GEOMORPHOLOGICAL ANALYSIS OF FLASH FLOODS USING MULTIPLE HAZARDS MODEL IN ABU HAD BASIN, RED SEA, EGYPT

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Abstract

The Ras Gharib area on the Red Sea coast of Egypt received heavy rainfall from Wadi Abu Had on October 26–27, 2016. The area experienced flash flooding due to this abnormal quantity of rainfall, which resulted in the deaths of tens of people and significant damage to infrastructure and properties. Multi-hazard risk analysis is a general term that refers to the analysis of the dangers in a given time and place, their magnitude, the description of how they interact, and the interpretation of the results of this compounding on a target group. The objective of this paper is to build a model of the multiple hazards that result from the flash floods in the Wadi Ras-Ghareb basin and analyze their effects on Ras-Ghareb city. To determine the likelihood of heavy floods occurring in the valley basin and Ras-Ghareb city, we utilized satellite images, carried out extensive fieldwork in the valley, and conducted runoff analysis, which includes various morphometric parameters and valley flood analysis models. We generate hydrological and surface analyses using GIS tools. Some important morphometric analyses are calculated for basin description. The geologic and geomorphologic characteristics of the study area controlled the intensity and distribution of flood destruction. Therefore, rapid precipitation and unplanned development intensify the flood's impact. The results reveal the possibility of future general flooding threatening the populous city of Ras-Ghareb. Therefore, the construction of a canal to absorb the flood load and discharge it into the Red Sea is vital to protect the city from future flood risks.

Keywords: multi-hazards model; Wadi Ras-Ghareb; The Red Sea; Egypt.

1. Introduction

Flash flooding is known as the most frequent and increasing natural hazard that occurs during a high-intensity rainstorm. High-intensity rainstorms are characterized as convective storms with high rainfall rates, rapid runoff, and an unpredictable time and location of occurrence. These severe storms, or sometimes heavy rain, result in both an increasing frequency and intensity of downstream flash floods. The rapid and episodic nature of flash flood rainfall events often results in substantial losses to human life, public safety, and private interests, including damage to roads and bridges, substructure undermining, and infrastructural failure. Therefore, flash flood events necessitate accurate, instant, or near real-time forecasting and monitoring to provide sufficient time for warning and evacuation measures to the local authorities and vulnerable population. Geographic Information Systems play a crucial role in mapping and assessing high-risk areas during high-intensity rainfall events, including flash flood hazards and environmental vulnerability. The occurrence of flash flood rainfall hazards in semi-arid wadi regions is due to several geographical or meteorological circumstances associated with them. These regions are situated in an arid area and are therefore weakly vegetated because of the scarce but relatively intense and sudden rainfall that falls in cyclonic rain systems. The frequent recurrence of flash floods has resulted in a significant number of casualties and considerable property damage. Permeable soils and massive land use have historically contributed to the rapidity of water runoff in wadis, causing a sudden change in the wadi boundary outlines. These regions lack a robust utility network of climatological and hydrological stations or observatories. These phenomena are more likely to occur in regions where human activities increase soil erosion and encroach on floodplains, primarily to meet economic and social needs and ultimately to improve quality of life. Wadis serve as natural canal systems, conveying runoff during periods of heavy precipitation to designated discharge points (Mahmood and Rahman, 2019).

Flash floods are extreme natural events that alter many landscape features and create considerable geomorphological hazards. In the surrounding landscape, flash floods initiate numerous geomorphological impacts, which include erosion, mass movement, and deposition processes. The compound hazards related to these flash floods can cause substantial potential damage to infrastructure, displace local communities, and lead to fatalities. Interactions between multiple natural hazards are particularly important, such as compound risk in multi-hazard events. Flooding has the potential to either increase or decrease the occurrence of other secondary hazards, such as mass movements, which can significantly intensify the impact of a specific compound flood (Beilicci and Beilicci, 2024).

We can summarize this study's main objectives as follows:

a) To explore the Abu Had Basin in Ras Ghareb city in great detail in order to guess and analyze the geomorphological setting of disasters. This will help create a records-based archive that shows different types of evidence that show how the Earth has changed over thousands of years, such as field evidence of flash floods in the basin and geomorphometric structure.

b) By utilizing a multiple hazards model, this paper makes a unique contribution to the existing models and field studies on the geomorphology of flash floods. The model demonstrates robustness in responding to and recovering from multiple hazards, surpassing the performance of previous models or reviews. Furthermore, the model effectively manages and mitigates flash floods, improves preparedness during the flood phase, and fosters perseverance during the hazard phase. The population in question relied on the model to demonstrate the probability of flash flooding in their daily lives. Such information is vital to designing an emergency and disaster preparedness program based on unique hazards. In the past, these models have received minimal attention, and the multiple hazards model continues to provide a more effective prediction strategy than existing models.

