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Flood Hazard evaluation and Water Harvesting Estimation in South Sinai by using Remote Sensing and GIS Techniques, case study (Dahab and Kid valleys)

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Abstract— Sinai Peninsula is one the most vital areas in Egypt due to its wealth of mineral resources, oil wells and gas fields. This is in addition to its tourist resorts and geographical location which overlooks three of the world continents. The objectives of this work were to develop the drainage networks in Dahab and Kid valleys and to make an assessment of the expected flood hazards and their management. Arc hydro extension under ArcGIS software was used to develop the drainage network in both valleys for the digital elevation model (DEM). Flood hazard was derived from the morphometric characteristics of each valley. The dam sites were proposed. The major results of this work was the development of the drainage network for both valleys and their sub-basins by using GIS-techniques. Flood hazard was more serious in Dahab valley when compared with Kid valley due to variations among the morphometric, topographic and climatic characteristics of both valleys. However, local variations were also observed among the different sub-basins within each valley. Dam sites were proposed to protect infrastructure from flood hazard, to harvest and sustain water resources and to develop settled villages.

Index Terms Drainage network, flood Hazard, GIS, Remote sensing, morphometric parameters, water harvest, Sinai Peninsula.

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1 Introduction

Flash flood is one of the most devastating natural hazards especially in arid mountainous regions. They could cause severe damage in both public and private properties and loss of many lives. About 54,000 person were killed and about 950,000 people were affected by flash floods in all parts of world from 2000 to 2009 according to the World Disasters Report 2010 [1]. Worldwide, floods also cause economic damage worth greater than 11 million US dollars annually. Flash floods can be instantaneously generated during or shortly after a rainfall event, especially when an intensive rain falls on steep rocky slopes. They are generally characterized by raging torrents, which results in flood waves that sweep everything before them. Also, the debris load magnifies the destructive power of a flash flood [2]. Current researches make an intensive use of the GIS techniques digital elevation models (DEMs) in making a quantitative description of the geometry of the drainage basins and their networks. The morphometric parameters of basins can be classified into two groups: the measured and the calculated parameters. On the other hand, the calculated parameters include the number of streams, stream length, bifurcation ratio, length of overland flow, drainage density, drainage frequency, form factor, circularity ratio, elongation ratio, relief ratio, surface slope, basin relief and ruggedness number [3]. Flood potential is directly associated with drainage basin morphometric parameters. The drainage density for instance is positively associated with the degree of runoff and channel abrasion for a given quantity of rainfall. Therefore, drainage density could provide both hydrologists and geo-morphologists with useful numerical assessment of landscape dissection and runoff potential [4].
Water harvesting is another approach for collecting runoff for useful using and providing an additional water resource. It reduces the speed of water during flood events over time, increases the concentration of hydrographic basins and reduces the flood risk [2]. GIS based suitability model was used in the central Rift Valley in Ethiopia to create suitability maps by integrating different factors through Multi Criteria Evaluation (MCE) [5]. Both remote sensing products and GIS were integrated to determine rainwater harvesting sites in Unguja Island. Micro and Macro catchments were used to maps rainwater harvesting suitability and identify several possible impoundment sites [6].
Two valleys were used in this study, which are Dahab and Kid. They are located in in south Sinai, which is an arid region. Dahab is one of the major tourist sites in south Sinai and Kid was considered as a nature reserve area in 1992. Rainfall events in Sinai can be characterized as local convective storm events with high spatial variability and short durations [2]. In Dahab, flood events are not frequent, however they are very severe when happen. Some of tourist areas are affected by these flood events and some of the nearby cities such as Nuweiba become also flooded. Flood disasters have been reported in 1990, 1997, 2002 and 2010 at Dahab-Nuweiba highway [7]. Therefore, flood prevention should not be limited to the very frequent flood events bout it should also include rare events [2].
The objective of this work was to develop the drainage networks in Dahab and Kid valleys by using GIS techniques. This is in addition to deriving the morphometric parameters of the two valleys and assessing the magnitude of the expected flood hazards and their locations. Also, to identify several possible impoundment sites suitable for rainwater harvesting and

management.

2 MATERIAL AND METHODS

2.1. Description of study area

Two valleys in south Sinai were used in this study, which are Dahab and Kid as represented in Figure 1. Dahab valley is located between these coordinates 28°22'43.4" and 28°52'18.5" N and 33°55' 46.9" and 34°31'28.8" E and it covers an area of about 2050 km². Kid valley is bounded by these coordinates 28°07'15" and 28°31'10" N and longitude 34°20' 10" and 34°22' 30" E and it covers an area of about 1020 km².

