GEOLOGICAL SETTING AS AN IMPORTANT FACTOR IN MANGROVE PLANTATION SITE SELECTION IN THE RED SEA

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Abstract: Mangroves play a vital role supporting the surrounding environment. Mangrove thickets are the natural nursing grounds for hundreds of aquatic species, including economically important fish and shellfish. Mangroves play an important role in controlling erosion and protecting the coastline. Along the Red Sea coast in Egypt, mangrove stands are distributed. Since the mid- 1980s, these stands have been threatened by rapid tourist development and grazing by Bedouins. The size and the number of these stands have been reduced and many of the stands have been destroyed completely. Thus, it is necessary to conserve the existing mangroves stands and plant mangroves where ever they can be grown. This paper describes a method to locate the best suitable sites for mangrove plantations along the south Egyptian Red Sea coast based on the geological setting of the area. Geological characteristics such as soil types and soil renovation resources, geomorphology, discharge of drainage effluents will be considered as primary sitting criteria. Different types of satellite images and data elevation models (DEM) will be interpreted to determine some of the parameters. A field check will be carried out as necessary.

Keywords: mangrove, geology, remote sensing, GIS, plantation, conservation, environment

Introduction

Mangroves protect shorelines from erosion by stabilizing sediments with their tangled root systems. They maintain water quality and clarity, filtering pollutants and trapping sediments originating from land.

Mangroves function as nurseries for shrimp and recreational fisheries, exporters of organic matter to adjacent coastal food chains, and enormous sources of valuable nutrients.