Numerous studies have previously examined the phenomenon of flash floods in Egypt in relation to various factors. Some focused on the effects of cold drop systems. Others investigated flash floods in Wadi Hagoul in the Eastern Desert. Studies examined the flash flooding hazard risk of the aqueous catchment, Ras El Hegez, in Abou Zenima, SW Sinai. Researchers studied the early warning systems, the mistakes made by both the government and the public, and the traditional solutions of Wadi El-Broq in Ras Gharib. Recently, researchers examined flash flood disasters in the eastern deserts, Wadi El Arish and Wadi Feiran, in South Sinai, Egypt. Researchers conducted several studies on flash floods in both the eastern and western deserts of Egypt. (Abd-Elaty et al. 2022) (Arnous et al. 2022) (Bauer et al., 2020) (Rashwan et al. 2023) (Baldi et al., 2020) (El-Saadawy et al. 2020).

2. Study Area

Heavy flash-flood rainfall characterizes this area, leading to an increase in flood hazards and their risk. The study area is considered an arid region that receives its rains from ineffective low-pressure systems during winter. Geologists greatly value the study area for its simplified sediments that record the Nubian sandstone. Additionally, they study the geomorphological features that result from landform classification, which will reveal various types of ancient movement on different geographical scales. However, there is inadequate documentation on the watershed's properties and the significant role of human activities in channel changes. The Abu Had wadi, with its recurrence intervals of 5 years, is considered one of the major wadis in the area. It drains an area of about 1300 km² in the Red Sea Eastern Desert that receives wintertime precipitation. During landform classification, the wadi and tributaries obviously show differently oriented geomorphological features. There We identify shallow features on numerous lands using topographic maps, aerial photographs, and the Digital Elevation Model. We use both materials and the interpretations of maps and photographs to justify our research. However, the proportional increase in shaded area is a classical approach to non-topographic map interpretations (Mohamed, 2024).

The Wadi Abu Had basin is located in the Eastern Desert of Egypt, with an area of about 1300 km2, between latitudes 28° 20' 0"- 28° 0' 0" N and longitudes 32° 20' 0"- 33° 0' 0" E. It originates from the Red Sea Mountain ranges and flows into the Red Sea near Ras Ghareb City (Fig.1).

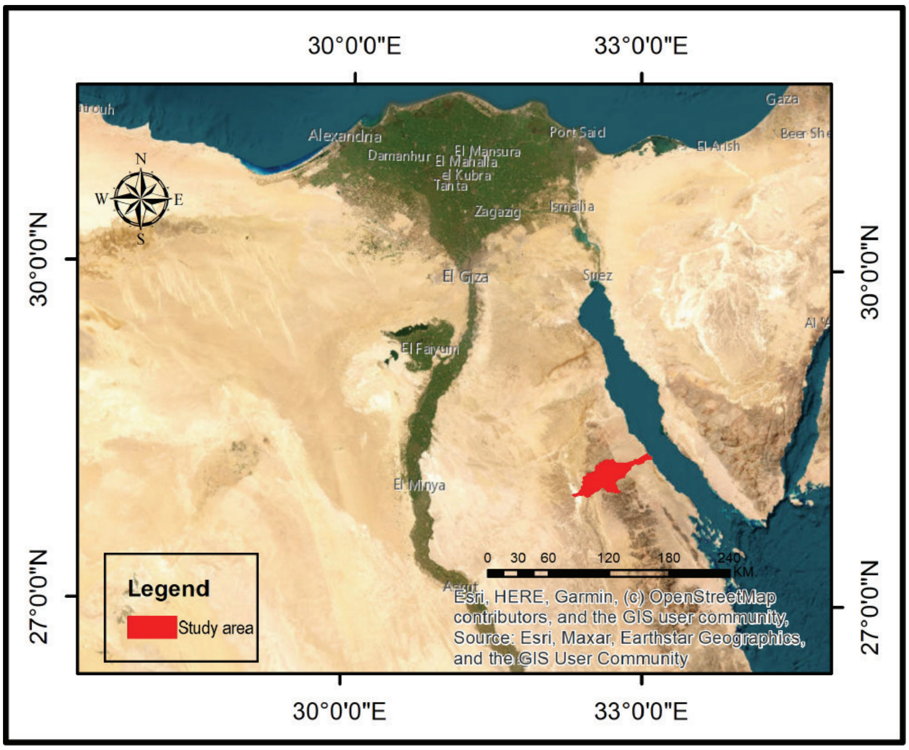


Fig.1: Location map of the study area

2.1. Geology

The area is considered part of the Red Sea Rift System. Quaternary sediments, particularly wadi sediments and beach sands, cover the basement rocks in the study area. The Proterozoic rocks that emerge in the Eastern Desert, easily recognizable as steep slopes with rugged terrain, represent the older rocks. We have subjected the basement rocks to geological study, as modern sediments can conceal their significance. Moreover, wind-blown sands with soft characteristics cover most of the older rocks, which are located in the northern part of the study area and extend to the Red Sea. The tectonic evolution of the Red Sea is a result of the separation between the African and Arab tectonic plates. A network of main faults, trending in different directions, bound the nearby area. Formations in the eastern desert host a mixture of sedimentary, metamorphic, and igneous rocks. The following geological formations, from the oldest to the youngest, cover the exposed rocks in the study area (Fig. 2):

Acid metavolcanics (Cambrian): Acid metavolcanics, one of Egypt's most significant geological and economic groups, dominate the study area, especially in the area under consideration. It forms a part of a vast, narrow, east-west trending belt. Tectonically, the metavolcanics insert themselves into a series of basic metavolcanic outcrops. Fantasy et al. (2024) say that the metavolcanics are made up of three sub-lithological units: a pinkish unit that breaks into layers all the time, a blue or green basic unit, and a group of metabasic and quartzite outcrops that are laid out horizontally between them.

