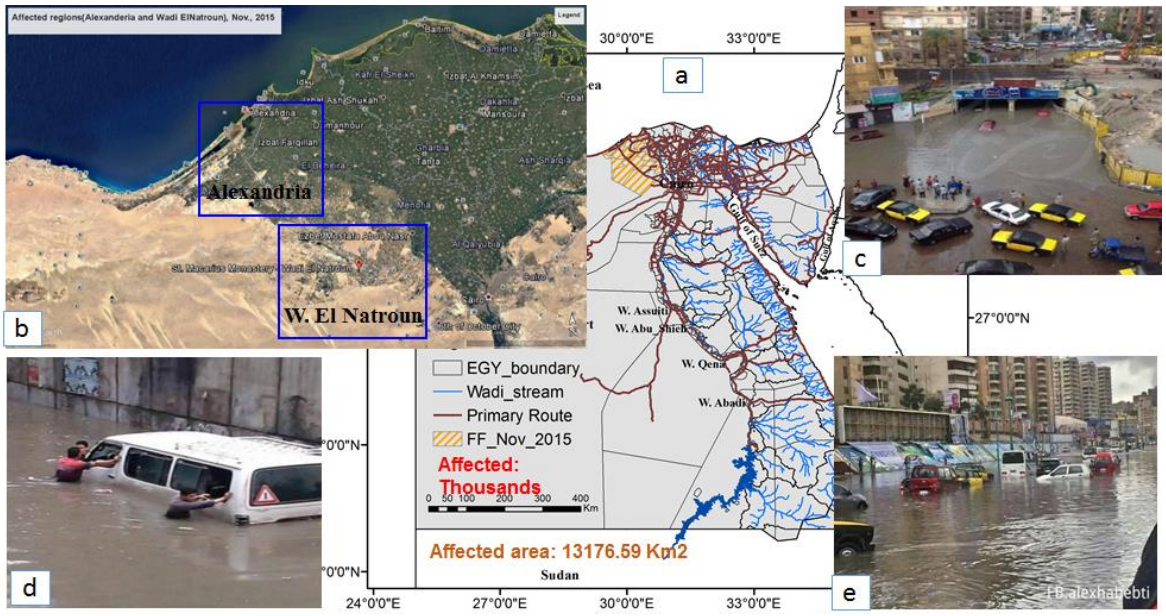


Fig. 4 Flash flood event of Nov. 2015 affecting Wadi El-Natrun in Beheira and Alexandria as highly populated regions (urban regions) (a & b), Flood inundation affecting thousands of houses and infrastructures (c-e).

resulting in huge damages in infrastructures, main transportation facilities, and stopping most of the public services in all cities (Fig. 4c, d, and e). Twenty-five people have been killed to date as a result of the floods in the province of Beheira, according to state-run MENA news agency (http://floodlist.com/africa/egypt-floods-beheira-alexandria-november-2015). According to WMO figures, 52 mm of rain fell in the city of Alexandria over a 24 hour period to 04 November. At least 6 people died in another flood that struck Alexandria in Egypt early on Sunday 25 October 2015 (http://floodlist.com/africa/egypt-floods-alexandria-6-dead). 25 Oct. 2015 flash floods was mainly urban floods affecting the city leaving high inundation floods affecting all the people's life and destroyed their properties (Fig. 4c, d, and e).

2.5 Flash floods (Oct. 2016)

The flash floods of 27-28 Oct. 2016 affected some of the Red Sea's cities especially Ras Gharib (the eastern Red Sea Governorate) and River Nile cities (Fig. 5a). Global Satellite Mapping of Precipitation (GSMaP) satellite rainfall real time observation shows that the spatial impact of the flash flood was very local and the maximum rainfall was about 30mm/hr (Fig. 5b). Based on the official governmental reports that at least 29 died and 73 injured, and the affected people around 32500. The government announced on 29 October the provision of 50 million pounds ($5.6m) for the flood-hit areas of the Governorates of Sohag, South Sinai and Red Sea (http://floodlist.com/africa/egypt-deadly-flash-floods-hit-sohag-red-sea). Egyptian Red Crescent reported that affected areas include: Red Sea, Assuit, Qena, Sohag. The floods cut off the roads between read sea governorates and Nile river cities (Fig. 5c) and huge damage was recorded in both infrastructures and agricultural lands.