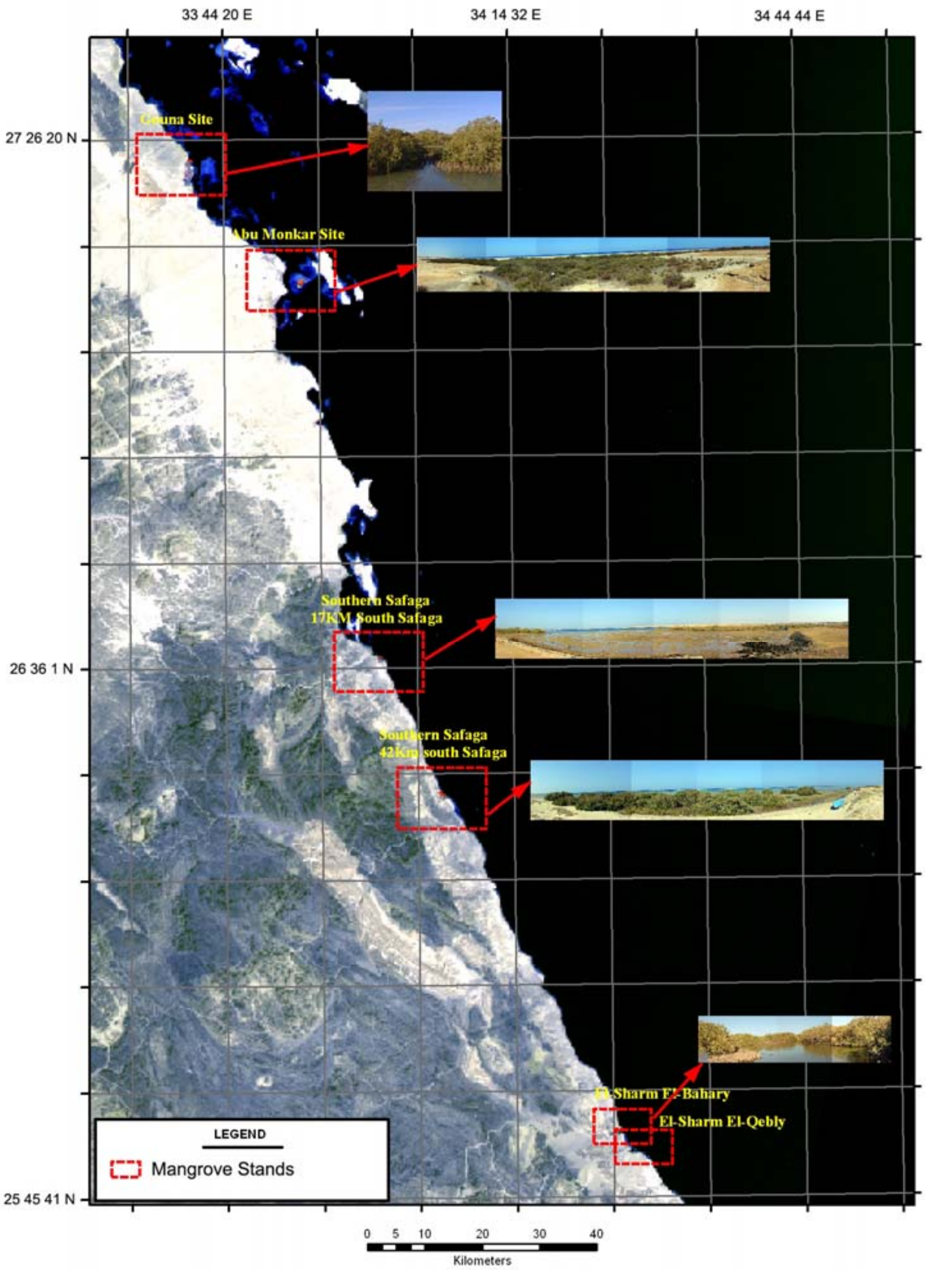


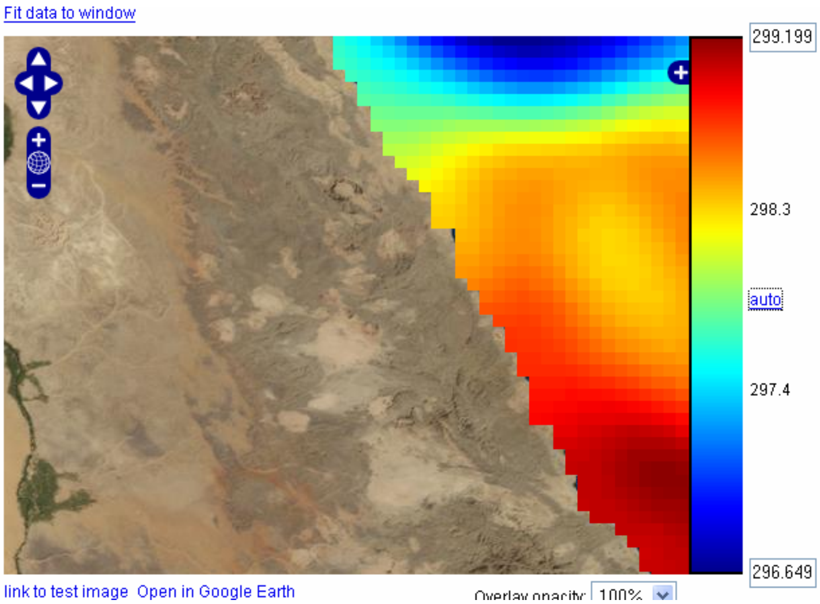
Fig. (1): Location of some Mangrove stands along Red Sea, Egypt.

Small mangrove stands are distributed along the Red Sea coast in Egypt (Fig.1)
These stands have been rapidly destroyed in recent years due to the rapid development tourist activities and old running problem of over grazing and using the trees as fuel.

Although ministry of environment's Red sea rangers are implementing a successful Mangrove conservation management plan but the existing Mangrove stands sites are few and need to be increased by through Mangrove plantation.

It is difficult to generalize the parameters determine sites of successful mangrove plantation but the most common parameters may include: water salinity, water temperature, tidal and wave energy, soil type and soil stability and flooding regime, spacing and thinning of mangroves, weed eradication, nursery techniques, community participation and total cost of restoration measures.

Temperature and salinity seem to be the same along the entire study area (Fig. 2) on the other hands spacing and thinning of mangroves, weed eradication and nursery techniques are parameters related to the plantation techniques more than site selection.



Kelvin

Fig. (2): Water temperature in along the study area. (Reading e-Science Centre (ReSC) is hosted at the NERC Environmental Systems Science Centre (ESSC): http://lovejoy.nerc-essc.ac.uk:8080/ncWMS/godiva2.html#)

Geological characteristics such as soil types, stability and soil renovation resources, surface geomorphology including slope, aspect, protection from direct high energy waves, and safety from flash flood will be considered as primary criteria for selecting sites suitable for mangrove plantation

Surface Geomorphology:

7.5-Minute Data Elevation Model (DEM) with 30- x 30-meter data spacing had been used to construct a 3D model of the study area (Fig. 3). Also, DEM was processed by the ArcGIS spatial analyst extension to determine the surface slope (Fig. 3).