Alkaline Undeformed Granite (Cambrian): The present work deals with the petrographic and radiometric study of an alkaline undeformed granite that crops out in the Eastern Desert of Egypt, almost near the Ras Ghareb area. The granite appears as a small stock, representing one of the numerous locations in the belt. It is gray in color and extremely fine-grained in texture, consisting mainly of quartz, microcline,

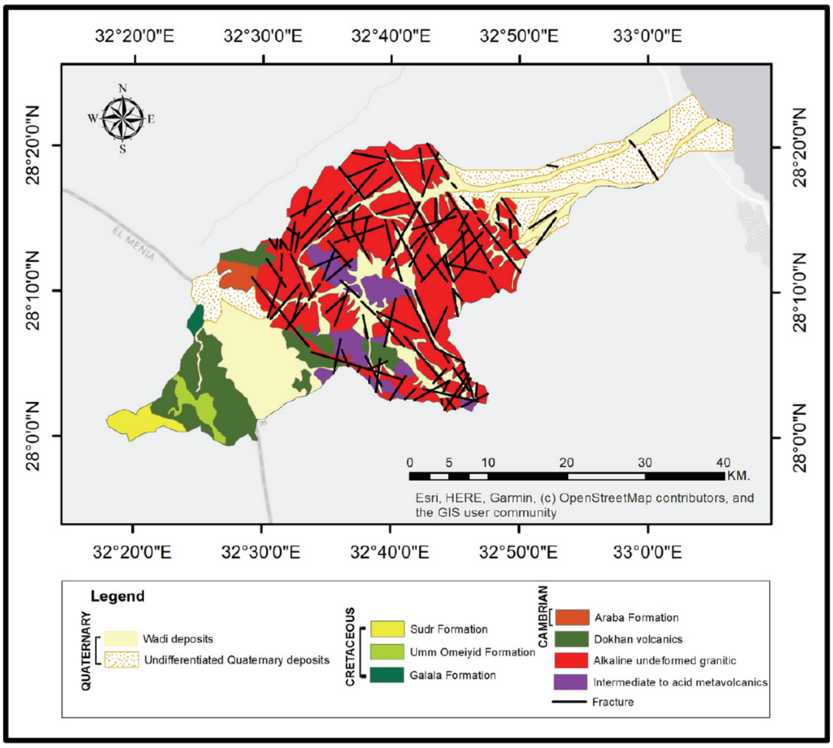


Fig.2: Geology of the study area (Conoco coral,1987).

and arfvedsonite. It has a charnockite texture (Fangary et al., 2024).

The Dokhan Formation (Cambrian): The previously known formations now have a new formal name: the Dokhan Formation. It occupies the northern part of the study area and belongs to the Neoproterozoic Era. It is considered one of the most extensive oil-producing formations along the regional trend and has the best reservoir properties. We have discovered large oil reservoirs and a few gas pools from the Dokhan Formation. The maximum thickness of the formation is about 43.60 m at the south of the investigated outcrop area. The surface exposures and weathered samples of the drill cuttings do not clearly reveal the base of the Dokhan Formation in the described cross-section. The facies changes show that in the northern part of the section, the Dokhan Formation conformably overlies the Ga'af Sandstone, and in the southern part, it unconformably overlies the basement. We can distinguish three members of the Dokhan Formation in the outcrop. Fangary et al. (2024) describe the lower member as well-bedded sandstone, siltstone, and claystone, mixed with limestone, dolomitic limestone, mudstone, anhydrite, and shale.

The Araba Formation (Cambrian): Near the Wadi Araba area in Ras Ghareb, the Eastern Desert of Egypt, lies the Araba Formation, a middle Eocene unit older than the overlying Thebes Formation. An environment similar to the younger formation deposited this sandstone, along with a negligible amount of siltstone and shale. We have not provided a summary log of the thicknesses carrying hydrocarbons from the exploration wells due to confidentiality concerns. We interpreted the seismic data and concluded the well ties to gain a comprehensive understanding of the onlaps, unconformities, and thickness changes. However, there are instances where these interpretations lack clarity. This study aims to gather all relevant data, such as wireline logs, seismic reflection profiles, and regional geological data, from the literature. It then reassesses layer terminations and structural features to derive interpretations of the local hydrocarbon potential.

The Galala Formation (Cretaceous): The area between Ras Ghareb and Wadi Khenays extensively exposes the Galala Formation, containing Middle Eocene specimens. Previously, the Danniyeh Formation was considered the source of these remnants, but the current study reveals that the best exposure for the studied specimens comes from the Middle Eocene strata near Wadi Khenayis (Moustafa, 2020).