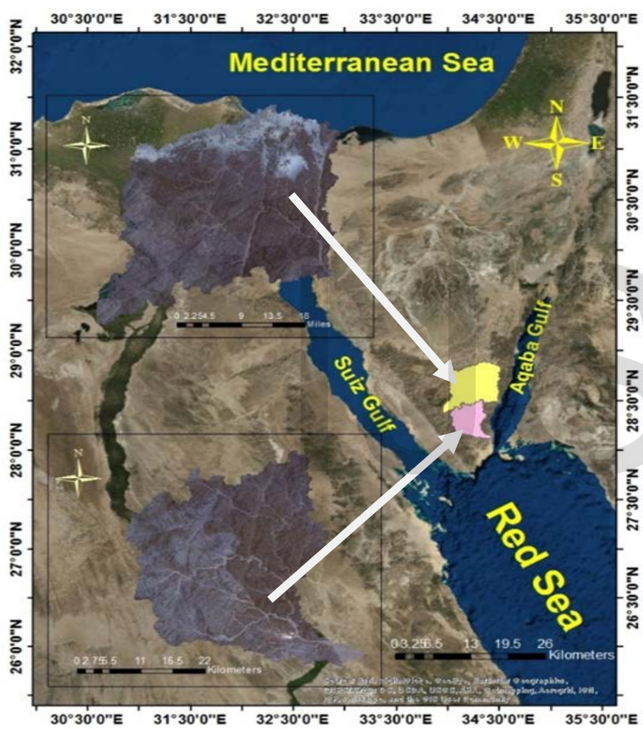

Fig.(1): Location map of Dahab and Kid valleys in South Sinai.

Climatic conditions in south Sinai are characterized by hot dry in summer and cold wet in winter. Meteorological data were collected from Dahab meteorological station. Weather elements were recorded on a daily basis in Dahab valley from 2009 to 2014, as represented in Table 1 (data downloaded from: http://www.worldweatheronline.com in January 15, 2014). The average monthly rainfall (AMR) in Dahab varied from 0.81 to 12.1 mm in 2009 and 2010, respectively. South Sinai came under very severe flash floods in 2010. The average monthly temperature (AMT) varied from 21.8 ^{0} to 25.4 ^{0}C in 2009 and 2014, respectively. July and August are the hottest months and January is the coldest. The MAP for Kid valley was calculated as the average of precipitation data for both Dahab and Sharm Elshiek. The calculated AMR for Kid valley was found to be about 11.5 mm in 2010.

The lithology of Dahab basin is covered by three types of rocks, which are: 1) Precambrian igneous rocks which cover more than 63% of the study area, 2) Metamorphic rocks which cover small parts of the study area (Sub-basin 1 and 4) and 3) Sedimentary rocks which cover the northern part of the study area including Cambrian to Upper Cretaceous rocks [8].

2.2 Sources of data and data analysis

A 30 m digital elevation model (DEM) for the studied areas was downloaded from the ASTER GDEM website in January 17, 2015 [9]. Drainage network, terrain attributes and morphometric features were derived from that DEM by using Archydo extension and ArcGIS 10.1 software package. The flowchart of the applied procedures is illustrated in Figure 2.

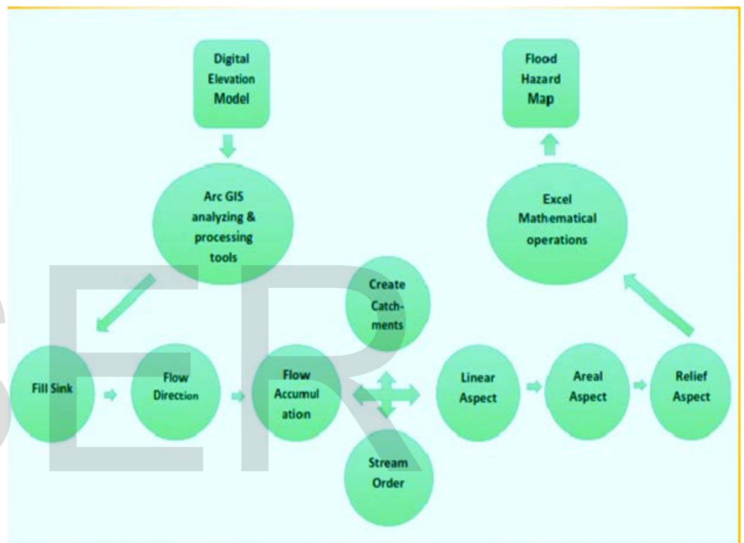

Fig. (2): Flowchart of the procedures that were carried out in this work.

The DEM was gone through a series of preprocesses in this sequential order “fill sink, flow direction, flow accumulation, create catchment and stream order” to derive the drainage network in both valleys. All these processes were carried out by using the Archydro extension in ArcGIS 10.1. Terrain attributes (i.e. slope, aspect and elevation) were derived from the DEM by using the spatial analyst in ArcGIS. The different morphometric parameters for both valleys were also derived from the DEM. These parameters were classified into two types: linear parameters (Table 2) and areal parameters (Table 3). The studied linear parameters included: Stream order(U) (Figures 3and4 shows 8th stream order for Dahab vally and 7th stream order for kid valley respectively), Max length of the basin (Lb), Stream number (Nu), Stream length (Lu), Bifurcation ratio (Rb), and Length of over land flow (Lo). However, the studied areal parameters included Drainage Density (D), Drainage Frequency (F), Form Factor (Rf), Circularity Ratio (Rc), Elongation Ratio (Re), Relief Ratio (Rh), and Ruggedness Number (R).