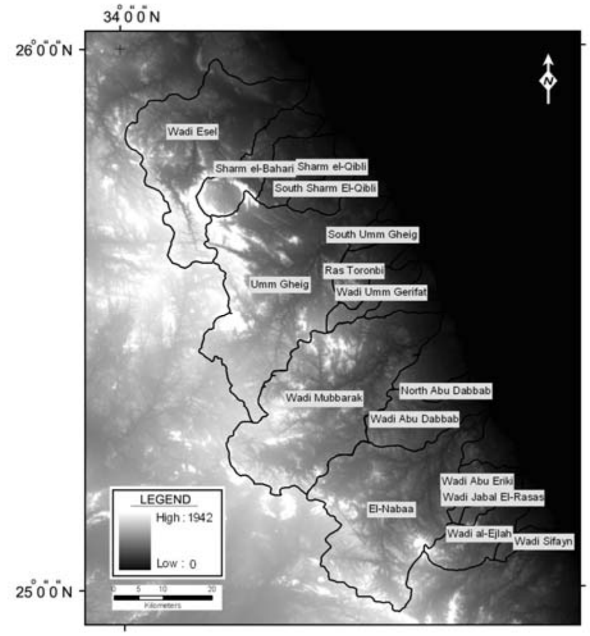


Fig. (3.a): Data Elevation Model of the Northern Sector.

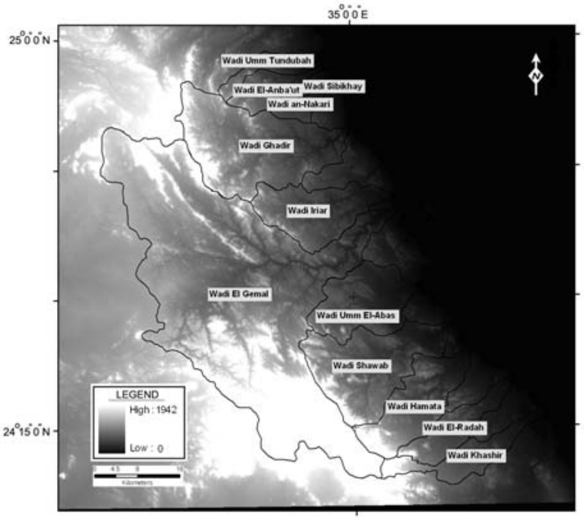


Fig. (3.b): Data Elevation Model of the Southern Sector.

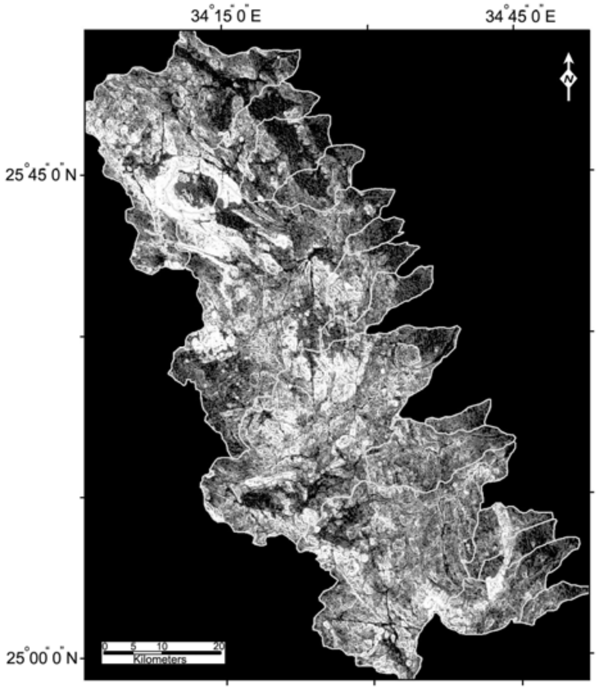


Fig. (4-a): Slope of the northern sector.

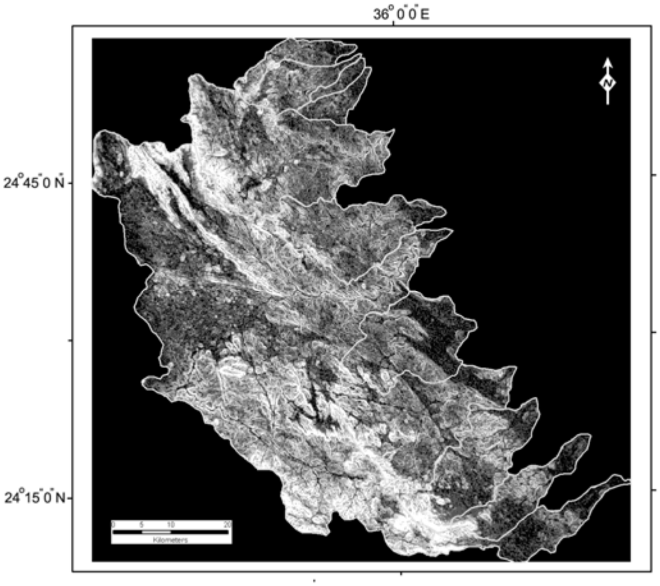


Fig. (4-b): Slope of the southern sector.

It is important that mangrove plantings be carried out on low energy areas where coastal erosion is minimal (Kairo, 1995). A the three dimension (3 D) model constructed by dropping the panchromatic TM image over the DEM, then used with slope grid of the study area to locate sites protected from direct sea waves and with low to moderate slope. Seven locations found to meet these criteria (Fig. 5).

