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MONITORING AND DETECTING LAND AND WATER RESOURCES POTENTIAL FOR RAINFED AGRICULTURE OF WADI MAGED IN WESTERN NORTH COAST - EGYPT USING REMOTE SENSING, GIS AND HYDROLOGICAL MODEL

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ABSTRACT

Egypt belongs to an arid and semi-arid climate region. About 960 000 km^2 or 96% of the Egyptian area is covered by desert (Sinai Peninsula, Eastern Desert and the Western desert). In the desert, the primary sources of water are rainfall and underground water, which is mostly saline or not available at all. When there is no rainfall, people face drought and famine. Those years without rain also reduce grazing lands, increase livestock mortality and bring additional misery for inhabitants of the areas. The main objectives of this study are: 1) Monitoring and detecting the water resources in terms of potential runoff, wetness index, power index, sedimentary index and finally location of cisterns of wadi-Mages basin in Northern West coast of Egypt, 2) Detecting the catchment areas and identifying the state of the suitable area for cultivation and soil resources at wadi-Mages basin by the integration of RS/GIS technologies through geostatistical analysis and hydrological model. To achieve these aims, it has been choosed the most suitable source of Digital Elevation Model (DEM) by using topographic maps, to identify the drainage network and catchment's areas of basins and sub-basins through DEM-Hydro processing. Estimation of runoff volume and runoff irrigation potential were through rational hydrological formula, and identifying potential sites for water harvesting and soil types of the rainfed agricultural areas of Wadi Maged catchment. Based on the location of outlets and the wetness index, soil samples were collected from 10 soil profiles and defined the soil types based on the results of soil properties. Results showed that Wadi Maged watershed have an area 21094 Fed. It was comprised 9 sub-basins at 2500m stream length with potential runoff irrigation areas ranged from 7 to 76 Fed. when rainfall is 100 mm/year, and ranged from 11 to 114 Fed. when rainfall is 150 mm/year, and ranged from 18 to 190 Fed. when rainfall is 250 mm/year. About 20 potential cisterns of Wadi Maged basin for runoff water harvesting and storage were assessed and their optimal locations were identified. Wadi Maged basin was classified into 3 classes are Typic Torriorthents, Typic Torripsamments and Lithic Torripsamments in addition to rocky areas. The integrated methodology of this study could be represented as a ready module for applying at different locations for rainfed agriculture in Egypt.

Keywords: Hydrological model, Geostatistical analyses, Rainfed agriculture, DEM, SRTM, ASTER, Wadi Maged, Matrouh.

INTRODUCTION

Mona A. *et. al.,* 2011, illustrated that the Coastal Zone of Western Desert (CZWD), historically Egypt is a pastoral zone, and the raising of livestock is the main socioeconomic activity. This zone has witnessed major changes over the last 50 years; demographic growth, urbanization, touristic development and agro-ecological diversification. More recently, the zone has faced a long drought period from 1995 to 2011, with low erratic rainfall (< 150

mm). The North West Coastal zone of Egypt typifies the challenges of sustainable natural resource management and agro-pastoral systems development in semi-arid environments. About 120,000 Bedouin whose livelihood depends upon largely rainfed agriculture areas. It has a low and sporadic rainfall (60 year average at Mersa Matrouh 144 mm, CV 45%), clearly within the realm of semi-arid non-equilibrium ecosystem conditions (Ellis, 1994). Human settlements and land use are entirely dependent on rainfall and various forms of water harvesting. The coastal zone of Egypt extends for more than 3500 km and is the home of more than 40% of the population. This dense population is concentrated around the industrial and commercial cities, including Matrouh, Alexandria, Port Said, Damietta, Rosetta and Sinai Governorates (El-Raey, 1993). The major constraints that affect crop production under low rainfed conditions in the north coastal region of Egypt summarized as follows: (1) low average rainfall; (2) poor soil fertility, (3) the majority of the soil is loose sand, which has poor water-holding capacity; (4) most farmers use a mono-culture system, they use a cereal-cereal crop system and do not use a cereal-legume crop rotation system; (5) overgrazing is common, which does not help to accumulate plant residues in the soil and hence does not build up soil organic matter; and (6) soil erosion by wind is common in these areas and reduces soil fertility (Hamdi, *et. al.,*2004). Egypt has limited water resources, and it will be under water stress by the year 2030. Therefore, Egypt should consider natural and non-conventional water resources to overcome such a problem. Rainwater is steadily becoming recognized as an important source of water. But it is still has some way to go before it can be accepted as a source of drinking water.
Rainwater does not gain any significant share of the global market as a source of drinking water. Rainwater is often characterized as better quality than other water sources (Thomas & Greene, 1993). The rainfed areas in the Northern Western Coastal plains extend over vast areas from western part of Alexandria towards the west at Al-Sallum near the Libyan borders. Rates of rainfall are very poor ranging from 100 m/yr. in the east and 150-200 mm/yr. in the west. Rainfall decreases from the seashore to inwards the desert for 15 km to reach only 50 mm/yr. (Ahmed Kamel, 2011). Productive or potentially productive areas in terms of runoff accumulation and soils are concentrated within a small number of wadis and depressions, mainly along the Coast. There are 218 wadis with their watersheds or sub-watersheds in the targeted area. One of the main issues is to increase the efficiency of runoff water use for human and animal consumption and cultivation, and to minimize soil erosion. To improve run-off efficiency necessitates constructing water harvesting structures; cisterns, and dykes. Water stored in cisterns is mainly used for domestic and livestock, and partly for summer irrigation of trees. Dykes are exclusively used for spreadsheet irrigation (Abdel-Kader, *et. al.* 2004).

Rainwater harvesting can reduce the use of drinking water for landscape irrigation and sanitation. It is also an effective water conservation tool and proves more beneficial when coupled with the use of native, low-water-use and desert-adapted plants. Additionally, rainwater is available free of charge and puts no added strain on the municipal supply or private wells.

Furthermore, groundwater recharge or deep drainage percolation is a hydrologic process where rainwater moves downward to the groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface. Recharge occurs both naturally (through the water cycle) and anthropologically (i.e., artificial groundwater recharge), where rainwater is routed to the subsurface (Abdel-Kader, *et. al*. 2004).

The main objectives of this study are: 1) Monitoring and detecting the water resources in terms of potential runoff, wetness index, power index, sedimentary index and finally location of cisterns of wadi-Mages basin in Northern West coast of Egypt. 2) Detecting the catchment areas and identifying the state of the suitable area for cultivation and soil resources at wadi-Mages basin through the integration of RS/GIS technologies with geostatistical analysis and hydrological model.

MATERIALS AND METHODS

Location and climatological data of the study area

The study area is located in the western part of Matrouh city south Zawyat Umm El-Rakham area as shown in Fig.1. The studied area is located between longitudes 26° 56′ 54.0" to 27° 07′ 22.4" East and latitudes 31° 10′ 48.7" to 31° 22′ 45.7" North. The International Coastal road passes in the middle of the study area from east side to west side and Al-Dabha Al-Sallum road pass through the south part of the study area. The northern part contains number of close valleys started from the North West costal road to the south up to the International Coastal road. The climate of the study area is rainy in the winter, dry hot in the summer, where the minimum annual rain is 87.10 mm/year and the maximum annual rain is 274.50 mm/year with an average rainfall of 145.06 mm/year of climatic period from 1944 up to 2008 (E.M.A., 2008).

