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ASSESSING FLOOD RISKS IN ARID ZONES BY LINKING REMOTE SENSING TECHNIQUES AND GIS

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ABSTRACT

Regarding the importance of protecting arid areas in Egypt from flood hazards, this research was initiated to assess flood hazards in such zones by integrating hydrologic modeling, hydrodynamic modeling, remote sensing techniques, and GIS, where Sudr Valley was considered a case study. This study presents a proposal for new methods to assess expected flood hazards that impacted the arid projects by simulating the Sudr Valley modeling case. The study is based on applying the HEC-HMS program to draw valleys and outflow basins and compute their morphometric attributes thus computing the peak flow hydrograph of floods for different basin outflow. The candidate also implied the hydraulic model (HEC-RAS) to calculate flood flow components (depth and velocity) thus mapping floodplain areas. Results were obtained; analyzed and represented on maps. The results highlighted that the updated information on Sudr Valley hydrology and morphology was important to decision-makers. In addition, the tooled modeling is applicable to delineate Sudr Valley. It was further recommended to follow the utilized methodology to visualize similar areas.

KEYWORDS: GIS, Remote Sensing, HEC-RAS, HEC-HMS, Floodplain

تقييم مخاطر الفيضانات في المناطق القاحلة بواسطة الربط بين تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية أحمد ماهر علي*

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الملخص

من حيث أهمية حماية المناطق القاحلة في مصر من مخاطر الفيضانات، فقد بدأ هذا البحث لتقييم مخاطر الفيضانات في هذه المناطق من خلال دمج النمذجة الهيدرولوجية والنمذجة الهيدروديناميكية وتقنيات الاستشعار عن بعد ونظم المعلومات الجغر افية، حيث تم اعتبار وادي سدر حاله دراسيه. تقدم هذه الدراسة اقتر احا لطرق جديدة لتقييم مخاطر الفيضانات المتوقعة التي أثرت على المشاريع القاحلة من خلال محاكاة حالة نمذجة وادي سدر . تعتمد الدراسة على تطبيق برنامج HEC-HMS لرسم الأودية وأحواض الندفق وحساب خصائصها المور فومترية وبالتالي حساب هيدر وغراف تدفق الذروة للفيضانات لتدفق الأحواض برنامج HEC-HMS لرسم الأودية وأحواض الندفق وحساب خصائصها المور فومترية وبالتالي حساب هيدر وغراف تدفق الذروة للفيضانات لتدفق الأحواض المختلفة. كما أشار البحث إلى النموذج الهيدروليكي (HEC-RAS) لحساب عناصر تدفق الفيضان (العمق والسرعة) وبالتالي رسم خرائط حرم مجري الفيضان . تم الحصول على النتائج. وتحليلها وتمثيلها على الخرائط. وأبرزت النتائج أن المعلومات المحدثة التي تم الحصول عليها حول هيدرولوجيا وادي سدر ومور فولوجيا كانت ذات أهمية كبيرة لصانعي القرار. بالإضافة إلى ذلك ، فإن النمذجة مزودة بأدوات قابلة للتطبيق في ترسيم وادي سدر ومور فولوجيا كانت ذات أهمية كبيرة لصانعي القرار. بالإضافة إلى ذلك ، فإن النمذجة مزودة بأدوات قابلة للتطبيق في ترسيم وادي سدر . ويوصي باتباع المنعجبية المستخدمة لتصور مجالات ممائلة.

الكلمات المفتاحية : نظم المعلومات الجغرافيه , الاستشعار عن بعد ,نظام النمذجة الهيدرولوجية, نظام تحليل الأنهار,حرم مجري الفيضان.