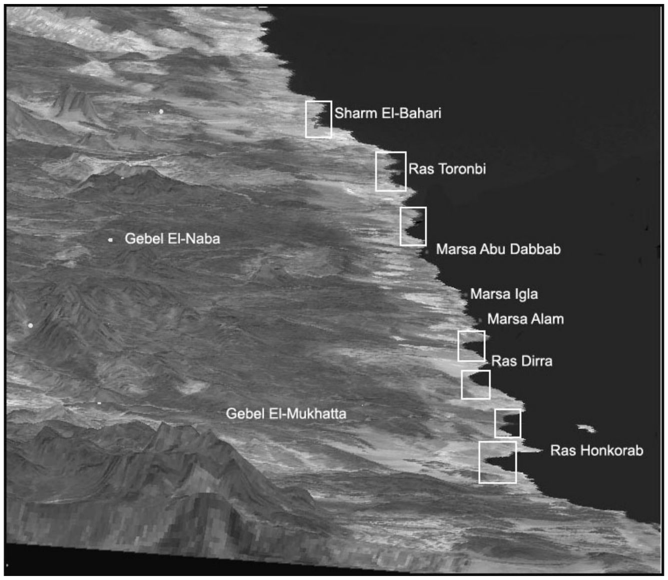


Fig. (5): Three dimension (3D) module for the study area shows seven primary selected locations for mangrove plantation.

The selected sites located on or near the outlet of the drainage basins drained from West to East. The history of the study area shows a very arid climate with years of dry seasons and sudden flash flooding, so special attention must be paid to soil stability and the flash flood potentiality of the study area drainage basins.

Basins Flash Flood Potentiality:

River Tools Software version 3.5 had been used to define the drainage network of the study area using the Data Elevation Model (DEM). An enhanced Panchromatic Thematic Mapper (Fig. 6) had been used to check and corrected the resulted drainage networks. The basin boundaries were defined manually (Fig. 7).

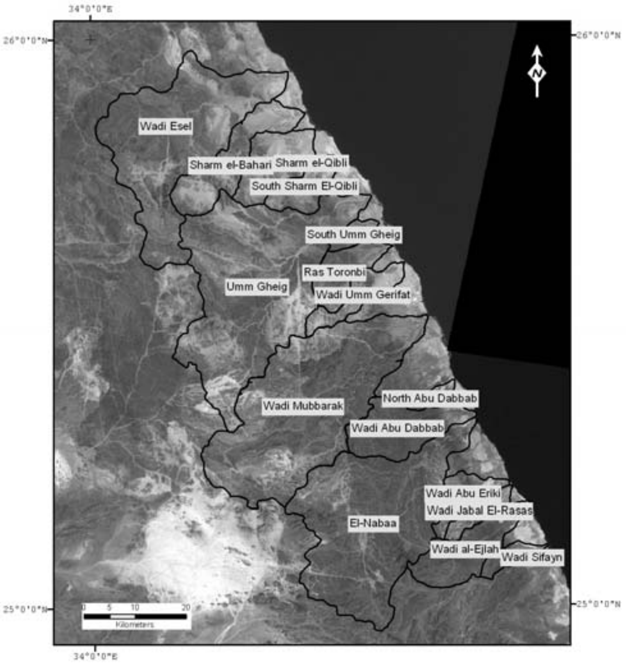


Fig. (6-a): Landsat TM panchromatic image of the northern sector showing the basin boundaries.

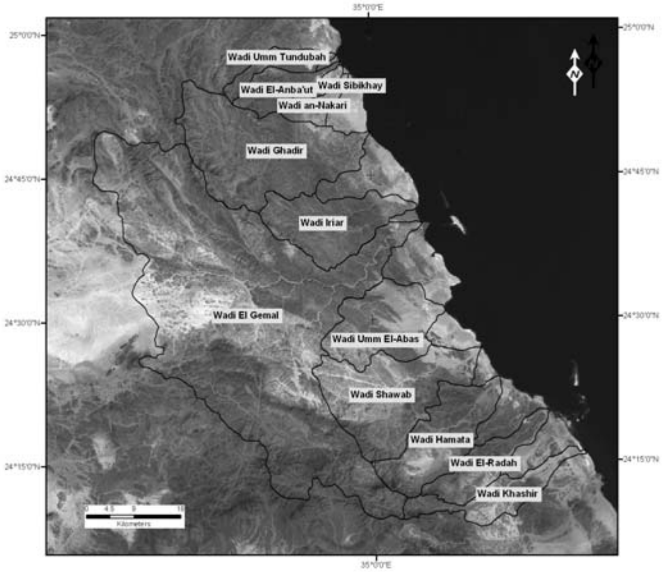


Fig. (6-b): Landsat TM panchromatic image of the northern sector showing the basin boundaries.