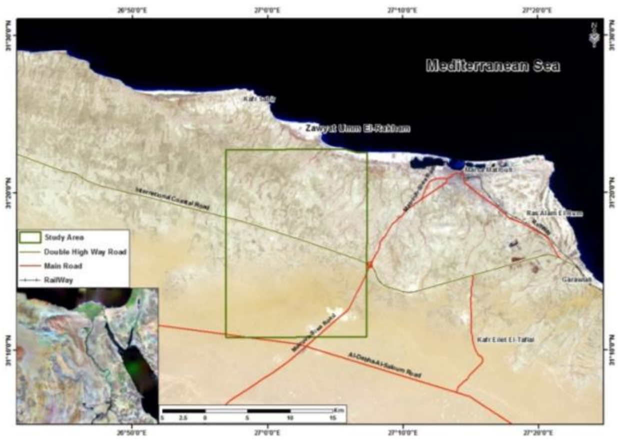


Fig. 1: location map of the study area

Materials and softwares:

- Digital Elevation Data of the Shuttle Radar Topography Mission (SRTM), February 11-22, 2000, with 90 m resolution cover the study area. USGS, (2013),
- The Advanced Space borne, Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM), October 2011 version 2, with accuracies generally between 10- and 25-meters (m) cover the study USGS, (2013),
- Four topographic Maps, named; Wadi Maged, Kariat Ragwah, El Ramsa, and Abar Emaira with 1: 25,000 scale, produced by Department of Military Survey, MSA (1986),
- LANDSAT ETM+ of scene P179 R038 of year 2013, projection: Universal Transverse Mercator (UTM), with Datum: WGS 1984, Ellipsoid parameters: a=6378137.00 and 1/f=298.257, Northern Hemisphere, and Zone 35.
- Remote sensing and GIS softwares (ERDAS imagine 2013, ArcGIS desktop V.10.2, and ILWIS Academic V.3.3).

Methodology:

Selection suitable digital elevation model (DEM)

As shown in Fig 2 which describes DEM creation steps from various sources and ending with the selection of the most appropriate source of DEM to apply the hydrological processes as follows:

A. Digital Elevation Model (DEM): DEM was created using the Geostatistical analyses of the final contour point's map of the studied area. Geostatistical analysis was carried out at two-steps procedure: (a) the calculation of the experimental semi-variogram and fitting a model; and (b) interpolation through Ordinary Kriging, which uses the semi-variogram parameters (Stein, 1998).

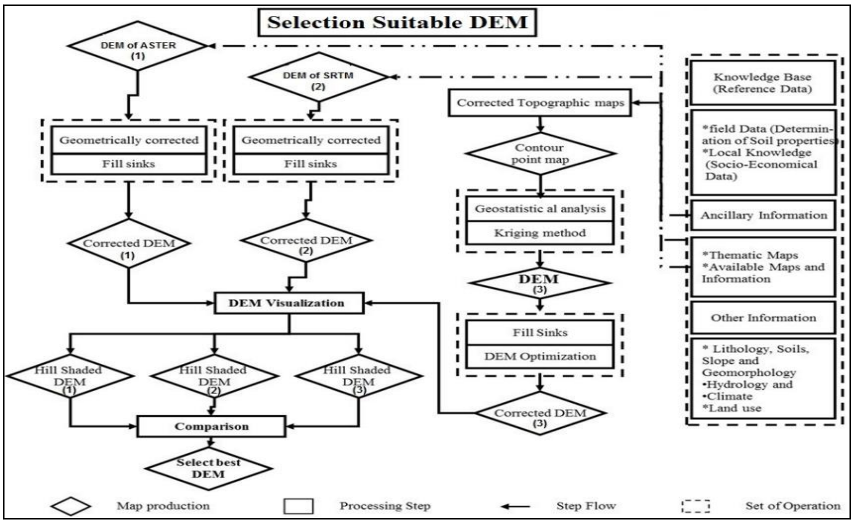


Fig. 2: Flow-chart of selection suitable DEM

The estimated or predicted values are thus a linear combination of the input values, (Stein, 1998). Kriging can be seen as an interpolation point, which requires a map point as input, and it was used as the main technique for geostatistical analysis.

B. Fill sink: Intended to cleaning Digital Elevation Model (DEM), by removing the following:

- Depressions that consist of a single pixel, i.e. any pixel with a smaller height value than all of its 8 neighboring pixels,
- Depressions that consist of multiple pixels, i.e. any group of adjacent pixels where the pixels that have smaller height values than all pixels that surround such a depression.

C. DEM Visualization: creates a color composite from a DEM. By creating three shadow maps, filters and combination of them in a color composite gives a very good impression of the relief the study area.

D. Comparison DEM: The three DEM productions of Topographic maps, SRTM, and ASTER were compared based on the best DEM Visualization and statistically accepted with good resolution.

DEM hydrological processing:

As shown in Fig. 3 the sketch of hydrological processing steps to extract the main basin, sub-basin, and hydrological parameters. Basins and sub-basins were generated through many steps, such as stream pattern, DEM optimization, flow direction, flow accumulation, variable thresholds computation, drainage network extraction, drainage network ordering, and catchments areas extraction as following:

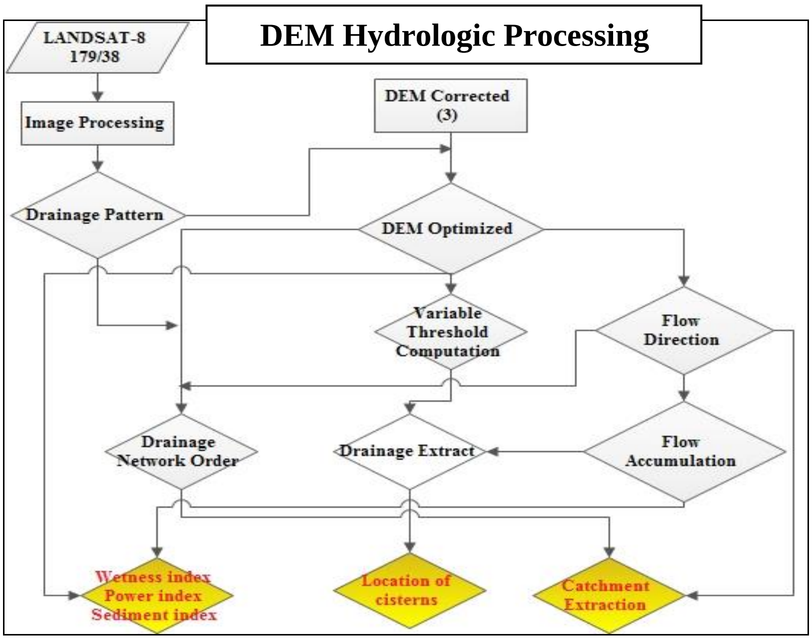


Fig. 3: Flow-chart of DEM Hydrology processing steps

A. Image processing: Image processing of LANDSAT 8 Mean that visual interpretation of drainage pattern which delineated by screen digitizing of the study area images to use it in DEM optimization.

B. DEM optimization: The DEM optimization operation enables to 'burn' existing drainage features into a Digital Elevation Model (DEM), so that a subsequent flow direction operation on the output DEM will enhance the existing drainage pattern.

C. Flow direction: Operation determines into which neighboring pixel any water in a central pixel will flow. The output map contains flow directions as N (to the North), NE (to the North East), .etc.

D. Flow accumulation: Operation to perform a cumulative count of the number of pixels that naturally drain into outlets. The operation used to find the drainage pattern of a terrain.

E. Variable threshold computation: Operation helps to prepare a threshold map that used in the Drainage network extraction operation.

F. Drainage network extraction: Operation to extract a basic drainage network.

G. Drainage network ordering: Operation to find individual streams within a drainage network and assigns a unique ID to each stream.

H. Catchment extraction: Operation constructs catchment areas; which calculated for each stream found in the output map of the Drainage network ordering operation.

Basin and sub-basin areas are normally defined as the total area flowing to a given outlet, or pour point. An attribute table was created with drainage network ordering included Up stream link ID, Up stream coordinates, Up stream elevation, Down stream link ID, Down stream coordinates, Down stream elevation, Elevation difference, Strahler, Shreve, Slope along drainage %, Slope along drainage degree, Slope drainage straight %, Slope drainage straight degree, Sinuosity, Total Up stream along drainage length, and Strahler class also.