Table 1 Average Monthly of Rainfall and Temperature in DahabValley

Month	Average Monthly Rainfall						Average Monthly Temperature						Average Temperature
	2009	2010	2011	2012	2013	2014	2009	2010	2011	2012	2013	2014	
Jan.	0.0	6.5	0.8	0.7	2.6	2.9	11.6	12.4	17.2	14.4	17.3	18.5	15.2
Feb.	0.0	0.9	0.2	0.0	0.0	0.0	11.3	16.6	17.6	19.1	18.7	20.1	17.2
Mar.	0.0	0.0	0.0	0.0	0.0	2.8	14	18	19.6	19	21.6	21.5	19.0
Apr.	0.2	0.1	0.5	0.1	0.0	0.6	22.4	23	21.2	23.2	23.4	24.8	23.0
May	0.5	0.2	0.5	0.1	0.3	1.4	23.2	25.2	24.6	25.9	26.6	28.3	25.6
June	0.0	0.0	0.0	0.0	0.0	0.0	29.3	28.8	28.2	29.4	29.3	29.6	29.1
July	0.0	0.0	0.0	0.0	0.0	0.0	30.8	30.6	30.2	30.6	29.9	30.6	30.5
Aug.	0.0	0.0	0.0	0.0	0.0	0.0	30.2	30.6	30.4	29.4	29.8	31.3	30.3
Sep.	0.0	1.0	0.0	0.5	0.0	0.0	27	28.6	28	29.2	29.5	29.4	28.6
Oct.	0.1	0.3	0.0	0.8	0.0	0.2	23	27.4	25.6	27.9	25.5	27.2	26.1
Nov.	0.1	2.7	0.0	0.7	0.1	0.0	15.8	23.6	18.8	25.3	23.8	23.1	21.7
Dec.	0.0	0.4	0.0	0.1	1.2	1.1	23	19.6	17.6	19.9	15.3	20.6	19.3
Average	0.81	12.1	1.98	3.04	4.26	8.88	21.8	23.7	23.3	24.4	24.2	25.4	23.8

2.3 Floods hazard Index

The degree of flash floods hazard for each sub-basins in both Dahab and Kid were determined based on the derived morphometric parameters. Each parameter for all the basins and sub-basins were first normalized by using feature scaling method. Since the values of each morphometric parameter (A, S, U, R, D, F, Rc, Rh, ∑ Nu, ∑ Lu) vary widely for each sub-basin, therefore it is necessary to normalize the raw data before processing. As a result each parameter has a value that ranges between zero and one.

Since, both the Lo and Rb parameters have a reverse relationship with the flood risk. The Flood Hazard Index is calculate according to the following equation:

$$\text{Flood Hazard} = N(A)+N(S)+N(U)+N(R)+N(D)+N(F)+N(Rc)+N(Rh)+N(\sum Nu)+N(\sum Lu)+N(Lo)+N(Rb) \quad (1)$$

Where, N is the normalized values for each of the studied parameters [10].

Results and Discussions

3.1 Drainage network and Morphometric Analysis in Dahab Valley

Thirty eight sub-basins were delineated and analyzed in Dahab valley as illustrated in Figure 3. Results of the studied morphometric parameters are represented in Table 5. The linear parameters indicated that the perimeter of sub-basins varied from 8.28 to 223 km, stream order ranged between 2 and 6, basin length varied from 2.9 to 75.88 km, length of overland flow varied from 0.19 to 0.26, and stream number and stream length significantly varied from 7 to 1578 and 4.26 to 965 km, respectively[11].

On the other hand, the areal parameters revealed that the bifurcation ratio ranged between 2 to 8.8. In general, this ratio ranges between 3 and 5 for areas that are relatively homogeneous in lithology. The largest sub-basin (No 4) has an area of about 433 km2, whereas the smallest sub-basin (No 25) has an area of about 1.91 km² [12]. Drainage density varied from 1.90 to 2.67 and drainage frequency ranged between 2.58 and 6.19. The Form factor varied from 0.047 to 0.45 and the circularity ratio varied from 0.06 to 0.39.

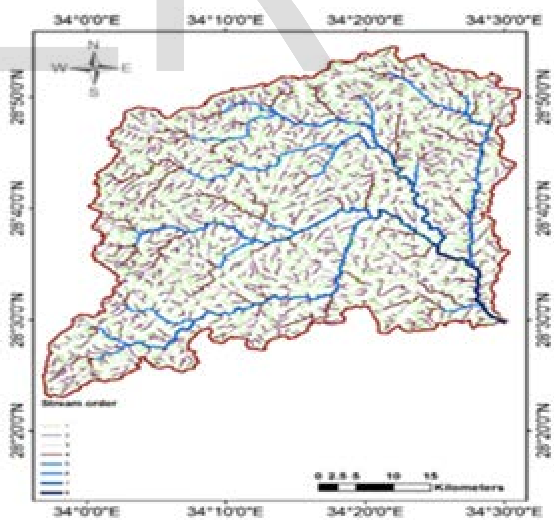

Figure 3. Sub-basins in Dahab valley and their drainage network and stream orders.