Based on reporting the impacts of some recent flash floods in Egypt. We found that the downstream regions at Wadi system outlets are considered as prone areas for flash floods impacts in arid regions. Most of River Nile and Red Sea cities are located at the outlets while the cities including housing and agriculture lands are prone for the flash floods impacts. This review stated that flash floods in Egypt become more frequent and devastating, especially after 2010, there is almost one or two flash floods affected Egypt every year. Most of these floods impacts was mainly on the downstream of the wadis. The flash floods was

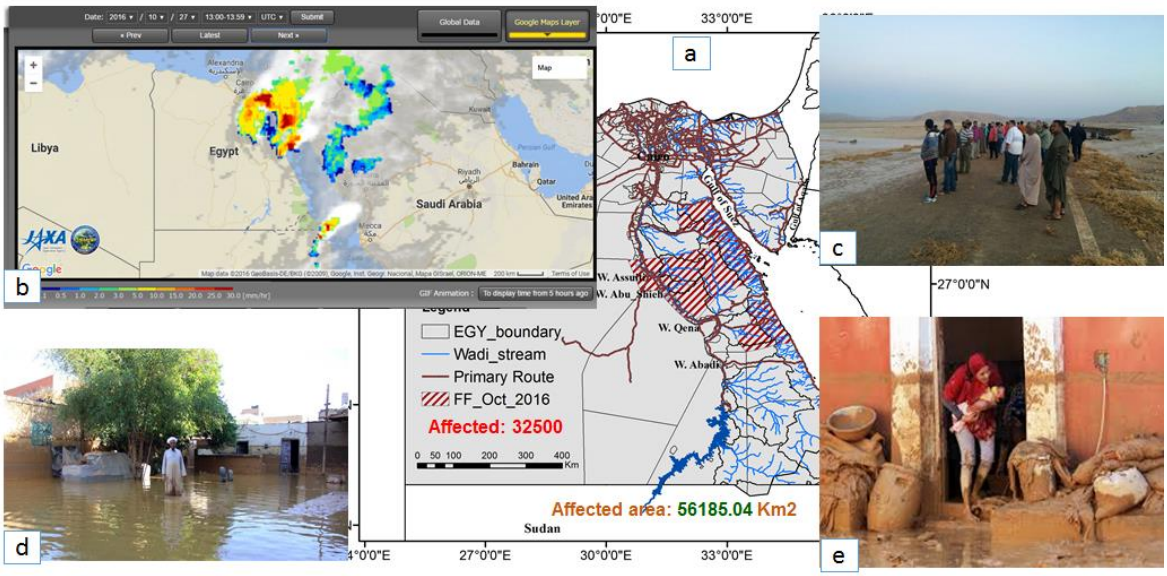


Fig. 5 Flash flood event of Oct. 2016 affecting local areas such as affecting red seas cities such as. Ras Gharib and Hurgada and River Nile cities (Assiut, and Sohag) (a), GSMaP satellite rainfall data showing the spatial local impact of the flash floods (maximum rainfall was about 30mm/hr) (b), impacts on the high ways of Red Sea cities(c), and residences in these cities (d & e).

variable in special impacts as recording not only in wadis but also in urbanized regions. We also noticed that most of the urbanized regions are established without any pre-planning, and even not well constructed which in turn increases the possibility for the flash floods impacts in such regions. Therefore, flash floods risk assessment is quite important issue in order to mitigate disaster impacts.