Basin Hydrological characteristics

Estimation of Runoff Volume

Ali, 2000, Abdel-Kader and FitzSimon 2002, Abdel-Kader et., al., 2004 and Abdel-Kader and Yacoub 2009 used the Rational formula to estimate the runoff volume in the drainage of basins and sub-basins. The formula uses three parameters i.e. rainfall, drainage area and runoff coefficient based on the topography, land uses and soils characteristics of the drainage area. The runoff volume for each sub-basin was estimated for three annual rainfall scenarios, 100 mm, 150 mm, and 250 mm according to following expression:

$V_{ip} = 10^3 C_{ip} P_{ip} A_i$ Where

V_{ip} = Annual runoff volume (m^3 for sub-basin "i" and rainfall scenario "p"

C_{ip}, = Runoff coefficient for sub-basin "i" and rainfall scenario "p"

P_{ip} = Annual rainfall (mm) for sub-basin "i" and rainfall scenario "p"

A = Drainage area (km^2) of i" sub-basin (Bare Land).

Annual runoff volume for whole watershed is thus worked out by summation the volume of the each sub-basin (i.e. V_p = Summation V_{ip}).

The runoff coefficient for the i^{th} sub-basin was obtained by the equation:

$$C_i = C.\ Cs/C_{0.5\%}$$

Where the value of C was determined from the equation derived from the relation developed by Davy *et al.* 1976 in Ali, 2000 for bare rock (at least 30%) and steppe as follows:

$$C = 3.8855\ e^{(0.0119\ rainfall)}\ .$$

The coastline-inland decline of the rainfall percentage: % rainfall = 100.629 $^{e\ (-0.293\ distance\ from\ coast\ (km))}$ was considered to estimate the rainfall amount for each pixel in the grid file.

The correction factor $Cs/C_{0.5\%}$ was used to incorporate the effect of surface slope (%) as $Cs/C_{0.5\%} = 1.3388\ slope^{\ (0.395)}$ based on the relationship developed by Rodier & Ribstein 1988, in Ali, 2000.

Annual runoff volume was estimated for rainfall scenarios 100 mm, 150 mm, and 250 mm for each sub-basin in the watershed area. It was assumed that effective rainfall on the cultivated and range areas should provide volume of water directly to that area without generating runoff. Therefore, the bare areas were only considered as drainage areas for runoff generation.

Runoff Irrigation Potential:

The area, which can be irrigated by the estimated volume of runoff, was calculated based on water requirement of annual crop. A value of 250 mm was used for water requirement of barley as an annual crop.

Maximum irrigated area = Annual runoff volume (m^3) / water requirement of annual crops (m)

Hydrological analysis of Wadi Maged basin:

Sub-basin areas were estimated at 5000, 2500, and 1000 m to identify the main basin, the North, Middle, and South sub-basin groups. Runoff volumes were estimated for each sub-basin at stream length 2500 and 1000 meter, and identified the most important outlets for water harvesting by cisterns.

Identification of potential sites for water and soil conservation measures:

A. Potential cisterns sites for rainwater harvesting and storage.

For each sub-basin potential cistern numbers were calculated on the base storage average of $500m^3$. Optimal cisterns spatial sites were located with respect to the downstream coordinate and the sinuosity (A measure for meandering of the streams i.e. Stream Length/Straight length).

B. Wetness index.

The wetness index sets catchments area in relation to the slope gradient. ILWIS Academic 3.3 is an idea of the spatial distribution and zones of saturation or variable.

C. Sediment transport index.

The sediment transport index accounts for the effect of topography on soil erosion. The two-dimensional catchments area were used instead of the one-dimensional slope length factor as in the universal Soil Loss Equation ILWIS Academic 3.3.

D. Stream power index.

The stream power index is the product of catchments area and slope. ILWIS Academic 3.3 could be used to identify suitable locations for soil conservation measures to reduce the effect of concentrated surface runoff.

Field Work:

10 soil profiles were selected according to location of outlets and the wetness index of the investigated area to define the soil types of this areas. Soil samples were collected based on the morphological description, and air dried, gently crushed, and then sieved through a 2-mm sieve. Fractions below 2 mm were subjected to soil analyses.

Laboratory Analyses:

Laboratory analyses were carried out for particle size distribution, using the pipette method (Piper, 1950); calcium carbonate content using calcimeter (Black, 1982); soil pH in the soil paste using pH meter according to Jackson (1976) and salinity as electrical conductivity (EC) in the soil paste extract according to Rhoades (1982).

RESULTS AND DESICCATIONS

Image processing.

Visual Interpretation was done on the LANDSAT-8 to detect the dranige pattern of the study area where identified three dranige orders. First drainage order have length about 19.0 km, the scound draiange order have length about 55.5 km and the third draiange order have length about 93.0 km. Output drainage pattern map was used to optimize the DEM product in DEM optimization process. Fig. 4 shows LANDSAT-8 Image and the visual interpertation of the drainge pattern on the false color composite RGB 5, 4, 3 of the study area.

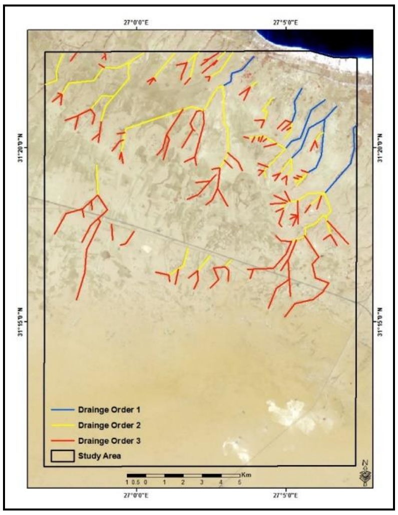


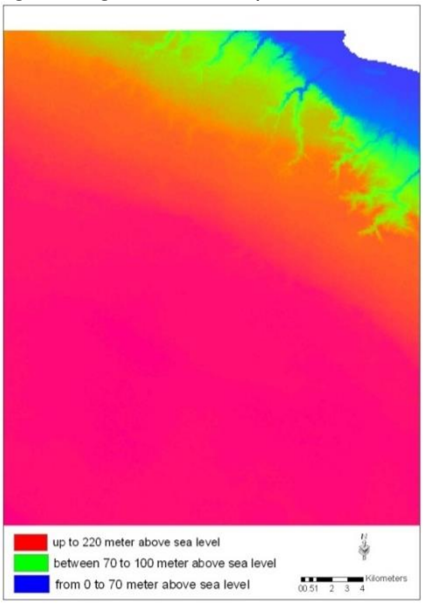
Fig. 4: LANDSAT-8 image and drainage pattern orders of the study area

Digital Elevation Analysis:

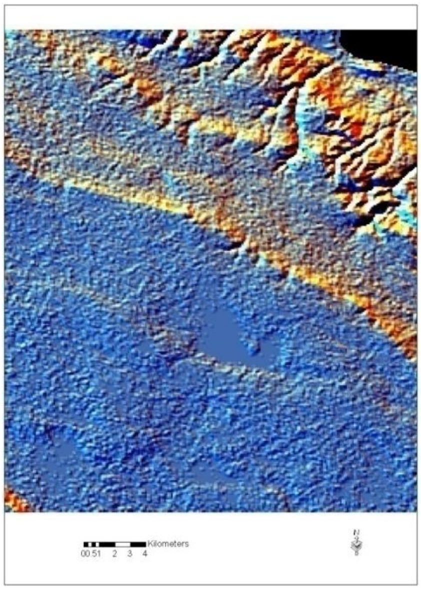
Three types of DEM from various sources and various resolution were used to select and calculate the hydrological parameters of the most suitable DEM. DEM were created from Shuttle Radar Topography Mission (SRTM), Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) and Topographic maps scale 1:25,000. The hill shad operation in ILWIS Academic 3.3 software was used to select the most suitable DEM to calculate the hydrological parameters of studied area.

DEM of SRTM:

The Shuttle Radar Topography Mission (SRTM) was flown aboard the space shuttle Endeavour February 11-22, 2000 (USGS, 2013). The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) participated in an international project to acquire radar data, which were used to create the first near-global set of land elevations. The results of DEM from original SRTM image show that the number of pixels cover the study area was 88175 with resolution 90.1 meters and the lowest value was -1 m and highest value was 220 m with an average of 109 m and Std. Division of 64 m and standard error of 4.302. After applied fill sink operation the results show the lowest value was 0 m and highest value was 220 m with an average of 110 m and Std. Division of 64 m and standard error of 4.302. Fig. 5-a Shows the DEM of the study area using SRTM image after Fill sink operation, while Fig. 5-b shows the DEM of SRTM image using hill shade operation.