Table 5. Morphometeric parameters of Dahab sub-basins.

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basin				Linear Aspect						Areal Aspect						Relief Aspect		
code	P	U	L b	sum(Nu	SUM(Lu)	Rb	Lo	A	D	F	Rf	Rc	Re	S	H	Rh	R
1	175	6	55	880	589.6	3.78	0.21	245.7	2.40	3.58	0.08	0.10	0.32	14.56	852	0.02	2.04
2	159	6	50	1075	728.9	3.08	0.20	286.3	2.55	3.75	0.11	0.14	0.38	11.98	898	0.02	2.29
3	190	6	49	1444	964.9	3.62	0.21	413.4	2.33	3.49	0.17	0.14	0.47	17.31	1632	0.03	3.81
4	223	6	76	1578	962.4	3.94	0.22	432.9	2.22	3.65	0.08	0.11	0.31	19.66	1924	0.03	4.28
5	90	5	26	415	213.9	3.33	0.20	85.8	2.49	4.84	0.13	0.13	0.40	10.66	710.0	0.03	1.77
6	49	5	18	146	86.2	3.31	0.19	32.8	2.62	4.45	0.11	0.17	0.37	9.28	497	0.03	1.30
7	44	4	14	143	82.8	2.49	0.19	31.6	2.62	4.53	0.17	0.21	0.46	9.58	359	0.03	0.94
8	36	5	11	125	77.9	3.03	0.19	29.1	2.67	4.29	0.24	0.29	0.55	9.87	405	0.04	1.08
9	38	4	14	105	61.1	3.10	0.20	24.8	2.46	4.24	0.13	0.22	0.41	14.10	420	0.03	1.04
10	22	4	7.6	38	20.8	3.07	0.20	8.3	2.49	4.55	0.14	0.22	0.43	11.37	260	0.03	0.65
11	38	4	11	101	50.7	3.38	0.21	21.1	2.40	4.79	0.17	0.19	0.47	10.88	471	0.04	1.13
12	10	3	2.9	10	6.4	2.45	0.20	2.6	2.48	3.89	0.30	0.31	0.61	18.09	451	0.15	1.12
13	18	3	6.3	37	16.2	2.58	0.24	7.9	2.05	4.67	0.20	0.30	0.50	18.75	489	0.08	1.00
14	24	3	8.8	31	23.6	2.65	0.24	11.1	2.11	2.78	0.14	0.24	0.43	20.46	559	0.06	1.18
15	39	4	12	86	44.7	3.08	0.22	19.7	2.27	4.36	0.15	0.16	0.43	17.26	690	0.06	1.57
16	22	4	6.9	45	21.0	3.01	0.26	11.1	1.90	4.07	0.23	0.28	0.54	23.88	789	0.11	1.50
17	19	4	8.2	36	17.2	2.72	0.24	8.1	2.11	4.42	0.12	0.29	0.39	22.93	811	0.10	1.71
18	12	3	2.9	23	9.2	3.46	0.21	3.9	2.35	5.89	0.45	0.34	0.76	21.88	543	0.18	1.28
19	66	5	19	389	207.3	3.39	0.23	96.7	2.14	4.02	0.25	0.28	0.57	23.46	1527	0.08	3.27
20	40	4	13	134	70.3	2.64	0.24	33.7	2.08	3.97	0.22	0.26	0.52	21.29	1182	0.09	2.46
21	26	4	11	64	34.0	2.52	0.24	16.1	2.11	3.97	0.13	0.29	0.41	21.91	835	0.08	1.76
22	17	3	5.3	27	11.6	4.00	0.26	6.1	1.91	4.45	0.22	0.28	0.53	22.77	583	0.11	1.11
23	11	3	3.9	11	6.9	2.83	0.23	3.2	2.15	3.43	0.21	0.32	0.51	17.93	549	0.14	1.18
24	10	3	3.8	10	4.9	2.45	0.22	2.1	2.30	4.67	0.15	0.27	0.43	21.31	566	0.15	1.30
25	8.4	3	3.1	9	4.8	2.24	0.20	1.9	2.54	4.71	0.20	0.34	0.50	22.75	545	0.18	1.38
26	23	3	6.8	54	22.7	2.30	0.21	9.7	2.34	5.57	0.21	0.23	0.52	15.05	452	0.07	1.06
27	13	2	4.6	23	9.1	2.64	0.21	3.7	2.42	6.14	0.18	0.29	0.48	15.60	465	0.10	1.12
28	15	4	5.6	26	14.6	2.45	0.19	5.6	2.62	4.65	0.18	0.30	0.48	15.50	383	0.07	1.00
29	16	3	6	22	11.9	2.00	0.22	5.3	2.24	4.13	0.15	0.25	0.43	15.60	392	0.06	0.88
30	16	3	4.7	27	13.0	2.23	0.21	5.5	2.39	4.94	0.24	0.28	0.56	15.89	448	0.09	1.07
31	15	4	4.1	31	13.8	2.66	0.25	6.9	1.99	4.46	0.41	0.38	0.72	24.57	763	0.19	1.52
32	9.7	3	3.8	18	6.2	2.45	0.24	2.9	2.13	6.19	0.21	0.39	0.51	27.40	772	0.21	1.64
33	42	4	15	51	43.3	6.32	0.23	19.8	2.19	2.58	0.09	0.14	0.34	26.93	722	0.05	1.58
34	83	4	29	128	88.5	8.80	0.22	39.8	2.22	3.22	0.05	0.07	0.24	20.95	747	0.03	1.66
35	10	3	2.9	16	6.6	2.00	0.23	3.1	2.14	5.18	0.37	0.36	0.69	23.66	726	0.25	1.56
36	8.3	3	3	7	4.3	2.00	0.23	1.9	2.22	3.63	0.21	0.35	0.52	15.95	342	0.11	0.76
37	116	4	34	281	171.8	2.01	0.20	68.8	2.50	4.09	0.06	0.06	0.27	19.59	834	0.02	2.08
38	73	3	19	92	83.1	2.50	0.20	33.2	2.51	2.78	0.09	0.08	0.33	21.31	907	0.05	2.27