1. INTRODUCTION

Worldwide, assessing flood risks and undertaking measures to mitigate their danger is an important issue to consider. Accordingly, many researchers are interested in this field. Likewise, it is the case in Egypt, where many researchers are involved in mitigating flood risks in several areas in the Sinai Peninsula (i.e. Wadi Watir and Wadi Grundel). This is achieved within the framework of fulfilling the 2030 Egypt Vision objectives. Among them, for example, is Abo Taha (2021), who assessed flood hazards by incorporating hydrologic so as hydrodynamic modeling. Similarly, Noha Mahmoud (2017) investigated floodplain management, where Wadi Watir- Sinai was taken as a case study. Likewise, Nedovic-Budic (2016) integrated planning and flood risk management, where he established a conceptual framework for the integrated infrastructure. Similarly, Benavides (2001) implemented hydrologic models (i.e. HEC-HMS, NEXRAD, and HEC-RAS) to model an area in Texas.

Moreover, Hegger (2013) established consortium methods for flood management. Likewise, Abdel-Lattif (2012) used GIS techniques and remote sensing to find the interrelation between the morphometric parameters by using statistical correlation to determine the area under varying flood conditions. Moreover, Attia Karima's (2010) This study investigates the impact of high releases downstream of Assiut Barrages (544.75 km from the low Aswan Dam).

Moreover, Gabr (2015) quantified the hydrological parameters for the flash flood event of 17th January 2010 in Sinai using multiple sets of remote sensing data and fieldwork for Non-gaged catchments. Moreover, Sonbol (2005) studied the types of errors that cause inaccurate conclusions of the hydrological analysis results. Moreover, John Shelley (2015) studied unsteady flow and sediment modeling in a large reservoir using the ras.

Moreover, Shuhua (2013) modeled the extent of inundation around Poyang Lake, china using Landsat images digital elevation models. Moreover, Mahmoud (2017) Developed Flash Floods Inundation Maps Using Remote Sensing in Wadi AL-Arish, Sinai, Egypt. Moreover, Ran (2016) studied the integration of spatial planning with flood-risk management prominence as an approach to mitigating the risks of flooding.

Consequently, this research originated with the impartial of assessing flood risks by linking remote sensing techniques and GIS, where Sudr Valley was taken as a case study within the framework of protecting arid areas in Egypt.

2. SITE VISITS AND STUDY AREA RECONNAISSANCE

Several visits were carried out to accumulate data about the area. Moreover, native residents were interviewed to obtain additional information. The assembled data and information were analyzed to perceive a complete picture of the study area.

Based on the analyzed data, the study area was reconnoitered, from which the study area, figure (1), was described, as follows:

- The Study Area is located between the latitudes 29°40'0.00" N and 29°50'0.00"N, whereas it is located between the longitudes 32°45'0.00"E and 33° 0'0.00" E.
- The study area is 609.81 km^2 .
- The study area is located in Northeast Suez Gulf.
- It encompasses Wadi Sudr, which is the most significant wadi in South Sinai.
- Wadi Sudr leads to Suez Gulf.



Figure (1) Study area location in the Sinai Peninsula

3. NUMERICAL MODELLING

This section elaborates on the implemented models, remote sensing, hydrologic modeling, and digital elevation model, as follows:

3.a. IMPLEMENTED MODELS

WMS & HEC-HMS hydrologic models were used. In addition, HEC RAS was tooled to calculate the flood limits, while ARC GIS was utilized to manage flood areas; estimate the torrential hazards; produce flood maps; envisage the hydrological condition; visualize the morphological consequences, and produce maps.

3. b. REMOTE SENSING

The remote sensing features were integrated with the geographic information systems and the severities of the urban progress were obtained.

In addition, ARC GIS remote sensing analyzed the satellite images, and the flood path area expansion, within the boundaries, was obtained.

3. c. HYDROLOGICAL MODELLING

A hydrogeological model was implemented, where basins were delineated; the streams were defined and the morphological features were recognized.

Moreover, several models were utilized and a high delineation to Wadi Sudr was obtained, where the external boundaries delineation was achieved by GIS software. In addition, HEC-HMS software was tooled and the waterways were signposted.

Obvious was that the main basin has 11 sub-basins, where 7 are known by name to the native residents (i.e. Bedouins).

4.d. DIGITAL ELEVATION MODEL

Furthermore, a *D*igital *E*levation *M*odel "DEM" (i.e. 30 m resolution) was obtained from the Earth Explorer Website of the USGS, where streams were displayed per 200 m². This is considered to be accurate; in terms of the available DEM; Figure (2).