(a)

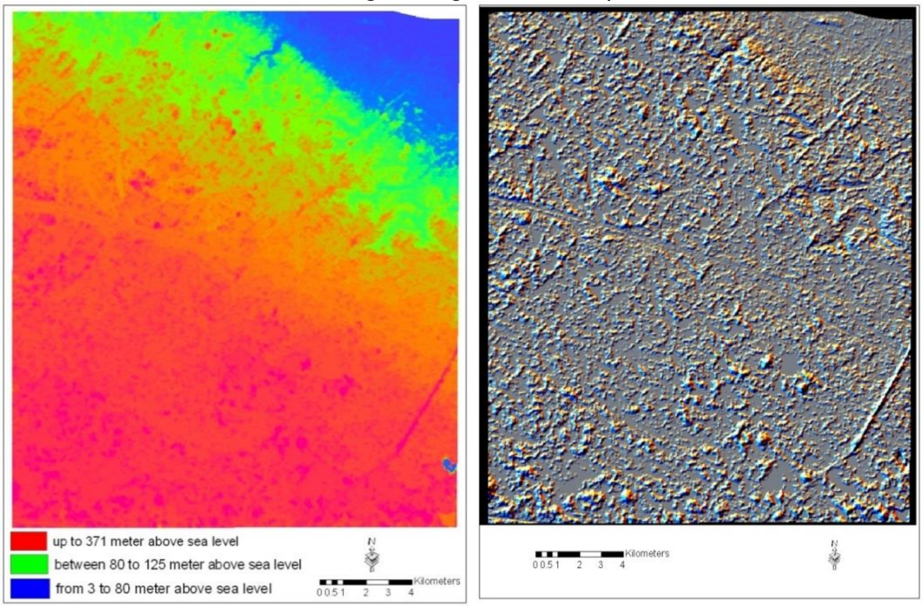


(b)

Fig. 5: DEM of SRTM Image: a) after fill sink, b) 3D hill shade of the studied area

DEM of Aster image

ASTER is capable of collecting in-track stereo using nadir- and aft-looking near infrared cameras Since 2001, these stereo pairs have been used to produce single-scene (60 x 60 km) digital elevation models (DEM) having vertical (root-mean-squared-error) accuracies generally between 10- and 25-meters (USGS, 2013). The results of DEM from original ASTER image show that the number of pixels cover the study area were 447883 with resolution 15.0 meters and the lowest value was 0 m and highest value was 371 m with an average of 175 m and Std. Division of 102 and standard error of 5.467. After applied fill sink operation the results show the lowest value was 3 m and highest value was 371 m with an average of 176 m and Std. Division of 102 m and standard error of 5.467. Fig. 6-a shows the DEM of the study area using ASTER image after Fill sink operation, while Fig. 6-b shows the DEM of ASTER image using hill shade operation.



(a) **(b)**

Fig. 6: DEM of ASTER Image: a) after fill sink, b) 3D hill shade of the studied area

DEM by using Topographic maps

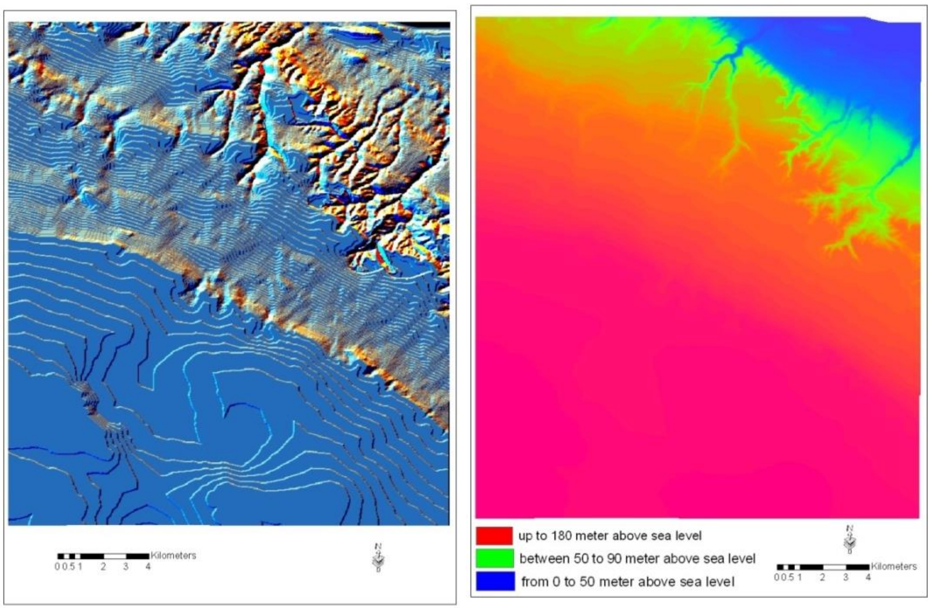
Four topographic maps of the North coast area sheets “Wadi Maged”, “El Ramsa”, “Kariat Ragwah”, and “Abar Emaira” scale 1:25,000 were produced by the Milatry Survey Authority (MSA, 1986) were used to generate the Digital Elevation Model (DEM). The contour lines of the four maps were digitized, and changed to points map with 100 meters intervals. The ground control points of the topographic maps of the studied area were digitized and then combined with the changed contour line.

In total 36,716 contour points covers 4 topographic maps (Contour lines and spot height) were digitized. The contour points were ranged between 0 to 194 meters ASL (Above Sea Level) and the average was 92.6 meters ASL. The standard deviation was 39.87 m ASL and standard error was 2.222. Using the ILWIS Academic 3.3 facility, the dependent output Tables of the contour point maps were defined, and calculated. Five models were tested to select the most fitted model of contour point map. The parameters of the best fitting model (Spherical model, R2=0.96) were used to create the DEM as shown in Table 1 . The result of the kriging error maps were ranged from 0.5 to 2.4 m ASL, with average of 1.42 m ASL. DEM. Fill sink and DEM optimization using also the stream pattern map which is obtain from the LANDSAT-8 image was used to improve the final DEM values map.

Table 1: The DEM model parameters of the contour points map and their goodness of fitting.

Models	Parameters			Goodness of fitting semi-variogram (R^2)
	Nugget	Sill or slope	Range	
Spherical	5.0	1595	5350	0.96
Gaussian	15.0	985	8225	0.91
Exponential	10.0	465	3450	0.93
Power	25.0	0.00325	1.0	0.85
Wave	20.0	550	2625	0.88

The results of DEM from original topographic maps show that the number of pixels cover the study area was 445886 with resolution 28.5 m, the lowest value was 0 m, and highest value was 180 m with an average of 90 m and Std. Division of 25.6 and standard error of 1.78. After applied fill sink and DEM optimization operations the results show the lowest value was 0 m and highest value was 180 m with an average of 90 m and Std. Division of 18.3 and standard error of 0.96. Fig. 7-a shows the DEM of the study area using topographic maps after Fill sink operation, while Fig. 7-b shows the DEM of topographic maps using hill shade operation.