Fig. (7-a) Drainage networks of the northern sector, basin boundaries shown in black.

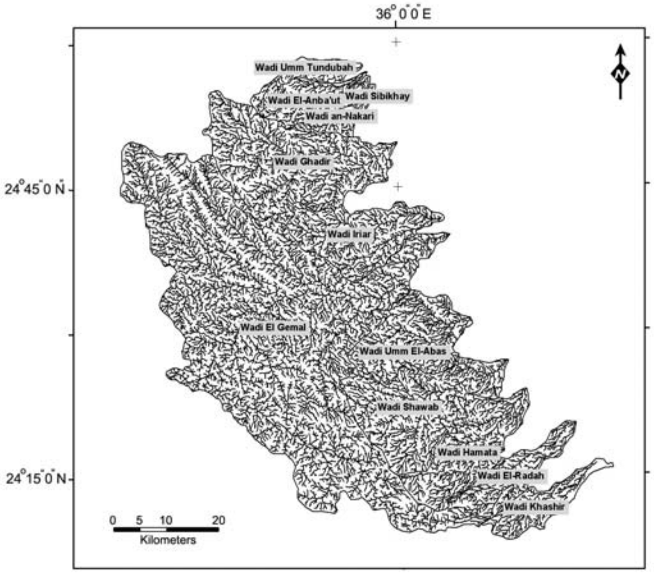


Fig. (7-b) Drainage networks of the southern sector, basin boundaries shown in black.

Several drainage basin geomorphometric parameters contribute to the possibility a flash flood will occur in any particular drainage area (basin flood potentiality):

Drainage basin area, it is the most important basin characteristic for hydrologic analysis. It reflects the volume of water that can be generated from a rainfall.
Basin Length, it is the length measured along the principal flow path from the watershed outlet to the basin boundary. It is a measure of the travel time of water through the basin.
Basin slope, it affects the momentum, speed and concentration of runoff. The possibility to start a runoff is increased with the increasing of slope. The average slope of basins had been determined by dissolving the slope grid derived from DEM (Fig. 4) by basin names.
Basin Shape, shape of the basin reflects the way that runoff will stream through different parts of the basin and how the runoff dashing out the outlet. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time. An elliptical watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the runoff to be spread out over time, thus producing a smaller flood peak than that of the circular watershed. Basin shape estimated by determining basin circularity ration (Fc) and basin elongation ration (Re) (Uditha, 2005):

$$\mathbf{Fc = P/(4\pi A)^{0.5}}$$

Where, ***P*** and ***A*** are the perimeter and area of the watershed, respectively.

$$\mathbf{Re = 2/Lm(A/\pi)^{0.5}}$$

Where, ***Lm*** is the maximum length of the basin parallel to the principal drainage lines.

Drainage density and stream frequency, these are the total length and total number of the entire stream segments in a drainage basin divided by the total area of the drainage basin. High drainage density or/and stream frequency of a basin indicates a rapid storm response and consequently high probability to form flash flood (Strahler, 1981)

Bifurcation Ratio, it is defined as the ratio of the number of streams of any order to the number of streams of the next highest order. The lower bifurcation ratio indicates a circular basin with high flood potentiality and vise versa. In order to determine the bifurcation ratio the steam order - which determined the degree of stream branching within a basin - had been determined for the entire segments in each basin using Horton law (Horton, 1932) (Fig. 8).

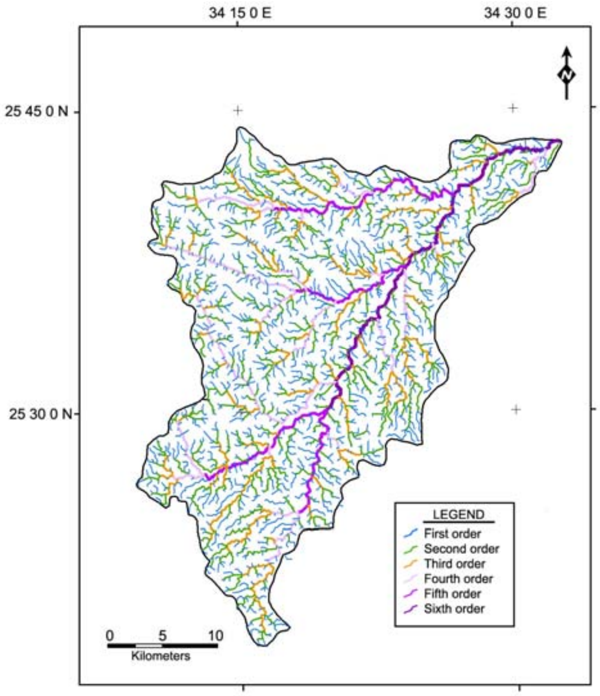


Fig. (8): Stream order of Wadi Umm Gheig drainage segments.