Umm Omeiyid Formation (Cretaceous): The formation represents a ridge trending in a northwest-southeast direction with an average thickness of 113 m, composed mainly of sandstone with siltstone as interbeds. A regionally flat-lying fault with a northeast direction separates it from the El Omeda Formation, which underlies the Abu Durba Formation. Sandstone interbedded with siltstone and claystone composes the lower part of the Umm Omeiyid Formation, directly overlying the Abu Durba Formation. The sandstone is medium to coarse-grained and has a dominantly quartzose composition. Grey coloration with green mottles is prevalent within the sandstone. We recorded cross-stratification and massive beds at the basal part of the formation (Azab et al., 2024).

The Sudr Formation (Cretaceous) exhibits varying lithology and thickness in various areas within the eastern sector of Egypt. Many researchers have studied it, either in subsurface formations or in outcrops. This report presents data on the Sudr encountered in a detailed lithological section at Mirdif near Ras Ghareb, based on a set of samples collected from the surface. The upper Sudr at the foot of the first cliff is quite thick, measuring 4.9 m high, and represents the standard lower and upper Sudr members. In addition to the alteration of the clay minerals, the shale samples from the studied section and the diagenetic Sudr sediment hold significant importance. This is because these locations have largely maintained their original marine environment since their early diagenesis, thereby preserving and recording valuable data about the diagenetic environment of the Sudr material (Salman et al., 2021).

2.2. Topography

The steep topography of Abu Had Wadi, with an average slope of 11° and a maximum slope of 32.7°, categorizes it into upper, middle, and downstream regions (Fig. 3). The upstream part of Abu Had Wadi is mountainous, characterized by very shallow depressions that give rise to numerous small seasonal wadis. These wadis occasionally fall on the alluvial fans, then distribute to shallow depressions and travel through a system of natural drainages. The Wadi Valley consistently deepens toward the south of the study area. We should correlate the development history of Wadi alluvial fans with past changes in their drain. We study the relative age and tectonic shapes of these alluvial fans using longitudinal profiles and morphometric measurements. We can use these shapes to store radioactive and cosmic nuclei deposited as alluvium by examining how the origin of sediments changes over time, along with changes in weather and earthquake activity (Fig. 4).

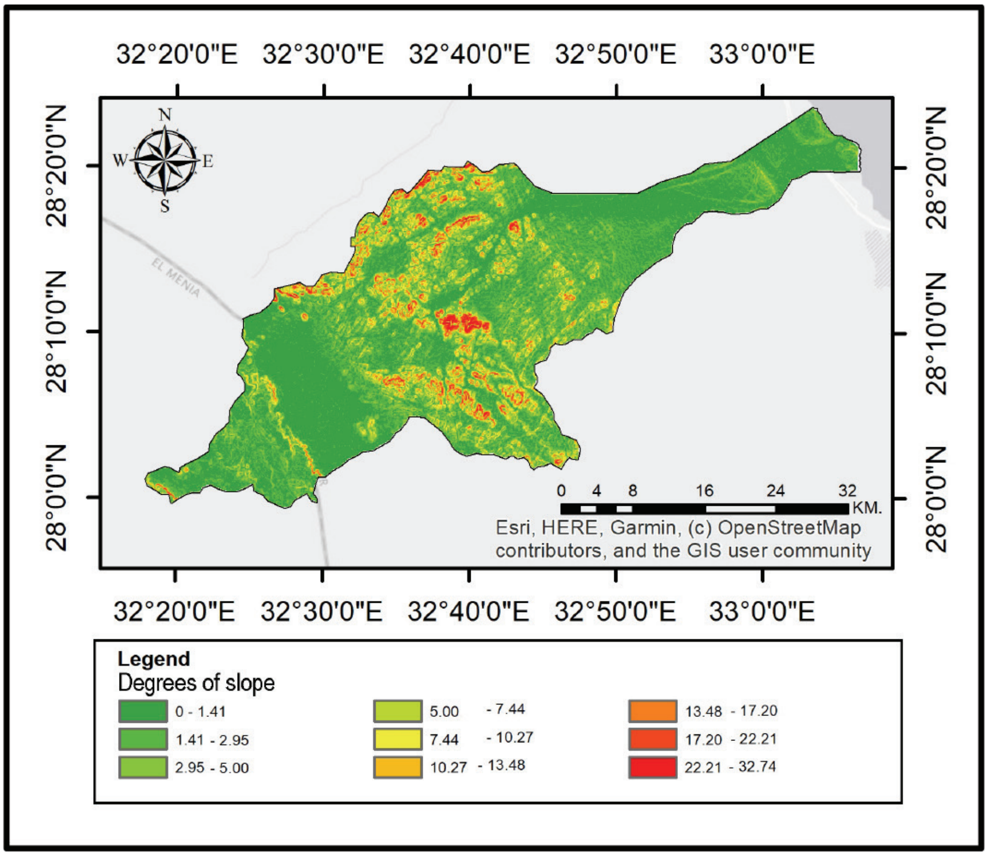
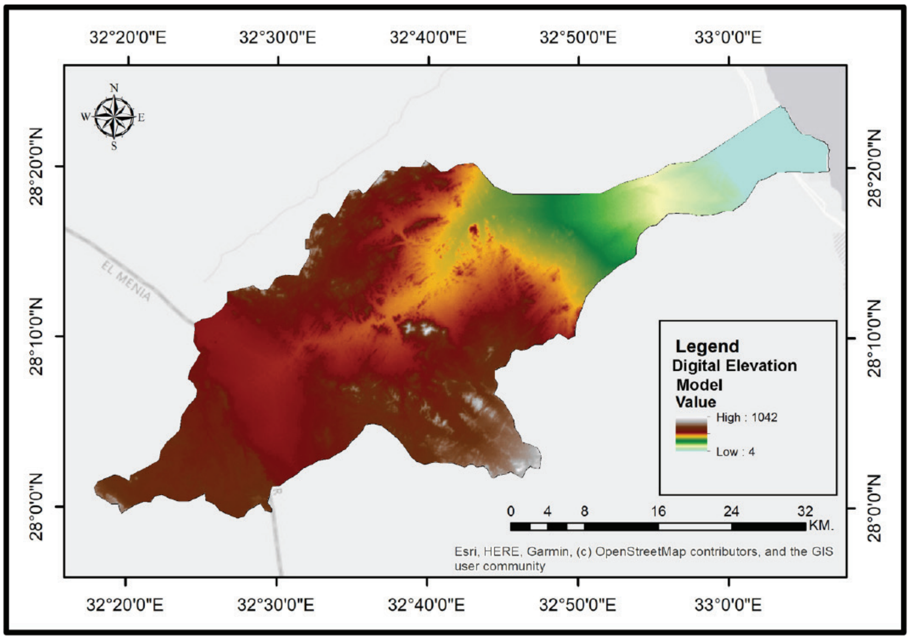