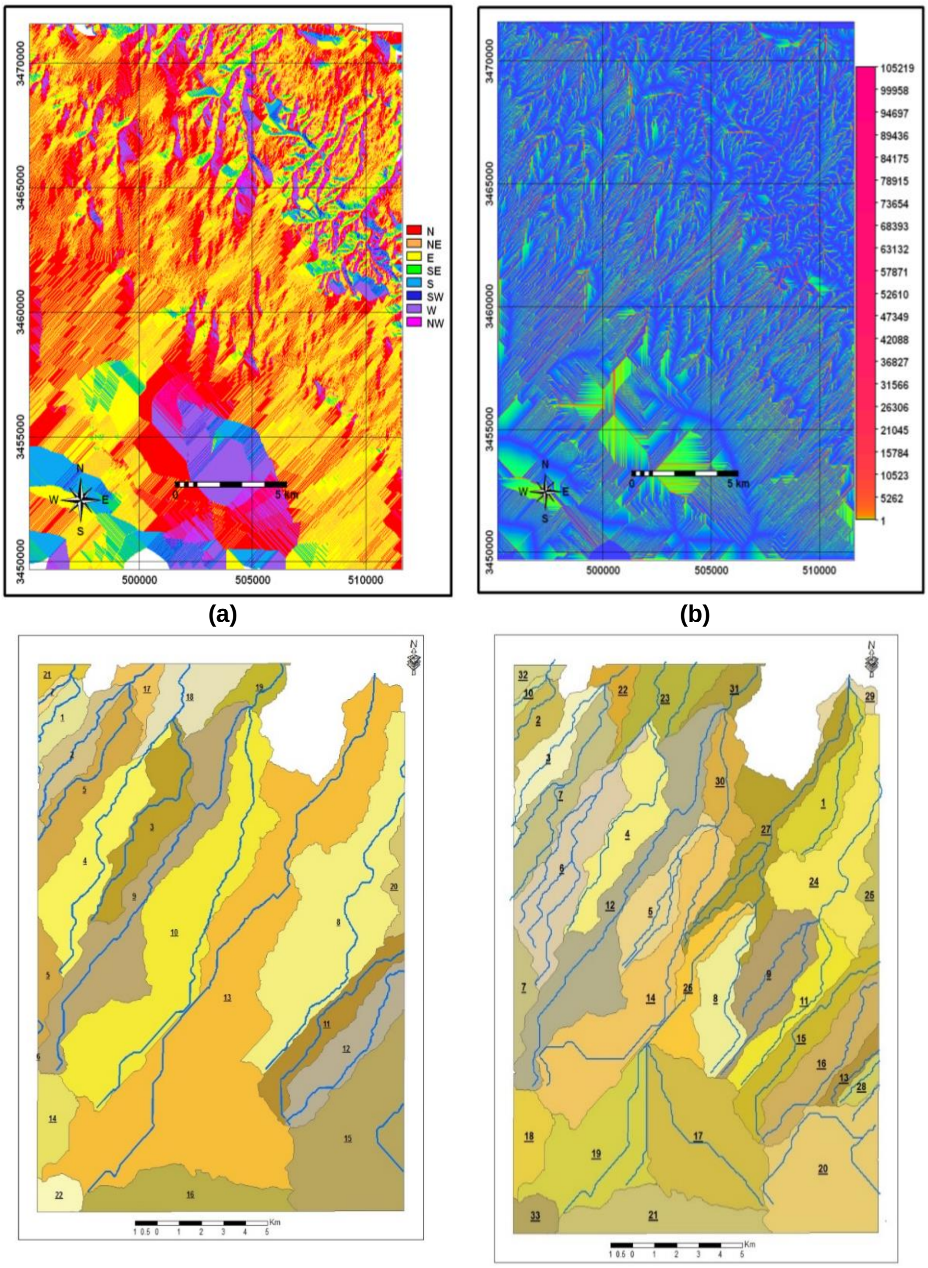
(b) **(a)**

Fig. 7: DEM of topographic maps: a) after fill sink, b) 3D hill shade of the studied area

According to DEM Visualization and statistically accepted with good resolution of 3D hill shade maps of the three different DEM sources concluded that the DEM of topographic maps are highly accurate and efficient to use in the hydrologic model because the DEM are lowest standard error and very good distinguish for relief characteristics than the other two. The DEM of ASTER image have good resolution (15m pixel size), but have high standard error and very poor of relief characteristics distinguish than the others.

DEM Hydro-processing

As previously mentioned, DEM Hydro processing of the starting of flow direction and flow accumulation and ending with drainage network order considered intermediate stages to identify catchment areas. As shown in Fig. 8-a to 8-d flow direction, flow accumulation, variable threshold computation, drainage network extraction, drainage network order, and catchments extraction operations were performed. Twenty one main basins with minimum stream length of 10000 meter of the studied area and 33 sub-basins with minimum stream length of 5000 meter of the studied area were performed as shown in Table 2.



(a) (b)

(c) (d)

Fig. 8: a) Flow direction, b) Flow accumulation, c) Drainage network order and Basin extraction and d) Drainage network order and Sub-basin extraction of the study area

Table 2: Basins area ID, Center Catchment, Center Drainage, total upstream area and longest flow length of the studied area.

Basin ID	Center Catchment	Center Drainage	Total Upstream Area (m^2)	Longest Flow Length (m)	Area (Hectare)	Area (Fed.)
1	(480273.69, 3473565.75)	(479997.00, 3473580.00)	10313240	11176.9	437	1040
2	(488586.19, 3470473.50)	(488433.00, 3470473.50)	8995770	11694.0	688	1638
3	(509861.44, 3467538.00)	(509865.00, 3467566.50)	12485196	11697.7	1249	2973
4	(519526.50, 3465585.75)	(520296.00, 3466512.00)	17898335	13811.4	1783	4245
5	(489269.00, 3466569.00)	(488718.00, 3466911.00)	26013829	19777.6	1173	2793
5	(494524.88, 3467010.75)	(495187.50, 3467367.00)	26013829	19777.6	337	802
7	(495672.00, 3466583.25)	(495786.00, 3467167.50)	42760597	21701.6	84	201
8	(500623.87, 3465357.75)	(499975.50, 3465828.00)	45377869	21373.9	3922	9338
9	(489407.34, 3465229.50)	(490342.50, 3465030.00)	28135832	19754.3	2808	6686
10	(501543.00, 3462750.00)	(502312.50, 3462835.50)	42681504	20457.5	4268	10162
11	(497724.00, 3464274.75)	(497866.50, 3464659.50)	10933596	11942.7	1009	2404
12	(522211.41, 3462336.75)	(523630.50, 3462265.50)	14376013	12209.0	1192	2838
13 (Wadi Maged basin)	(482533.50, 3460740.75)	(482533.50, 3461838.00)	88999755	28505.2	8859	21094
14	(488119.50, 3459586.50)	(487834.50, 3459615.00)	102755614	35770.5	538	1280
15	(501192.69, 3459486.75)	(502170.00, 3459102.00)	176277846	41373.4	2755	6559
16	(508164.50, 3457050.00)	(508468.50, 3457990.50)	80029266	23746.1	1212	2886
17	(497054.25, 3445593.00)	(496698.00, 3445593.00)	35009600	5881.8	320	761
18	(502276.87, 3445550.25)	(497211.00, 3445735.50)	30383531	9079.4	899	2141
19	(497068.50, 3445536.00)	(496726.50, 3445536.00)	70817335	3931.7	370	881
20	(496797.75, 3445393.50)	(496470.00, 3445393.50)	25309609	11313.0	260	619
21	(502127.25, 3445322.25)	(497353.50, 3445621.50)	53073836	7599.9	155	369
22	(511640.14, 3448428.75)	(512259.00, 3449554.50)	172026732	10312.0	280	667

As shown in Table 2 it was that basin id 13 (Wadi Maged) have an area 21190 Fed. (8900 Hectares), total upstream area recorded 88999755 m2 and longest flow length 28505.2 m.

Hydrological parameters of Wadi Maged basin:

DEM, slope classes, flow direction, flow accumulation, variable threshold computation, drainage network extraction, drainage network ordering, catchments extraction, wetness index, sedimentary index, and power index operations were preformed of Wadi Maged basin as shown in Fig. 9. Wadi Maged basin contains 9 sub-basin classified into 3 sub-basin groups north, middle and south sub-basins. Using drainage network order of 2500 meters of stream length to identify and calculate the water runoff of the sub-basin groups as shown in Table 3.