3. Study Area

Some important wadi basins along the River Nile were selected for numerical simulation of flash floods. Wadi Abu-Shieh, and Wadi Abu-Subiera, in Egypt (Fig. 6). They are located the eastern desert and flowing towards the River Nile.

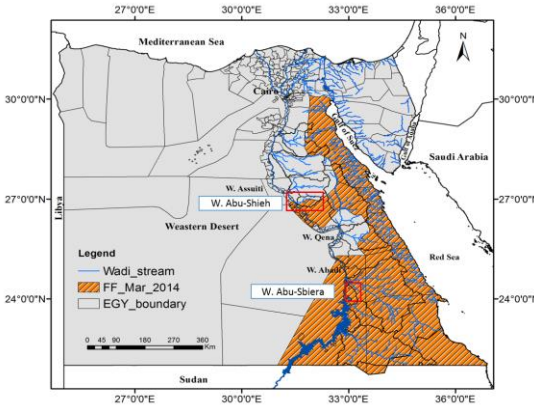


Fig. 6 Location map of the study area showing the spatial coverage impacts of flash flood event of March 2014.

4. Methodology and approach

An integrated approach is used to explore and identify the prone regions for flash floods in these arid regions throughout 1) Field survey to investigate the real situation for the regions susceptible to the flash floods impacts, 2) Topographical analysis for the DEM using GIS, and 3) Rainfall runoff modeling for flash floods.