Fig.3: Slope of Abu Had Basin

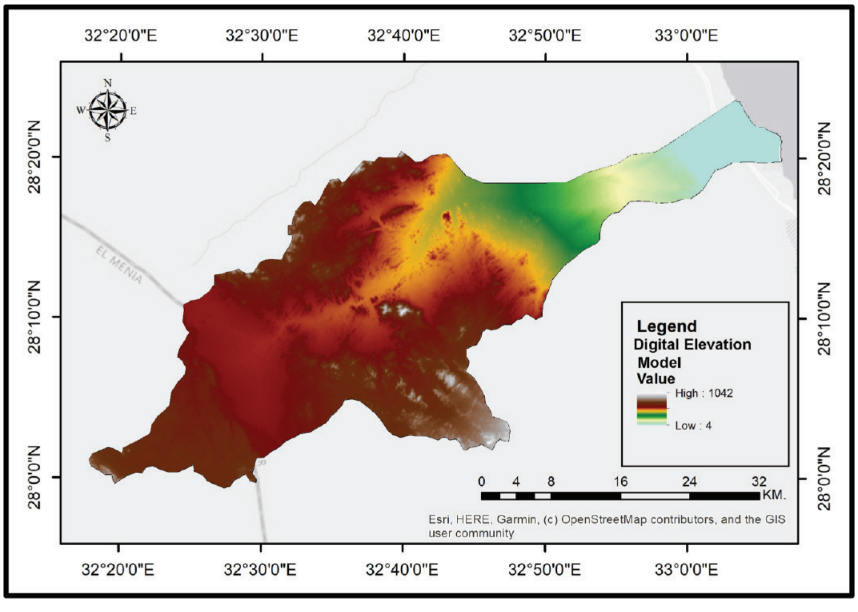


Source: Landsat 8 Operational Land Imager "OLI" 2015

Fig.4: Topography of Abu Had Basin

2.3. The digital elevation model (DEM)

We obtained the DEM for the area through the processing of two images. We used image processor software to process the images. We performed several operations on the previously mentioned images. These operations include contrast enhancement, image matching, data density, DEM generation, transformation from a geoid model to a local vertical datum, and final georeferencing. The required operations for DEM generation are at a resolution of 7-14 m. The angle dominance of the DEM transform reveals an arc plain in the upper Wadi, a slope in the middle, and a depression in the lower region. This indicates that the Wadi upper and middle are flat while the Wadi lower is in a depression (Fig. 5).



Source: ASTER GDEM TM2 digital elevation model with 7-14 m resolution

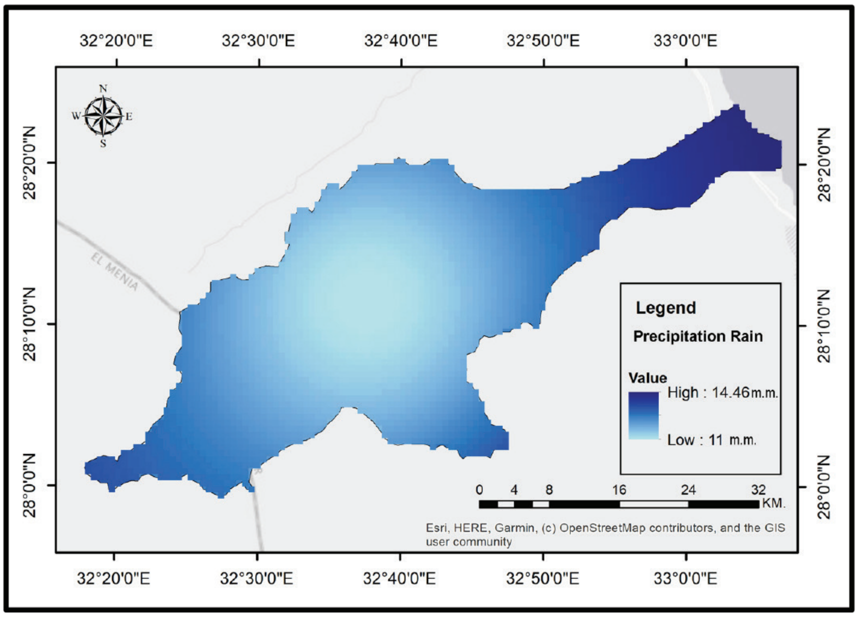
Fig.5: The digital elevation model (DEM)