5. RESULTS ANALYSIS AND DISCUSSION

Results of hydrogeological modeling, rainfall, losses, surface runoff, and hydrodynamic modeling were obtained; analyzed, and presented in figures (3) to (18) together with tables (1) to (4).

5. a RESULTS OF HYDROGEOLOGICAL MODELLING

Results were obtained; analyzed and represented in figures (2) to (7). Figure (2) designates the implemented DEM, while figures (3) to (7) represent the contour lines, slope intensity to the study area topography, streams in Wadi Sudr with 200 m² resolution, streams orders, and percentage of stream order, respectively. In addition, tables (1) and (2) designate % of stream order and sub-basin characteristics. Moreover, figure (8) represents the sub-basins in the study area.



Figure (2) Implemented DEM



Figure (3) Contour lines in the study area



Figure (4) Slope intensity of the study area topography



Figure (5) Streams in Wadi Sudr with 200 m² resolution



Figure (6) streams orders in Wadi Sudr without background



Figure (7) Percentage of streams orders

Stream Order	Length (km)	Percentage (%)
1	378.46	49.41
2	177.48	23.17
3	110.78	14.46
4	29.84	3.90
5	54.66	7.14
6	14.77	1.93
Sum	765.99	100.00

Table (1) Lengths and % of stream order

Table (2) Sub-basins characteristics

Subbasin	Area(Km2)	Longest Flowpath Length (KM)	Longest Flowpath Slope (M/M)	Centroidal Flowpath Length (KM)	Centroidal Flowpath Slope (M/M)	10-85 Flowpath Length (KM)	10-85 Flowpat h Slope (M/M)	Basin Slope (M/M)	Basin Relief (M)	Relief Ratio	Elongation Ratio	Drainage Density (KM/KM²)
1	70.619	15.92846	0.00716	6.31845	0.00541	11.94635	0.00556	0.06589	277	0.01739	0.59531	0.08221
2	46.623	21.35468	0.00897	9.71273	0.00849	16.01601	0.00744	0.08263	275	0.01288	0.3608	0.16082
3	44.462	19.63142	0.02015	9.40359	0.01356	14.72356	0.0127	0.16324	410	0.02088	0.38326	0.09817
4	41.535	17.08645	0.02555	8.56758	0.02609	12.81484	0.02154	0.20583	438	0.02563	0.42561	0.02562
5	35.124	13.68189	0.03179	6.3498	0.01559	10.26142	0.02752	0.13866	445	0.03252	0.48878	0.02684
6	37.215	16.76512	0.02326	8.33897	0.01424	12.57384	0.0158	0.15059	483	0.02881	0.41059	0.05604
7	38.951	14.43644	0.03221	7.19514	0.01787	10.82733	0.0263	0.13757	465	0.03221	0.48781	0.21302
8	122.8	26.40541	0.01572	7.43885	0.01344	19.80406	0.01546	0.11097	457	0.01731	0.47354	0.13817
9	41.456	16.82675	0.03025	8.95054	0.00793	12.62006	0.01267	0.16962	517	0.03072	0.43177	0.2887
10	37.371	19.75842	0.02445	10.08805	0.00615	14.81882	0.00904	0.14484	483	0.02445	0.34912	0.4155
11	104.3	40.36337	0.00969	23.42552	0.0041	30.27252	0.00817	0.06833	443	0.01098	0.28551	0.23942

4.b. RESULTS OF RAINFALL

Rainfall data were attained; examined and presented, where Figure (9) and Table (3) are provided to represent the statistical analysis of Wadi Sudr Station and the rain depths for different return periods, respectively.

It is to be noted that images were acquired. They represent the statistical analysis of the available data on rain, which is similar to the study area. This was achieved by Weibull-Distribution-Method, where this method incorporates probability theory and statistics. It is a continuous probability distribution, which is named after a Swedish mathematician.

This is similar to the maximum moment's method, which is authorized by the Egyptian Code for protection from flooding rains danger.