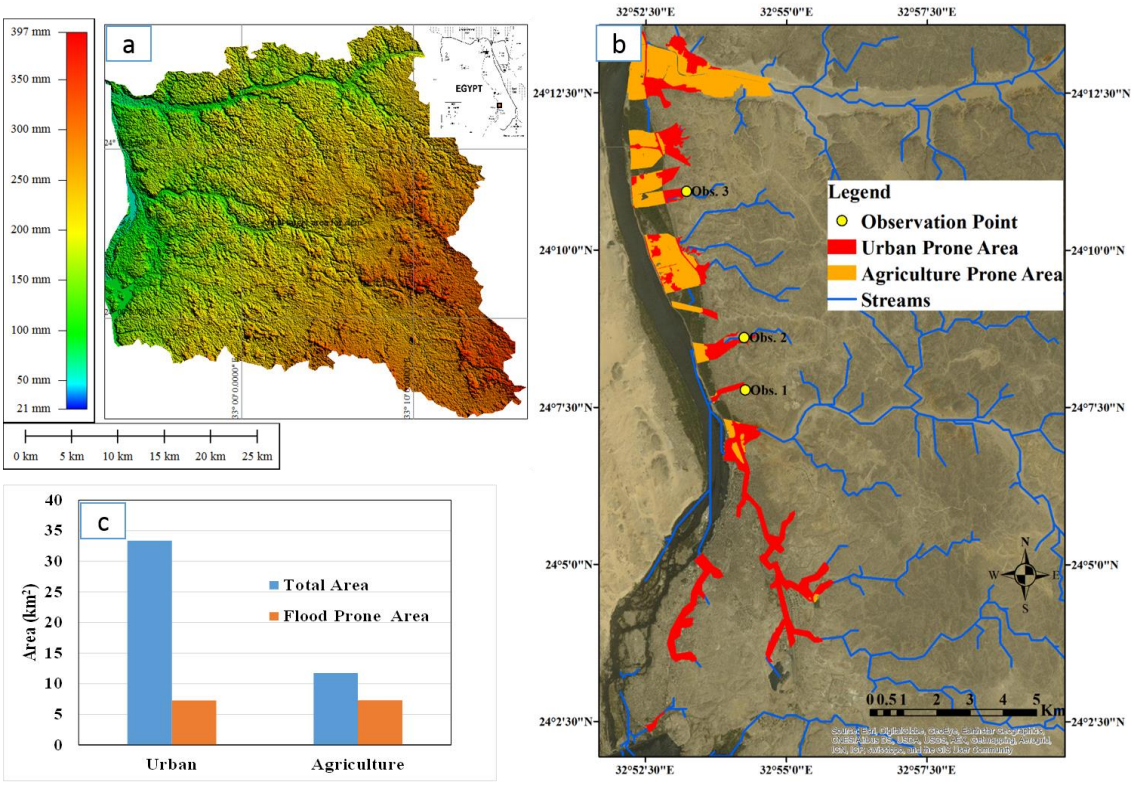


Fig. 7 Location map of the study region, (b) Map showing the vulnerable urban locations (red colour) and agriculture lands (orange colour) for the flash floods along the River Nile, Aswan City, Egypt, (c) Chart for the percentage of prone regions for the flash floods at the investigated area.

4.1 Field Survey

In order to explore the prone regions for the flash floods along the River Nile, field survey was conducted on 2012 starting from Aswan city to Assiut City, and we have investigated several locations at different wadi outlets along the River Nile. In this paper, we are just focusing on some selected locations (Fig. 7a and b) around Aswan cities (obs. 1: Nagaa Al Shima, obs. 2: Elshikh ali, and obs. 3: Alkhatara). We found that many urbanized areas are directly located at the outlet of wadi systems which means they are subjected for the flash floods impacts in case of the lack of proper mitigations measures. For instance Fig. 8 shows the occurring of houses at wadi downstream points at obs. 1(a, b), and obs.2 (c), and obs.3 (d). Additionally, based on public survey with the residences, they said that they was suffering from the flash floods at these regions and especially in 2010. In fact, most of the urbanized regions in Aswan cities are constructed without any pre-planning from the governmental, thus, their houses were not well constructed which resulting in increasing the possibility of failure and damage with any extreme flash floods. Delineation of the vulnerable urbanized and agricultural regions was carried out using GIS and DEM, showing that about 21 % of the urbanized regions and about 62 % of the agriculture lands are under the threat of any future flash floods at the investigated area (Fig. 7b & c).

The main problems are represented in expansion of the agricultural activities and urbanization due to development and increasing population. As we observed at Wadi abu-Shieh that the agricultural lands expanded from 2000 to 2016 about 100% (Fig. 9 a & b). In addition to extension of urbanization at many wadis along the River Niler such as in Naga Al kajuj, Aswan (Fig. 9 c, and d).