The bifurcation ratio of a basin is the average of the bifurcation ratios of each stream order:

$$\mathbf{Rb = [\sum\limits_{N = (I-1)}^{N = 1} S_n / S_{(n+1)}] / (I - 1)}$$

Where,

I   Basin order.

Sn Number of segments of order n

Rb Bifurcation ratio

The flash flood potentiality of each basin has been evaluated based on its geomrphometeric parameters (Table 1). See Figure (9)

Table (1-a): Geomorphometric parameters and flood potentiality of North sector basins.

Basin Name	D	F	Rb	Slope	Perimeter (km)	Area (Sq. km)	Basin Length(km)	Circularity	Elongation	Flood Potentiality
W. Sifayn	1.960	2.290	4.00	1.30	33.401	37.802	13730	1.533	0.505	High
W. al-Ejlah	1.860	2.280	4.00	1.63	69.836	169.382	26360	1.514	0.557	Moderate
W. Jabal El-Rasas	2.000	2.100	4.33	1.44	39.050	51.779	16720	1.531	0.486	Moderate
W. Abu Eriki	1.840	2.470	3.50	1.50	48.413	76.666	17410	1.560	0.568	Moderate
El-Nabaa	1.840	2.390	4.60	1.84	147.267	749.231	46550	1.518	0.664	Low
W. Abu Dabbab	1.860	2.270	4.25	1.63	67.603	186.221	25480	1.398	0.604	Low
North Abu Dabbab	2.110	2.120	4.00	1.39	29.062	32.652	10690	1.435	0.603	Low
W. Mubbarak	1.820	2.300	4.20	1.77	154.837	830.794	52020	1.516	0.625	Low
W. Umm Gerifat	1.920	2.020	5.33	1.50	58.946	87.368	23490	1.779	0.449	Moderate
Ras Toronbi	1.910	2.240	4.00	1.35	49.381	102.788	17540	1.374	0.652	Low
South Umm Gheig	2.040	2.170	4.00	1.05	28.555	35.851	10440	1.346	0.647	Low
Umm Gheig	1.860	2.250	4.20	1.82	172.280	873.207	49130	1.645	0.679	Low
South Sharm El-Qibli	1.980	2.350	3.75	1.18	45.704	95.563	16540	1.319	0.667	Moderate
Sharm el-Qibli	2.030	2.240	4.00	1.64	53.919	146.862	20480	1.255	0.668	Low
Sharm el-Bahari	1.930	2.330	4.50	2.27	84.722	189.076	30900	1.739	0.502	High
W. Esel	1.870	2.340	4.40	1.87	149.957	644.434	36940	1.667	0.776	Low

D = Drainage Density *F = Stream Frequency* *Rb = Bifurcation Ratio*

Table (1-b): Geomorphometric parameters and flood potentiality of South sector basins.

Basin Name	D	F	Rb	Slope	Perimeter (km)	Area (Sq. km)	Basin Length (km)	Circularity	Elongation	Flood Potentiality
Wadi Khashir	1.68	1.97	4	1.6	146.348	94.038	24790	2.193	0.551	Moderate
Wadi El-Radah	2.03	2.3	4	2.63	140.881	70.804	27190	1.683	0.493	High
Wadi Hamata	1.92	2.43	4.75	1.82	260.366	85.141	29950	1.489	0.608	Low
Wadi Shawab	1.84	2.34	5.25	2.58	389.764	105.724	49930	1.511	0.446	Moderate
Wadi Umm El-Abas	1.99	2.46	3.6	1.74	258.640	74.838	27290	1.313	0.665	Moderate
Wadi Iriar	1.88	2.32	4.75	2.22	255.668	81.957	27860	1.446	0.648	Low
Wadi El Gemal	1.81	2.42	4	2.37	1952.989	300.404	54180	1.918	0.921	Moderate
Wadi Ghadir	1.8	2.32	3.8	2.21	511.914	142.809	34140	1.781	0.748	Moderate
Wadi an-Nakari	1.97	2.2	3	1.42	48.939	37.505	13510	1.513	0.584	Moderate
Wadi Sibikhay	2	1.96	3.33	1.79	23.328	27.282	10880	1.594	0.501	High
Wadi El-Anba'ut	1.85	2.39	4	2.3	98.508	53.066	21890	1.509	0.512	High
Wadi Umm Tundubah	1.82	2.11	5.33	1.65	74.477	55.168	16450	1.804	0.592	Low