Figure (8) Statistical analysis of Wadi Sudr Station

 Table (3) Rain depths for different return periods

Return Period	10	25	50	100
Max24 Hr. Precipitation				
Depth(Mm)	19.4	29.3	37.3	45.7

4. c. RESULTS OF LOSSES

Results were obtained; investigated and presented, where figures (10) and (11) are presented. They designate the land uses and geological map of the study area, respectively.

As for the *rainwater losses*, the soil type and land use were signposted. Regarding the *deep seepage*, *Curve-Number-Method used*, where for the desert and urban areas, the utilized numbers were 86 and 87, respectively. Focusing on the *images*, paintings from satellite imaging were employed, where the images were divided into several layers according to the wave frequency of the obtained image. Concentrating on the *soil*, it was obtained from the geological map, figure (11).



Figure(8) Land uses in the study area



Figure (9) Study area geological map

4.d. RESULTS OF SURFACE RUNOFF

Results were acquired; investigated and provided, where HEC HMS Program and the hydrography were obtained and presented in Figure (12). The figure indicates the losses in ml and surface runoff depth in mm.



Figure (10) Hydrograph from HEC HMS Program

4.e. RESULTS OF HYDRODYNAMIC MODELLING

Results were obtained; inspected and provided, where HEC RAS Program was utilized to calculate flood limits, at specified return periods and time, where the 2-D simulation was tooled in flood map calculation, for a 100 years return period. During this period, the study area was sustainable, in terms of the Egyptian Code for flood danger protection. In addition, a link was established between the GIS program and the HEC RAS program to reflect the inundation maps, where figures (13) and (14) are provided to represent the limits of flood inundation with maximum depth and maximum velocities, for a return period of 100 years, respectively.



Figure (11) Limits of flood inundation and maximum depth (100-year return period)



Figure (12) Limits of flood inundation and maximum velocities (100-year return period)

5. ASSESSING RISKS TO URBAN AREAS

Remote sensing techniques were linked to GIS and the zones in need for flood-protection places by works were designated. Accordingly, maps were produced for the Sudr Valley Delta Region, where most of the population is concentrated. This was achieved by utilizing high-resolution satellite maps of "type 1 Land Sat-8" and by involving ARC GIS.

A set of maps was produced, where urban developments during 2000-2022 were obtained. Moreover, its relationship to the flood plain and its impact on the increasing possibility of expansion was assessed under the immersion risk or exposure to flood risk.

This will provide decision-makers with adequate information to signpost their decision about urban expansions within the framework of Egypt 2030 vision.

Accordingly, figures (15) to (19) are provided to represent boundaries of flood inundation, flooded areas, flood inundation boundaries, in Jan 2000, and flood inundation boundaries in Jan 2012, for 100

year return period, in Wadi Sudr Delta, respectively. Moreover, table (4) is provided to list the flood inundation boundaries during a return period of 100 years.



Figure (13) Boundaries of flood inundation in Wadi Sudr Delta (100-year return period)



Figure (14) Flooded areas in Wadi Sudr Delta



(100-year return period)

Figure (15) Flood inundation boundaries in Wadi Sudr Delta (100-year return period) (Land use at Jan 2000)





Figure (16) Flood inundation boundaries in Wadi Sudr Delta (100-year return period)

Figure (17) Flood inundation boundaries in Wadi Sudr Delta (100-year return period) (Land use at Jan 2022)

Year	Urban areas (km²)	Increase in urban areas (km ²)
1990	2.9	
2000	3.55	0.65
2012	18	14.45
2022	69	51

 Table (4) Flood inundation boundaries during 100 years

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the obtained results, the following conclusions were deduced:

- The obtained results contributed to producing updated information on Sudr Valley hydrology and morphology.
- The implemented programs proved their reliability in delineating the study area
- The tooled models and GIS visualized inundation maps (maximum depth and maximum speed) during 1990-2022.

Based on the deduced conclusions, the following recommendations were suggested:

- Utilize the implemented methodology to visualize similar areas.
- Flood and urban expansion should be considered during designing mitigating measures to achieve Egypt's 2030 vision.

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