3.2 Drainage network and Morphometric Analysis in Kid Valley

Twenty one sub-basins were delineated and analyzed in kid valley as represented in Figure 4. The results of morphometric parameters are shown in Table 6. The linear parameters revealed that the perimeter of sub-basins varied from 9.42 to 213.8 km, stream order ranged between 3 and 7 , basin length varied from 3.42 to 45.49 km, length of overland flow varied from 0.15 to 0.27, and stream number and stream length significantly varied from 11 to 633 and 7to 357.42 km, respectively. However, the areal parameters indicated that the bifurcation ratio ranged between 2 to 3.747. The largest sub-basin (No 1) has an area of about 183.92 km2, whereas the smallest sub-basin (No 5) has an area of about 3.14 km^2. Drainage density varied from 1.82 to 3.25 and drainage frequency ranged between 3.02 and 7.26. The Form factor varied from 0.043 to 0.366 and the circularity ratio varied from 0.02 to 0.44. The elongation ratio ranged between 0.23 and 0.68, which indicate that the shape of sub-basins varies from very elongated to oval and nearly circular.

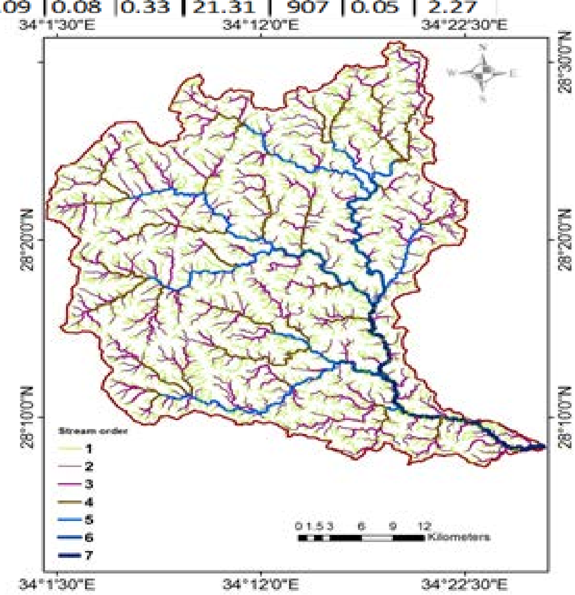

Figure 4. Sub-basins in Kid valley and their drainage network and stream orders.

Topographic parameters revealed that the average slope of sub-basins varied from 3.05° to 24.58°, where high slopes indicate a steep basin and low slopes indicates a flat basin. The

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total relief (H) of Dahab's sub-basins ranged between 66and 1973 m, the relief ratio varied from 0.01 to 0.17 and the ruggedness number varied from 0.19 to 3.99.

3.3 Production of Flood Hazard Maps for Dahab and Kid Valleys

The flood hazard map was produced by using ArcGIS and statistical method for both Dahab and Kid valleys based on their morphometric characteristics. The values of the food hazard index (FHI) were normalized in the range from one to six. The flood hazard potential (FHP) was classified into three categories based on the values of the FHI. These categories are low, moderate and high. The FHP is considered low if the FHI falls in the range from 1 to 2. Moderate FHP falls in the range from 3 to 4 and high potential falls in the range from 5 to 6. Accordingly, Sub-basins numbers 2, 3 and 4 in Dahab Valley are considered having a high FHP as illustrated in Figure 7a.