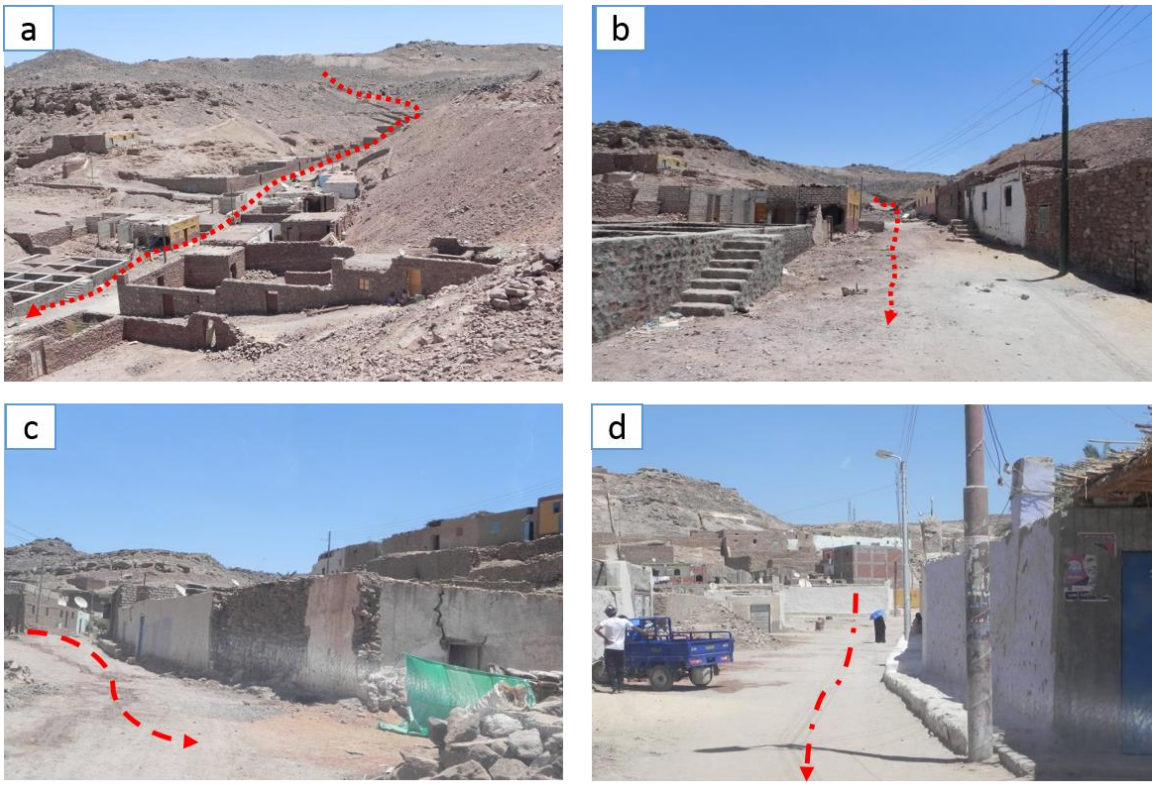


Fig. 8 Photos of the location of houses along wadi channel outlets at Obs.1 (a, b), Obs. 2 (c), and Obs. 3 (d), (Red dotted line is the wadi outlet direction), (Photos were taken by Mohamed Saber in 2012 during the field trip)