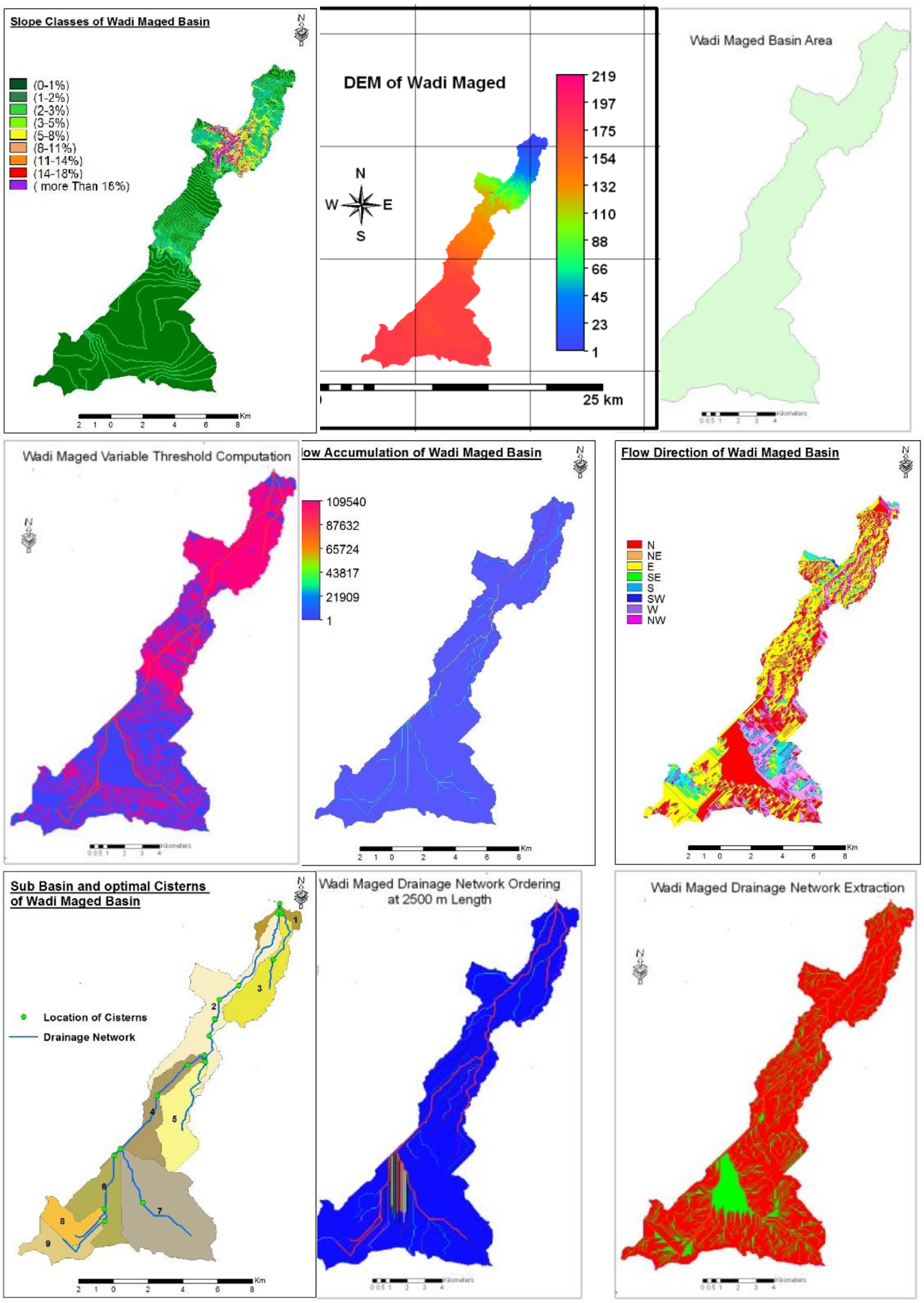


Fig. 9: Steps of Hydrological parameters in Wadi Maged basin

Table 3: Areas of the north, middle, and south sub-basin groups at 2500 meters of stream length

North Wadi Maged zone		Middle Wadi Maged zone		South Wadi Maged zone	
ID	Area (Fed.)	ID	Area (Fed.)	ID	Area (Fed.)
1	403	4	2323	6	5819
2	2154	5	1927	7	2198
3	3812			8	1194
				9	1264

Runoff volume, runoff irrigation potential and optimum locations of cisterns of Wadi Maged

Runoff volume, runoff irrigation potential and optimum locations of potential cisterns for rainwater harvesting and storage of Wadi Maged were estimated ILWES Academic 3.3 software with stream length 2500 meters (Third Shoulder) and with rain fall scenarios of 100mm, 150 mm and 250mm per year at the three zones (North, Middle, and South zone) as shown in Table 4.

Table 4: Estimated runoff volume, runoff irrigation potential, potential cisterns numbers of zones of Wadi Maged Basin at 2500 meters stream length.

Zone ID	Area (Fed.)	Drainage area (m^2)	Runoff for total area (m^3)			Runoff for drainage area (m^3)			Potential runoff irrigation (Fed.)			No. of potential Cisterns
			250 mm	150 mm	100 mm	250 mm	150 mm	100 mm	250 mm	150 mm	100 mm	
1 North zone	403	1269450	28165	16885	11252	21123	12663	8441	20	12	8	1
2 North zone	2154	6785100	150551	90250	60141	112913	67687	45106	108	64	43	7
3 North zone	3812	12007800	266425	159707	106427	199841	119792	79817	190	114	76	4
4 Middle zone	2323	4878300	160163	96015	63982	80083	48007	31992	76	46	30	3
5 Middle zone	1927	4046700	127388	76369	50892	63692	38186	25444	61	36	24	1
6 South zone	5819	6141450	392199	235121	156679	98049	58779	39170	93	56	37	1
7 South zone	2198	2307900	147383	88354	58878	36847	22089	14720	35	21	14	1
8 South zone	1194	1253700	80063	47996	31984	20016	11999	7996	19	11	8	1
9 South zone	1264	1327200	77579	46512	30996	19396	11628	7749	18	11	7	1

Runoff volume of Wadi Maged

Data in Table 4 showed the estimated runoff of north, middle and south zones of Wadi Maged Basin at 2500 meters stream length. Results showed that the maximum runoff volume occurred in the sub-basin No. 3 in North zone, where recorded 266425 m^3, 159707m^3 and 106427m^3 with values 250 mm, 150 mm and 100 mm respectively. On the other hand, the minimum runoff volume occurred in the sub-basin No. 1 in North zone, where recorded 28165 m^3, 16885 m^3 and 11252 m^3 with values 250 mm, 150 mm and 100 mm respectively.

Runoff irrigation potential

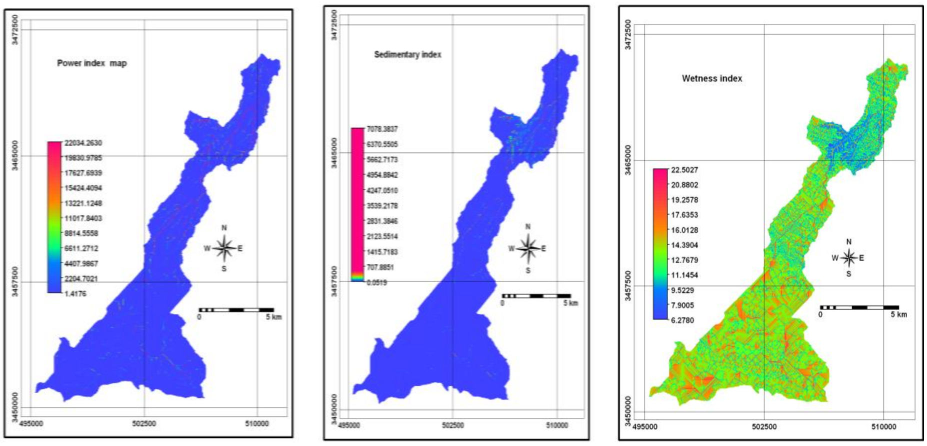
Also data in Table 4 obtained Runoff irrigation potential in Fed. of north, middle and south zones of Wadi Maged basin at 2500 meters stream length. Results showed that the maximum potential runoff area occurs in the sub-basin No. 3 in North zone, where recorded 190 fed., 114 fed. and 76 fed. with values 250 mm, 150 mm and 100 mm respectively. On the other hand, the minimum potential runoff area occurred in the sub-basin No. 9 in south zone, where recorded 18 fed., 11 fed. and 7 fed. with values 250 mm, 150 mm and 100 mm respectively.