Sub-basins 3 and 4 had higher surface areas, bifurcation ratios, lengths of overland flow, drainage densities and drainage frequencies. Although, sub-basin 4 has more longitudinal shape, the number of streams and their frequency contributed to the high FHP. On the other hand, sub-basin 3 has higher ruggedness number, which resulted in higher FHP. Sub-basins numbers 1, 5, 6, 7, 8, 12, 17, 18, 20, 24, 25, 27, 28, 30, 32 and 35 are considered having a moderate FHP. Although, sub-basin number 1 has a large surface area, its elongated shape contributed to its moderate FHP. The rest of sub-basins in Dahab valley are considered having a low FHP. Among the 21 sub-basins in Kid valley, sub-basins numbers 1, 2, 5, 13 and 16 are considered having a high FPH as represented in Figure 7b. However, sub-basins 1 and 16 had the highest vales. . Sub-basins 17 and 19 are having a low FHP, which could be attributed to their lower surface areas, circularity ratios, gentle slopes, elongation ratios and higher Form factors. The rest of sub-basins in Kid valley are having a moderate FPH. Although, sub-basins 5 and 7 had similar surface areas, drainage densities and frequencies, bifurcation ratios and lengths of overland flow, they were in different categories according to their FHP. Sub-basin 7 had more elongated shape which resulted in its low FHP, whereas sub-basin 5 had a higher ruggedness number which resulted in its higher FHP.

In conclusion, about 62% of the surface area in Dahab valley was considered under high FHP, about 27% of the valley was under moderate potential and the rest of the area (11%) was under low FHP. In Kid valley, about 56% was considered under high FHP, about 38% of the valley was under moderate potential and the rest of the area (6%) was under low FHP. Accordingly, serious concerns need to be given to these sub-basins that are located under moderate and high FHP in both valleys to protect these areas against flood hazards

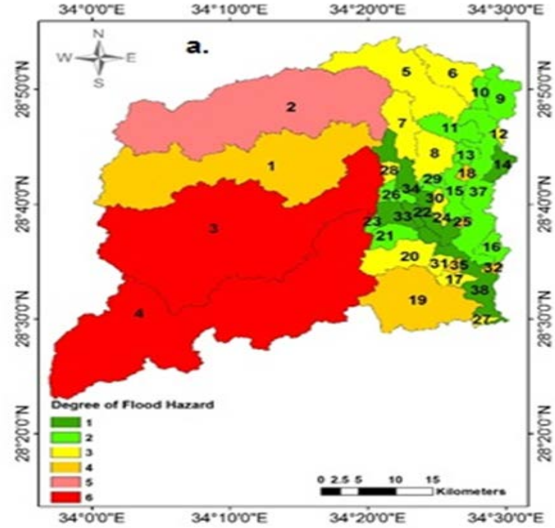

Figure 7.a Flood hazard map for Dahab sub-basins.

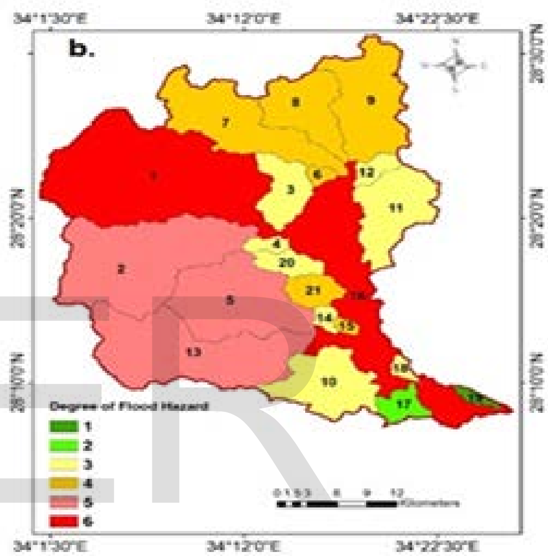

Figure 7.b Flood hazard map for Kid sub-basins.

3.3 Rainfall water management and proposed sites for dams

Rainfall data were calculated daily, monthly and annually during the period from 2009 until 2014. The, obtained data revealed that 2010 was the most rainy year when compared with the other mentioned year. In Dahab Valley, the annual rainfall was about 12.14 mm in 2010 with neglected evapotranspiration and absorption (Table 3). Due to the lack of rain gauges in Kid valley we were relied on rainfall data collected from both Sharm El-Sheikh, and Dahab meteorological station. Accordingly, the average annual rainfall in the Kid valley was about 11.5 mm in 2010.