D = Drainage Density *F = Stream Frequency* *Rb = Bifurcation Ratio*

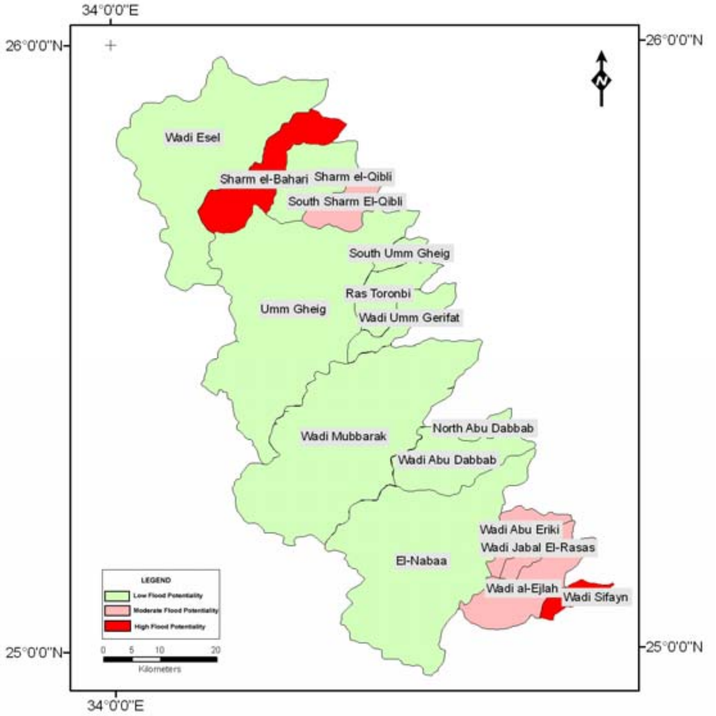


Fig. (9-a): Flash flood potentiality of basins of northern sector.

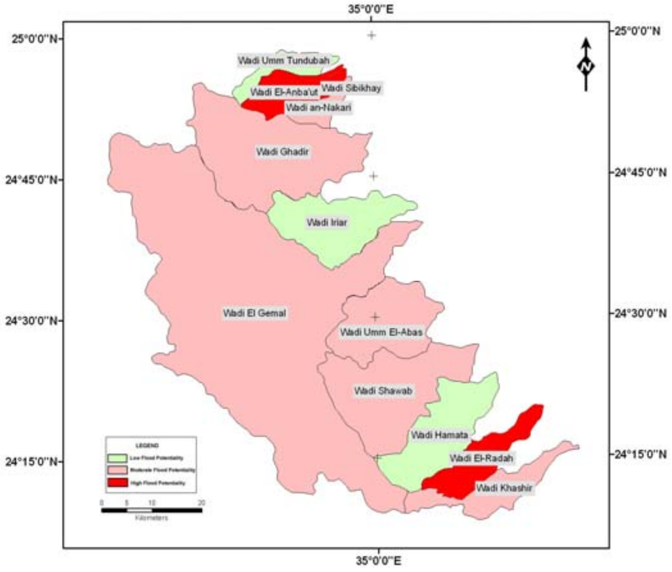


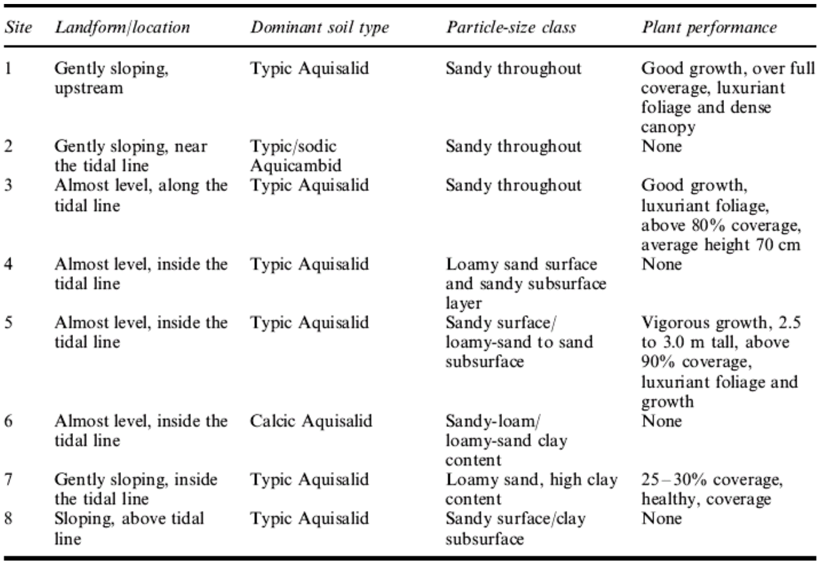
Fig. (9-b): Flash flood potentiality of basins of southern sect

Soil Stability, Type and Renovation:

The textural composition, salinity of the surface layer and the occurrence of anaerobic layer appeared to have played a major role in determining the establishment and growth of mangrove plants. The occurrence of aerobic surface layer and anaerobic subsurface layer supported maximum seedling establishment (N.R. BHAT AND M.K. SULEIMAN, 2004).