Potential numbers and optimum locations of cisterns

Table 4 recorded potential numbers of cisterns for rainwater harvesting and storages of north, middle and south zones of Wadi Maged Basin at 2500 meters stream length, Where 20 potential cisterns were identified for runoff water harvesting and storage.

Wetness, sedimentary and power indices

Wetness index, sedimentary index, and power index operations were performed and illustrated in Fig. 10. The wetness index sets catchment area in relation to the slope gradient. Where there is an inverse relationship between wetness index and quality and adequate of soil, meaning that with low values of wetness index indicate that a good soils and have a flat relief. On the other hand there is a positive relationship sedimentary and power indices and quality and adequate of soil, While with in case of low values of sedimentary and power indices indicate that the suitability of these soils are low, because in this case the soil more vulnerable to erosion.



Power index Sedimentary index Wetness index

Fig. 10: Wetness, Sedimentary and Power indices of Wadi Maged

Define the soil type of selected outlets

Based on the location of outlets and the wetness index, soil samples were collected from 10 soil profiles based on the morphological description. The Chemical and physical properties of the soil samples were determined. Results in Table 5 showed that, the dominant texture are sandy loam, and loamy sand in coarse valley and sand texture out the coarse valley. The soils of this area have deep effective soil depth (100 -120 cm) in the coarse valley and shallow to moderate deep effective soil depth (50-90 cm) out the coarse valley. The EC values ranged from 4.3dS/m up to 7.6 dS/m with an average of 5.3 dS/m, therefore, this soil is moderately saline soils and the dominant salt is sodium chloride. The pH values ranged from 7.6 to 8.7 with an average of 8.3. The total content of calcium carbonate percentage ranged from 24.8% up to 37.1% with an average of 33.6%. These soils are moderately to strongly calcareous soils. The gypsum content percentage was low and ranged from 0.14% to 1.3% with an average of 0.35%. These soils classified as non-gypsiric soils. The organic matter percentage was very low and ranged from 0.06% to 0.24% with an average of 0.12%. The ground water depth is more than 150 cm, therefore, these soils were classified as very deep ground water.

Table 5: Chemical and physical characteristics of the studied soil profiles of Wadi Maged

Profile	Depth (cm)	PH	EC (dS/m)	Total sand (%)	Silt (%)	Clay (%)	Texture	O.M (%)	$CaCO_3$ (%)
P1	0-20	8.5	7.3	63.3	21.4	15.3	Sandy Loam	0.24	35.9
	20-45	8.4	7.6	65.0	22.9	12.1	Sandy Loam	0.21	37.1
	45-70	8.6	6.5	70.4	23.7	5.9	Sandy Loam	0.13	33.5
	70-120	8.5	5.5	75.7	19.9	4.4	Loamy Sand	0.10	33.8
P2	0-35	8.5	5.3	68.6	17.9	13.5	Sandy Loam	0.22	35.9
	35-65	8.4	5.5	68.9	19.3	11.8	Sandy Loam	0.13	35.7
	65-80	8.6	4.8	76.9	18.5	9.6	Sandy Loam	0.11	33.1
	80-120	8.1	5.4	77.7	18.7	3.6	Loamy Sand	0.09	34.0
P3	0-25	8.4	5.1	68.4	18.5	13.1	Sandy Loam	0.23	36.1
	25-50	8.6	5.7	69.5	18.8	11.7	Sandy Loam	0.20	35.3
	50-80	8.5	5.8	76.3	19.1	4.6	Loamy Sand	0.11	33.4
	80-120	8.4	5.5	77.4	18.6	4.0	Loamy Sand	0.08	34.9
P4	0-30	8.5	6.1	72.1	16.4	11.5	Sandy Loam	0.17	36.3
	30-65	8.7	5.9	72.6	16.7	10.7	Sandy Loam	0.11	30.5
	65-120	8.3	5.6	78.4	18.3	3.3	Loamy Sand	0.10	34.7
P5	0-35	8.2	5.3	75.9	15.5	8.6	Sandy Loam	0.13	35.5
	35-65	8.3	5.9	77.9	14.8	7.3	Loamy Sand	0.11	33.3
	65-100	8.1	5	79.6	17.3	3.5	Loamy Sand	0.10	34.9
P6	0-40	8.1	4.8	80.1	13.8	6.1	Loamy Sand	0.13	34.7
	40-70	8.3	4.5	80.9	15.6	3.5	Loamy Sand	0.09	33.5
	70-100	8	4.9	79.3	17.0	3.7	Loamy Sand	0.10	35.0
P7	0-15	7.6	4.3	92.0	6.3	1.7	Sand	0.09	24.9
	15-45	7.9	4.5	91.0	7.5	1.5	Sand	0.06	36.0
P8	0-40	7.8	4.3	83.0	11.1	5.9	Loamy Sand	0.11	35.6
	40-100	7.9	4.9	83.1	13.4	3.5	Loamy Sand	0.08	33.5
P9	0-20	8.4	4.6	89.1	8.0	3.5	Sand	0.10	24.8
	20-50	8.5	4.3	90.2	7.3	2.5	Sand	0.10	28.5
	50-90	8.5	4.9	89.7	7.5	2.8	Sand	0.08	32.7
P10	0-25	8.7	5	88.3	7.9	3.8	Sand	0.11	35.8
	25-55	8.6	4.3	88.7	8.3	3.0	Sand	0.08	31.0
	55-90	8.3	4.4	90.6	7.1	2.3	Sand	0.06	30.7

According to the results of chemical and physical properties of the soil samples, soils of Wadi Maged area was classified as shown in Fig. 11 and Table 6.

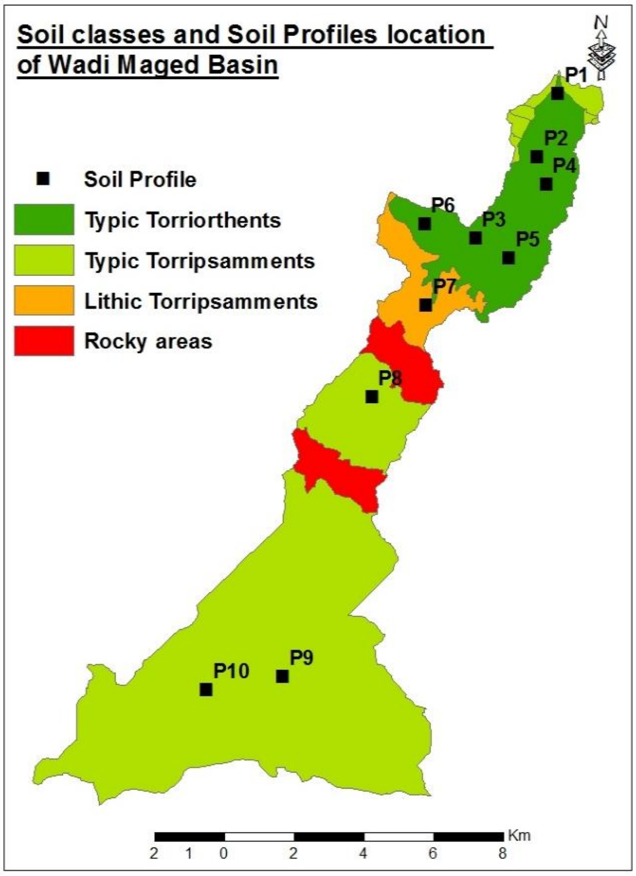


Fig. 11: Soils classes and soil profiles location of Wadi Maged basin

Table 6: Soil Classifications units of Wadi Maged basin

Taxonomy units	Representative soil profiles No.	Area	
		Fed.	%
Typic Torriorthents	1, 2, 3, 4, 5, 6	3540	16.78
Typic Torripsamments	8, 9, 10	15023	71.22
Lithic Torripsamments	7	1173	5.56
Rocky areas	--	1358	6.44
Total		21٠٩٤	100.00

According to the results are shown in Fig 11 and Table 6, it was found that Typic Torripsamments was the dominant class in Wadi Maged basin where occupied an area of about 15023 Fed. (71.2% of total area) and was represented by soil profiles 8, 9 and 10, while the minimum class of the basin was Lithic Torripsamments where occupied an area of about 1173 Fed. (5.5% of total area) and was represented by soil profile No. 7. Also present rock areas occupied an area of about 1358 Fed. (6.4% of total area).