Table 6. Morphometric parameters of Kid sub-basins.

basin		Linear Aspect						Areal Aspect						Relief Aspect			
code	P	U	Lb	SUM(Nu)	UM(Lu	Rb	Lo	A	D	F	Rf	Rc	Re	S	H	Rh	R
1	88	5	25.0	633	357.4	3.3	0.3	183.9	1.9	3.4	0.3	0.3	0.6	24.1	1639	0.1	3.2
2	76	5	27.0	403	252.2	3.1	0.3	126.3	2.0	3.2	0.2	0.3	0.5	24.6	1726	0.1	3.4
3	36	4	11.2	114	57.8	3.0	0.2	28.4	2.0	4.0	0.2	0.3	0.5	24.0	919	0.1	1.9
4	15	3	5.4	31	12.3	2.0	0.2	6.1	2.0	5.1	0.2	0.3	0.5	21.5	574	0.1	1.2
5	58	5	15.4	322	178.1	2.9	0.2	87.2	2.0	3.7	0.4	0.3	0.7	22.1	1326	0.1	2.7
6	12	3	3.8	27	8.4	2.2	0.3	4.5	1.8	6.0	0.3	0.4	0.6	24.4	576	0.2	1.1
7	77	5	23.1	234	153.9	2.6	0.3	77.5	2.0	3.0	0.1	0.2	0.4	23.2	1386	0.1	2.8
8	48	5	14.3	160	93.7	2.5	0.2	46.3	2.0	3.5	0.2	0.3	0.5	21.8	1017	0.1	2.1
9	64	5	19.8	255	147.5	3.5	0.2	71.9	2.1	3.5	0.2	0.2	0.5	22.3	1128	0.1	2.3
10	53	5	14.3	217	118.3	3.5	0.2	52.7	2.2	4.1	0.3	0.2	0.6	16.0	703	0.0	1.6
11	49	5	15.6	184	106.3	3.4	0.3	53.7	2.0	3.4	0.2	0.3	0.5	21.9	829	0.1	1.6
12	19	4	6.3	44	16.7	3.0	0.3	9.2	1.8	4.8	0.2	0.3	0.5	21.0	591	0.1	1.1
13	82	6	29.7	391	237.2	3.0	0.2	117.2	2.0	3.3	0.1	0.2	0.4	22.5	1973	0.1	4.0
14	13	3	4.6	23	9.9	2.6	0.3	5.0	2.0	4.6	0.2	0.4	0.5	23.8	638	0.1	1.3
15	9.4	3	3.4	11	7.0	2.8	0.2	3.1	2.2	3.5	0.3	0.4	0.6	22.2	588	0.2	1.3
16	214	7	45.5	454	287.9	3.7	0.2	88.6	3.2	5.1	0.0	0.0	0.2	19.4	1118	0.0	3.6
17	26	3	7.4	61	30.4	2.8	0.2	13.2	2.3	4.6	0.2	0.2	0.6	10.8	381	0.1	0.9
18	14	3	5.2	31	9.5	2.5	0.2	4.3	2.2	7.3	0.2	0.3	0.5	15.3	303	0.1	0.7
19	18	3	6.4	17	12.8	3.5	0.2	4.3	3.0	3.9	0.1	0.2	0.4	3.1	66	0.0	0.2
20	24	4	7.8	53	26.6	3.3	0.3	13.5	2.0	3.9	0.2	0.3	0.5	22.4	711	0.1	1.4
21	21	4	7.0	68	32.1	2.7	0.2	15.4	2.1	4.4	0.3	0.4	0.6	22.3	795	0.1	1.7

Building hydraulic facilities such as dams, reservoirs, lakes and ponds, were proposed in this work for water harvest. Many sites were suggested for dams in Dahab and Kid valleys to avoid severe damage resulted from flood hazards as illustrated in Figure 8 (a and b). This is in addition to supplying fresh water to the local population, which is suffering from water scarcity. Furthermore, is to provide water supply that is used in grazing, agricultural activities and recharging groundwater aquifers.

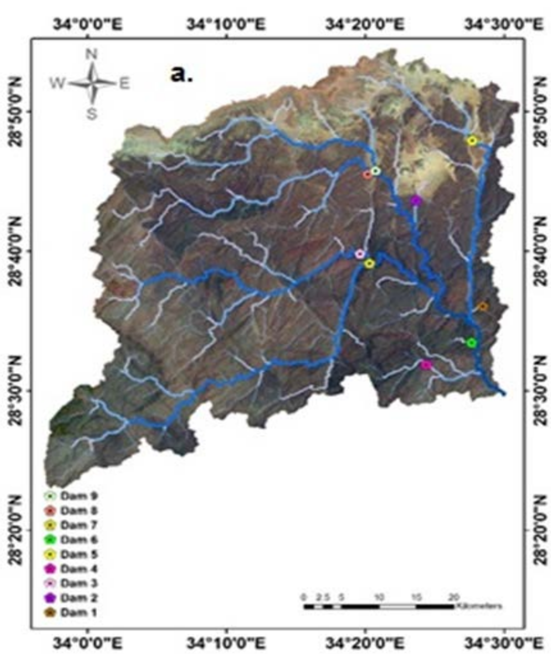

Figure 8.a Suggested sites for Dams in Dahab valley

These sites were proposed based on the amounts of rainfall and the morphometric characteristics of the drainage network in both valleys. Table 8 shows the calculations of water harvest at the suggested sites for dams in Dahab and Kid Valleys. All loss in water resulted from evaporation or transpiration were neglecting in this work, where the volume of water storage is the amount of rain water that is expected to be stored in the aquarium in 2010. The area of suggested dam is the area of basin that satisfy storage to the quantity of rain water before the suggested dam. The volume of suggested dam is the volume of basin, which is calculated by multiplying the height of water by the area suggested for a dam.