2.4. The climate

Local climate robustly follows its topography, from hot and arid to semiarid and hyper-arid climatic regimes. The Eastern Desert exhibits a wide variability in both temperature and precipitation. Despite the region's year-round dryness, it experiences sudden heavy rains at intermittent and spaced intervals. During the Sudanian and Arabian Intertropical Convergence Zones, precipitation synchronizes with the fall in pressure that accompanies it. The main source of sporadic rainfall in the Nile Valley and the coastal plains is the low-pressure system that originates during the winter with the polar front from November to January. The shift in wind systems, influenced by hyperboreal, tropical, and equatorial maritime air, causes warm and thunderstorm flow to affect the coastal and inland areas east of the Nile Valley over time. Understanding the topography and the associated climate is important for water resource plans and the hydrological system in the Eastern Desert wadis. Researchers have also recognized that the rapid change in topography can lead to significant rainfall within a short distance (Fig. 6).

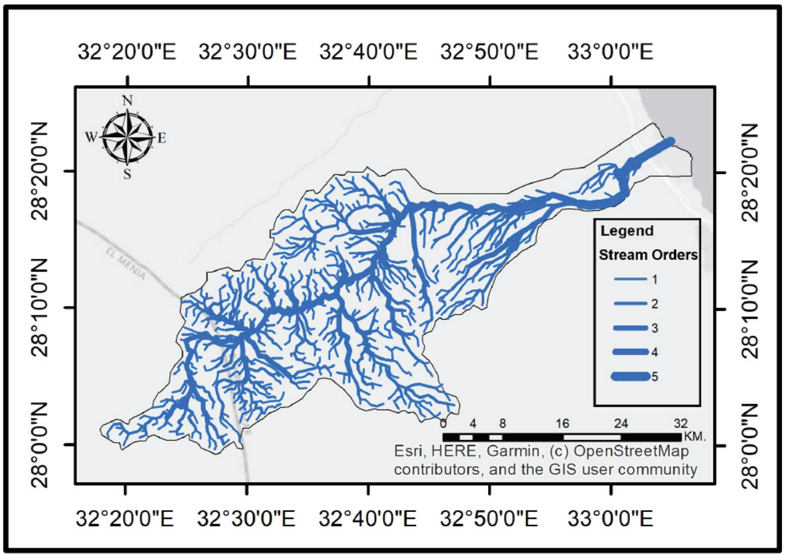
2.5. Stream network

Streams dominate Wadi Abu Had's drainage system, primarily dispersing from the canyons to the alluvial flat-lying area. Six orders divide the stream network hierarchically from the upper streams to the mouth. These classifications accurately reflect the physiogeographic structure of the study area. There is a clear seasonal variation in the stream flow regime, with streams presenting a perennial flow regime from October to April and evaporating during the remaining period. This occurs due to the seasonal pattern and high variability of the climatic conditions in the eastern desert of the Red Sea. Both topographic and climatic characteristics partly explain the above-described hydrological characteristics. Regulatory parameters responsible for the concentration of runoff depend on rock type, rock structure, and precipitation characteristics (Fig. 7).



Source: https://power.larc.nasa.gov/data-access-viewer/

Fig.6: The annual rainfall



Source: Analysis from DEM

Fig. 7: The drainage network of Abu Had Wadi

3. Research Methodology

The research methodology consisted of two main stages: data collection and the development of a Multiple Hazards Model. We conducted a geomorphological analysis and then conducted fieldwork in Abu Had Wadi to pinpoint the factors influencing Ras Ghareb City. First, the creation of a multiple hazards model involved several steps. Initially, we developed a model for geomorphological risks by identifying factors affecting the study area, creating layers based on these factors, and analyzing maps. This process involved integrating data from various layers or maps using Geographic Information Systems (GIS) software to produce a comprehensive map representing high-risk sites.

We created a hydrological model to identify dry valleys and their tributaries, derived a slope layer from a digital elevation model, created a land use layer based on aerial photographs, and incorporated climate change projections to assess future flood risk scenarios. Secondly, the field study phase involved conducting measurements using surveying equipment and visiting the study area to monitor and identify potential risks to Ras Ghareb City.