Integration of soil classes and some hydrological parameters of Wadi Maged basin:

Integration process was done by overlaying process between soil classes and hydrological parameters (catchment areas, drainage network and location of cisterns) by GIS software (ArcGIS V.10.2) and results are shown in Fig. 12 and Table 7.

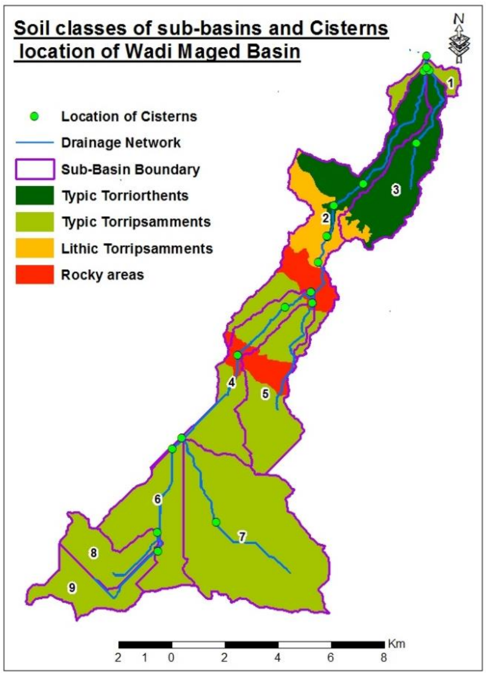


Fig. 12: Overlay of soils classes, sub-basins areas, location of cisterns and drainage network of Wadi Maged basin

Table 7: Soils classes of sub-basins of Wadi Maged basin

Sub-basin ID	Taxonomy Class	Area (Fed.)	%
1	*Typic Torripsamments*	403	1.9
2	*Typic Torriorthents*	1568	7.4
	Typic Torripsamments	589	2.8
	Lithic Torripsamments	995	4.7
	Rocky areas	654	3.1
3	*Typic Torriorthents*	1976	9.4
	Lithic Torripsamments	177	0.8
4	*Typic Torripsamments*	1680	8.0
	Rocky areas	248	1.2
5	*Typic Torripsamments*	1868	8.9
	Rocky areas	455	2.2
6	*Typic Torripsamments*	2199	10.4
7	*Typic Torripsamments*	5822	27.6
8	*Typic Torripsamments*	1195	5.7
9	*Typic Torripsamments*	1263	6.0
Total Area		**21094**	**100**

Data obtained and illustrated in Tables 4 and 7 and Fig. 12 showed that sub basin No. 3 which have the maximum runoff volume values (266425, 159707 and 106427 m^3) and the maximum runoff irrigation potential values (799, 479 and 319 Fed.). This sub basin contain two soil classes, Typic torriortents which have an area about 1976 Fed and 3 potential cisterns, and the second soil class was Lithic Torripsaments which have an area about 177 Fed and one potential cistern.

While data showed that sub basin No. 1 which have the minimum runoff volume values (28165, 16855 and 11252 m^3) and the minimum runoff irrigation potential values (84, 51 and 34 Fed.). This sub-basin contain one soil classes Typic Torripsaments which have an area about 403 Fed. and one potential cistern.

Data optioned in Table 4 and 7 and Fig. 12 indicate to the location of higher and lower water resources in different terms as rainfed sources and possibility to use it in cultivation.

CONSOLATION

This study clearly shows the importance of using modern techniques of Remote Sensing, GIS and hydrological models to monitor and detect the catchment areas for harvesting rain water in different valleys, all over Egypt. This also, will help us in detecting water and soil resources for rainfed agriculture and this will encourage the agriculture development especially in the large valleys, which receive a big amount of water through flash flooding season such as Sinai and Eastern Desert areas.

Also, integration of the RS/GIS technologies with geostatistical analyses and hydrological models was powerful for identifying the state and assess the suitable areas for cultivation of the water, and soil recourses at Wadi Maged basin

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رصد وتحديد الموارد الأرضية والمائية للزراعة المطرية بوادى ماجد بالساحل الشمالى الغربى - مصر باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية والنموذج الهيدرولوجى

محمد محمد حسنى شومان

وحدة الاستشعار عن بعد ونظم المعلومات الجغرافية - معهد بحوث الأراضى والبيئة – مركز البحوث الزراعية

تنتمى مصر إلى مناخ المنطقة القاحلة وشبه القاحلة حيث تغطي الصحراء حوالي ٩٦٠٠٠٠ كم[٢] أو ٩٦ ٪ من مساحة جمهورية مصر العربية (شبه جزيرة سيناء والصحراء الشرقية و الصحراء الغربية). وتعتبر مياه الامطار المصدر الرئيسي للمياه بجانب المياه الجوفية والتي في اغلب الاحوال إما أن تكون ملحية أو أنها غير متوفرة على الإطلاق. وعندما لا يكون هناك هطول للأمطار، يواجه السكان خطر الجفاف والمجاعة. وأيضا بدون مياه الامطار يقل الرعي، ويزيد معدل نفوق الماشية بجانب المشاكل الإضافية لسكان هذه المناطق.

أهداف هذه الدراسة هو مراقبة والكشف عن الموارد المائية والمواقع المحتملة لأماكن مستجمعات المياه بوادى ماجد وكذلك تحديد الموارد الأرضية عن طريق الكشف عن الأماكن الصالحة للاستزراع. ولتحقيق هذه الأهداف تم اختيار انسب مصدر لنموذج الارتفاعات الرقمى DEM، وهو الخرائط الطبوغرافية لإنتاج نموذج الارتفاعات الرقمية لتحديد شبكة المصارف ومناطق مستجمعات الامطار في الاحواض والاحواض الفرعية من خلال العمليات الهيدرولوجية، وأيضا تحديد نوعية أراضى الزراعة المطرية بوادى ماجد. مواقع تجميع المياه استخدمت كأساس لمواقع القطاعات الأرضية وتقدير نوعية هذه المناطق بناءاً على نتائج تحليل خصائصها الأرضية.

تقدر مساحة منطقة مستجمعات المياه بوادي ماجد بالساحل الشمالى الغربى حوالى ٢١٠٩٤ فدان . و تشمل ٩ مستجمعات فرعيه عند استخدام طول ٢٥٠٠م مع كمية مياه مستجمعة تكفى لري مناطق تتراوح مساحتها ما بين 7-76 فدان إذا كان معدل سقوط الأمطار ١٠٠ مم / سنة، وما بين 11-114 فدان إذا كان معدل سقوط الأمطار ١٥٠ مم / سنة، وما بين 18-190 فدان إذا كان معدل سقوط الأمطار ٢٥٠ ملم / سنة. وتم تقييم وتحديد مواقع حوالي ٢٠ بئرا محتمل في حوض وادي ماجد لحصاد مياه الجريان السطحي والتخزين. تم تقسيم منطقة وادى ماجد الى ٣ وحدات تقسيمية هي Typic Torriorthents وTypic Torripsamments وLithic Torripsamments بالإضافة الى بعض المناطق الصخرية.

المنهجية المتكاملة لهذه الدراسة يمكن أن تمثل وحدها نمطية جاهزة للتطبيق في أماكن مختلفة للزراعة المطرية في مصر. وتعد المنهج التحليلى لهذه الدراسة نموذجاً متكاملاً يمكن تطبيقه لتحليل تساقط مياه الأمطار بمناطق أخرى. كذلك يمكن اعتبار منهجية هذه الدراسة أداه للإدارة بالمشاركة مع السكان المحليين لتنمية المناطق الزراعية المطرية بمصر.