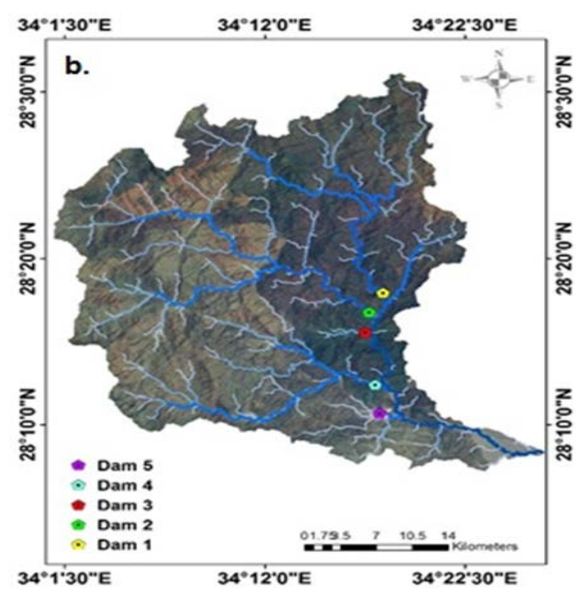

Figure 8.b Suggested sites for Dams in Kid valle

Table 8. Calculations of water harvest at the suggested sites

for dams in Dahab and Kid Valleys

For Dahab Wadi	Dam 1	Dam2	Dam3	Dam4	Dam5	Dam6	Dam7	Dam8	Dam9
X coordinates (m)	644212.941	636230.171	629750.17	637672.94	642712.941	642973.097	630853.839	630505.4066	631432.941
Y coordinates (m)	3164724.25	3178625.01	3171501.1	3156924.3	3186654.254	3159902.91	3170235.5	3182032.358	3182484.25
Basin Area (m2)	10340826	25300000	380633361	44815082	134821449	7981493	433501125	243457421	285716341
Annual Rainfall (mm)	12.1375	12.1375	12.1375	12.1375	12.1375	12.1375	12.1375	12.1375	12.1375
Vol. of water storage(m3)	125511.776	307078.75	4619937.4	543943.06	1636395.337	96875.3713	5261619.9	2954964.447	3467882.09
Area of suggested dam(m)	44965.5136	486143.875	1139413.4	205895.3	671414.0745	24347.3652	364118.558	244759.8898	752309.159
Height of water(m)	4	3	4.5	3	3	5	16	14	6
Vol.of suggested dam(m3)	179862.054	1458431.63	5127360.4	617685.9	2014242.223	121736.826	5825896.92	3426638.457	4513854.95

For Kid Wadi	Dam 1	Dam2	Dam3	Dam4	Dam5
X coordinates	627801.08	626661.08	626316.08	627253.64	627675.4709
Y coordinates	3131007.01	3128877.01	3126612	3120811	3117603.064
Basin Area (m2)	312197744	380698952	19411260	212521159	41398333
Annual Rainfall (mm)	11.5	11.5	11.5	11.5	11.5
Vol. of water storage(m3)	3590274.06	4378037.95	223229.49	2443993.3	476080.8295
Area of suggested dam(m)	685764.935	813963.494	72989.387	423077.14	194431.3423
Height of water(m)	6	6.5	4.5	7.5	3
Vol.of suggested dam(m3)	4114589.61	5290762.71	328452.24	3173078.5	583294.0269

5 Conclusions and Recommendation

GIS provides a wide range of valuable tools that can be used in developing drainage networks in watersheds and calculating morphometric parameters for each sub-basin, which can be used in evaluating flood risks and suggesting appropriate sites for water harvest. The flood hazard maps developed for sub- basins in Dahab and kid valleys indicated serious degrees of flood hazard potential (FHP) in both valleys. About, 62% of the surface area in Dahab valley was considered under high FHP and about 56% of surface area in Kid valley was in the same category. The FHP in these values was mainly affected by the relief ratio, elongated shape and drainage density.

These flood hazards have more destructive effects on the infrastructure and public and private property in the studied valleys. Accordingly, serious management practices should be considered to eliminate the risk of flood hazards in these areas due to their economic value and their role in the Egyptian national revenue. Some hydraulic facilities such as dams, reservoirs and ponds can be used for water harvest to provide a secondary fresh-water resource to the local population and to recharge groundwater aquifers.

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