We held meetings with the research team to establish the field study's objectives and ensure comprehensive data collection. 3.1. The Multiple Hazards Model Multiple hazards refer to more than one type of event that causes varying degrees of damage in an area. It also refers to one process causing damage as a direct consequence of another hazard event, such as high rainfall following a wildfire or debris flows occurring after an earthquake that created unstable hillsides. People are starting to recognize that two or more hazards typically cause damage, leading to the practice of multi-hazard studies. However, the scientific literature rarely uses this term. In this study, I utilize water scarcity and flood analysis to examine the impact of flash floods on human life and agriculture in Ras Ghareb and the Abu Had Basin. We analyzed the evolution of hazard footprints, utilizing precipitation characteristics that contribute to water scarcity. We attributed these phenomena to the available data. We attributed these phenomena to the available data. We found that the extra impact from direct rainfall and hill slope factors, which prepared the area for flash floods, contributed to the risk level during those years. and. The distribution and increase in hazard frequencies within the watershed could potentially play a crucial role in future risk modeling. Overall, this work portrays incoming changes rather than absolute future values forced upon the community in the area of Ras Ghareb. The findings might provide a backbone in planning adaptation strategies to cope with future hazard situations and decision-making by both the local residents regarding the maintenance and growth of their livelihoods, as well as spatial and administrative planning (Müller et al., 2020) (Mahmood and Rahman, 2019).

4. Results and Discussion

In the event of a flood disaster, it is crucial to assess the affected areas and provide up-to-date, detailed information in preparation for the assessment of potential future disasters. Today, the world widely uses the evaluation of digital images to provide rapid information during ongoing disasters, making it crucial to assess the current situation. Ras Ghareb, Abu Had Basin, has been hit by a flood disaster, and it is crucial to provide detailed, timely information in Formation about the flooded areas and damaged structures. Geomorphological analysis of flash floods helps the population determine whether there is a possibility of future disasters, allowing them to take protective measures on the scene. The information demonstrates that while streamflow direction maps are useful for understanding flood disasters, they are not sufficient. This study's method effectively facilitates swift and accurate formation during floods. The research aims to provide a rapid and precise evaluation of recent changes that occurred after the flood in valuable mountainous land environments, utilizing image and elevation data sets (Saharia et al., 2021).

4.1. Flash Flood Hazard Zones

We have recognized the outlet area of Abu Had Basin as a flash flood hazard zone near Ras Ghareb City on the coastline. Afterwards, the zone combines within the alluvial fan located in front of the valley. The first zone represents the high flash flood hazard zone, while the second, third, and fourth zones represent the low flash flood hazard zone. The main parameter for detecting flash flood hazard zones is vegetation. An area with dense vegetation from wild plantations created a high flash flood hazard zone. Normally, the clay soil in the area absorbs greater amounts of water. Arid regions typically observe a low flash flood hazard zone.

We consider additional parameters, such as flooding, the local geomorphology of the wadi, the hydraulic parameters of peak discharge, the possibility of debris colliding, the degree of fence-setting inhibition, and the type of accidents. The intense rainfall in Had Village and the steep slope of the drainage basins create a swift and powerful flash flood in the second zone, during which a high proportion of the damage occurs. As the discharge to the downstream decreases, the debris in the third and fourth zones becomes relatively lighter. The minimal damage during the low-frequency flash flood can be attributed to props such as wild plants, clay soils, dry and old pavement walls, water concentration holes in front of properties, high floor-standing levels, renovated brick walls, and newly established concrete barriers (Arnous et al., 2022).

4.2. The results of the Multiple Hazards Model

The Multiple Hazards Model generates the most optimal log-likelihood outputs and cumulative percentage probabilities. The results show that the most likely types of heavy flooding in the Wadi Abu Had in the Eastern

Desert have been weak to moderate floods. These floods usually cause wadibank erosion and floodplain sedimentation, which means there is a good chance that local farms will be flooded. The model returns a small probability of very infrequent severe events. The results from the expert models or simulations show that we need to pay more attention to the severity of the rainstorms and the natural factors that affect flooding in rivers and wadis. This will help make the local desert community less at risk and vulnerable to future floods. Knowing or considering one or a combination of rainstorm, wadi, and fluvial factors may provide a valuable guide to the design of strategies to reduce flood risks. Furthermore, this research will demonstrate the potential benefits of addressing the mortality threat to humans and wildlife in planning, design, and policy decisions. Only alluvial fans and basin catchments receiving a significant amount of annual precipitation can generalize these results. Updating the input data and periodically reviewing the expertise and soft data makes the results of this model particularly useful (Fig. 8).

4.3. Discussion

The present study demonstrates the potential for identifying high-risk sites within Wady Abu Had, the Red Sea coastline in Egypt, by means of Geographic Information System analyses. The steep cliffs of Wady Abu Had, which concentrate these high-risk sites in the upper catchment reach, significantly contribute to the high discharge of floods. Ras Gharib city's residents, situated at the mouth of the wadi, face significant risks to their facilities and individuals during high floods. We have noted some differences between these GIS-based assessments and traditional flood risk assessment methodologies in identifying high-risk areas. Higher vulnerability depends on important things like the number of high-risk land uses in a flash flood valley, the differences in channel composition, and stable alluvial ground levels (Mahmood et al., 2016).