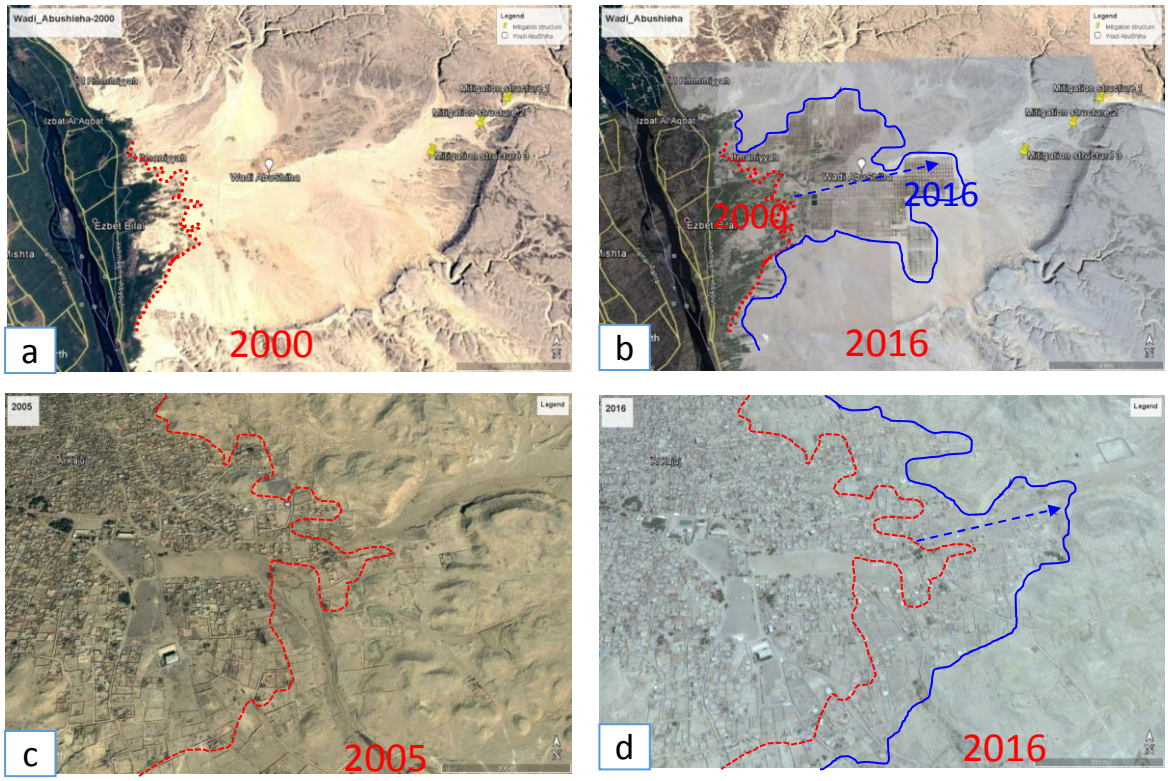


Fig. 9 Increasing agricultural and urbanization activates at wadi abu shieh, Egypt (a & b), Expansion of urbanized lands at wadi outlets at Naga Al Kajuj, Aswan city, Egypt (c & d, were taken during the field trip on 2012).

4.2 Rainfall-Runoff Modeling

Rainfall-Runoff-Inundation (RRI) 2D model (Sayama et al., 2012) is used to simulate flash floods discharge and inundation at the target basins. Fig. 10 shows a schematic diagram of the RRI model. The model deals with slopes and river channels separately. Lateral flows are simulated on slope cells on a 2D basis, at a grid cell on which a river channel is located, the model assumes that both slope and river are positioned within the same grid cell.

5. Flash Floods Simulation Using RRI

The was calibrated at Wadi Samail In Oman (Abdel-Fattah et al., 2015), therefore, in this study we used the same parameter setting in simulation. Flash flood event (Mar 2014) is simulated to estimate water depth & discharge (Fig. 11 a, c) and to develop an inundation map (Fig. 12 b, d) at wadi Abu-Shieh, and wadi Abu-Subiera, Egypt, respectively. Water inundation reach about 1.7 m at some locations in Wadi Abu-Shieh, and less than 1m at Wadi abu-Subiera.

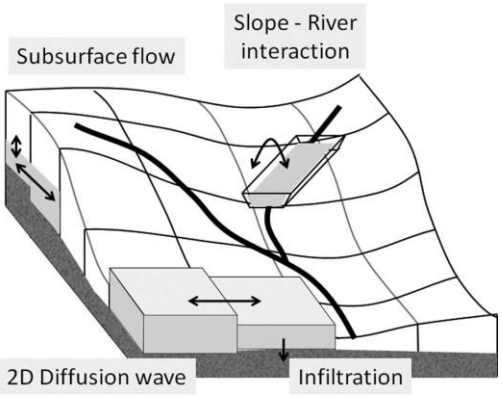
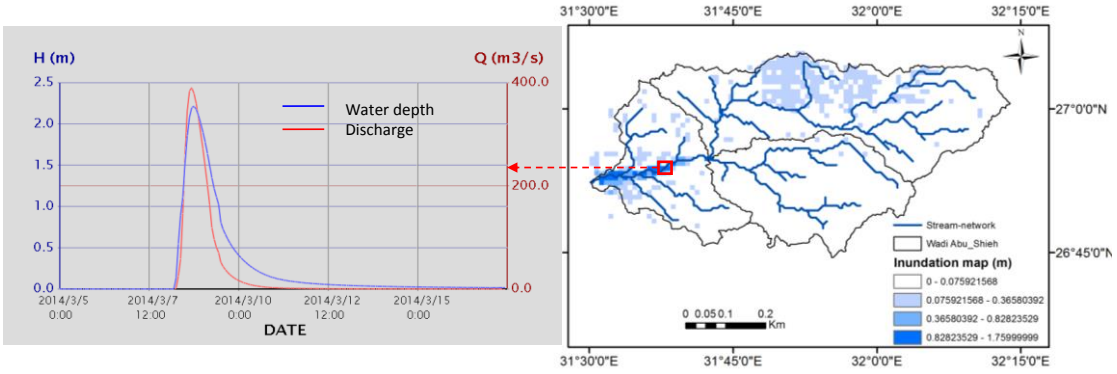


Fig. 10 Schematic diagram of RRI model (Sayama et al., 2012).