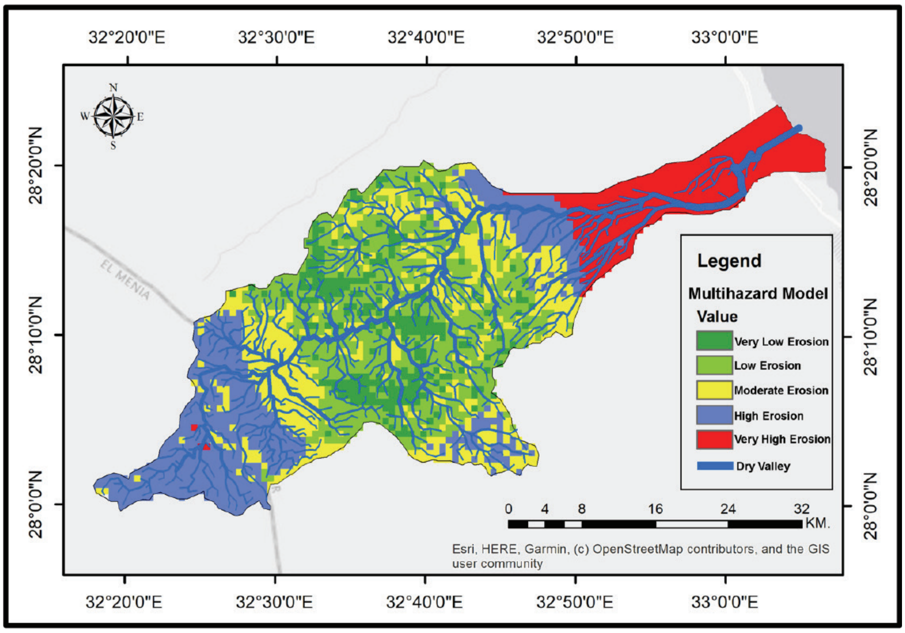


Fig.8: Multi hazards model of Abu Had Basin

All of these things make it more likely that floodwaters will come in at a higher depth and faster speed. The study also highlights the challenges and limitations faced by the researchers during their intensive and multifaceted analyses, which do not utilize the latest and most advanced science and technology expertise in GIS. At the same time, we recommend some mitigation interventions to lessen the loss of life and damage costs in the event of an extreme flood. The researchers also aim to expand the reach of current flood risk management solutions by raising awareness of channel data among local stakeholders and promoting medical emergency intervention measures for preventive and control strategies. These GIS-based assessments significantly improve the preparedness of those affected by a rare and unique flood incident, thereby enhancing the effectiveness and security of international survey teams entering the wadi (Ali et al. 2020).

5. Conclusions and recommendations

Growing sediment deposits within the basin bogs can control the flood catastrophe in Ras Ghareb City. After heavy rainfall, the bogs overbank and act as a floodplain, absorbing a significant portion of the floods for a certain period. The deposits, in conjunction with the bogs, produce a type of "cemented" floodplain with excellent potential for flood protection. We recommend building a small dam to enhance the water storage in the bogs and simultaneously extract the abundant clay layer at the basin floor. We use the sediments as backfill material in the construction of roads, bridges, buildings, and factories. We should connect the depositional areas or basin bogs with the Red Sea to expand the capacity for disposing of flash floods. This could potentially avert the need for a concrete solution to redirect the floodwaters into the Gulf of Suez. We should excavate or enlarge the Abu Had Basin until it can no longer accommodate the bush and street rubble generated within the study area.

The repetitive hazardous nature of flash floods constituted by wadis following rare high-intensity rainstorms in Egypt and the entire Middle East region has increased their destructive potential on manmade landscapes and infrastructure. There is thus a need to set priorities to mitigate and manage future flash floods using the newly digitalized geomorphological analysis model described in this work. However, this work recommends adding additional phases to the taxonomy model. These phases include There are two types of phases: minimal statistical phases, which include and exclude spatial factors, and variable statistical phases, which are a group of techniques made just for quasisynoptic studies. These phases enhance the accuracy of geomorphological analysis by accounting for changes in the size and speed of flash floods over time and space.

Another urgent need would be to suggest corresponding mitigation measures according to the results of this work concerning newly identified flash floods or zones with more destructive potentials for flash flood events, which could then be constructed, depending on priorities. For instance, the powerful force of runoff water during a flash flood event will inevitably defeat authorities' efforts to design supportive manmade infrastructures like levees, berms, or sandbags. Additionally, using heavy machinery during flash floods to manipulate water flow patterns in rock beds, such as canals or sediment pools, with the intention of increasing sediment volume and blocking water flow in critical hot spots poses significant risks and dangers. When we cannot guide runoff water as previously planned or when progressive clogging of pooling sediments occurs, these areas of intervention become critical. Therefore, future research should prioritize seclusion and minimize reliance on risky human support during high-intensity flash floods.

Author contributions

Magdy Torab conceived the article's ideas and conducted the data processing and interpretations; he also wrote and prepared the manuscript and conducted fieldwork in the study area.

Emad El-Bardan contributed to the analysis of the variables associated with hydrological characteristics, remote sensing, GIS data processing, design and drew all the maps in the article.

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Declarations of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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