(a) (b)

Fig. 11 RRI Flash floods simulation (Mar 2014 event) showing water depth & discharge (a) and inundation map (b) at wadi Abu-Shieh, Egypt.

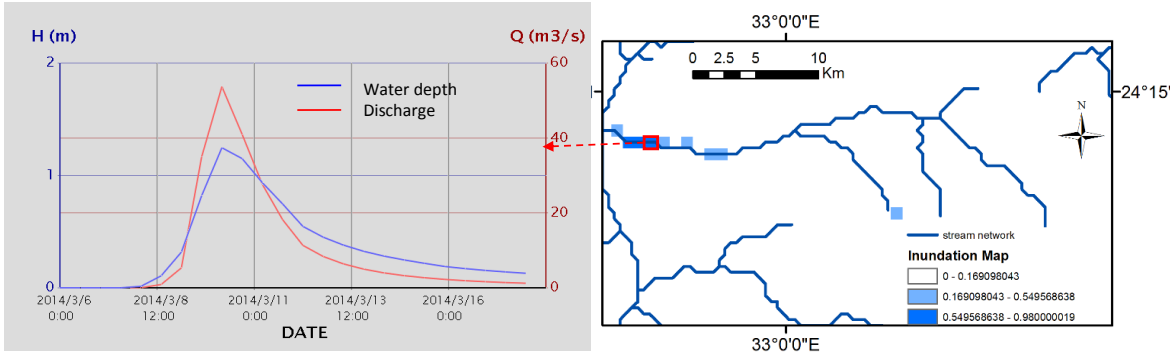


Fig. 12 RRI Flash floods simulation (Mar 2014 event) showing water depth & discharge (a) and inundation map (b) at wadi Abu-Subiera, Egypt.

6. Conclusions

In the present study, some of the recent flash floods were reported and discussed in order to understand how much the flash floods impacts at wadi systems in Egypt. Field survey for many wadi residences along the River Nile were conducted. As a result of the field survey and reported flash floods, we found that most of the urbanized regions in Aswan cities are constructed without any pre-planning from the government, thus, their houses were not well constructed which resulting in increasing the possibility of failure and damage due to any extreme flash floods. Additionally, increasing the agricultural activities and urbanization as a logic results of development and population growth. High variability of spatial impacts of flash floods were observed affecting not only wadi residences but also the urbanized regions with very high population. Delineation of the vulnerable urbanized and agricultural regions was carried out using GIS and DEM.

Investigation and exploring the prone urbanized regions and agriculture lands for flash floods threat at some locations in Aswan, Egypt were conducted based on the field survey and topographical analysis. Estimating and delineating the distributed percentage of urbanized and agriculture areas exhibit that about 21 % of the urbanized regions and about 62 % of the agriculture lands are under the threat of any future flash floods at the investigated area. Therefore, appropriate mitigation strategies should be considered in such critical regions based on these preliminary results to re-manage or re-allocate the urbanized regions to be far from the flash flood threat.

As extension for identifying the prone regions for flash floods, Flash flood event of Mar 2014 is simulated using RRI Model to estimate water depth & discharge and developing inundation maps for both wadi Abu-Shieh, and wadi Abu-Subiera, Egypt. Further work is still needed to develop the risk disaster maps based on several criteria such as water depth, mortality, damage costs, land uses, etc. This could be the way forward for flash floods risk reduction and for secured development of wadi society in Egypt and other arid regions.

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