Previous projects for mangrove plantation in condition similar to that of the Egyptian Red Sea coastal environment showing that mangrove plantation are more successful in soil with high sand contents and low silt and clay fractions and low Caco3 content. This condition along with the fluctuating water table appears to have prevented excessive salt accumulation particularly above the tidal line. In contrast, the presence of silt and clay and water saturated anaerobic horizons in the mudflats are probably responsible for increased salinity of soils at some places (Table 2) (Kuwit project Reference, 200x).

Table (2): Key to landform, soil type and mangrove growth in Kuwait project



Site	*Landform/location*	*Dominant soil type*	*Particle-size class*	*Plant performance*
1	Gently sloping, upstream	Typic Aquisalid	Sandy throughout	Good growth, over full coverage, luxuriant foliage and dense canopy
2	Gently sloping, near the tidal line	Typic/sodic Aquicambid	Sandy throughout	None
3	Almost level, along the tidal line	Typic Aquisalid	Sandy throughout	Good growth, luxuriant foliage, above 80% coverage, average height 70 cm
4	Almost level, inside the tidal line	Typic Aquisalid	Loamy sand surface and sandy subsurface layer	None
5	Almost level, inside the tidal line	Typic Aquisalid	Sandy surface/ loamy-sand to sand subsurface	Vigorous growth, 2.5 to 3.0 m tall, above 90% coverage, luxuriant foliage and growth
6	Almost level, inside the tidal line	Calcic Aquisalid	Sandy-loam/ loamy-sand clay content	None
7	Gently sloping, inside the tidal line	Typic Aquisalid	Loamy sand, high clay content	25–30% coverage, healthy, coverage
8	Sloping, above tidal line	Typic Aquisalid	Sandy surface/clay subsurface	None

The characteristic of the soil cover the Red Sea coast is affected mainly by the type of rocks exposed locally and the soil transported from the basins that drained to the Red Sea from the West.

The following is a trial to evaluate the capability of each basin on the study area to be a source of the soil suitable for mangrove plantation. The following are the parameters used:
Factors affecting the erosion and weathering process:

- Lineament Intensity (Fig. 10).
- Drainage density.
- Mineral composition.
- Area of rock exposed on the surface (Fig. 11). This layer is based on the geological map published in 1978 by the Geological survey of Egypt (Aswan Quadrangle), boundaries of the rock unites corrected and checked against Landsat thematic Mapper image.

Factors affecting the transportation of soil:

- Basin Order.
- Basin Bifurcation ratio.
- Drainage density.
- Slope.

Factors affecting the soil texture and soil mineral composition:

- Mineral composition of the exposed rocks.
- Area of rock exposed on the surface.

Taking into consideration that the suitable soils for mangrove plantation are those with high sand content and low clay and calcium carbonate content, the formations and rock groups exposed on the surface on the study area has been ranked based on the mineral composition of their rocks (Table 3). For example, granitic rock will be assigned moderate rank because when weathering process affects granite the following components are released:

- Oxides of iron and alumina (sesquioxides Al_2O_3, Fe_2O_3).
- Various forms of silica (silicon-oxide compounds).
- Stable wastes as very fine silt (mostly fine quartz) and coarser quartz (sand).

Although one of the erosion product of granite will be sand particles, but Aluminum silicates derived mainly from the Feldspar minerals (Orthoclase and Microcline $KAlSi_3O_8$ and Albite $NaAlSi_3O_8$) react with water to give clay minerals (colonization process). Another example is the formation composed mostly of $CaCO_3$ rocks will be ranked down because the acidity of the sea water at the study area is low (ph is high) (Hassan and Shabara, 2003), as the water becomes less acidic, $CaCO_3$ become insoluble and accumulated around the plant roots.

Soil suitability factor was determined for every rock unit exposure within the basin using the following equation:

Soil Suitability Factor = (Area/Basin Area) + (Basin Order/Maximum Basin Order) + (DD/Maximum DD) + (Rb/Maximum Rb) + (Slope/Maximum Slope) + (LL/Maximum LL) + (Lithology Rank/Maximum Lithology Rank)

Where,
DD = Drainage Density
Rb = Bifurcation Ratio
LL = Lineament Intensity
Soil suitability factor was determined for each basin by averaging those of all rock unit exposed within the basin (Table 4).

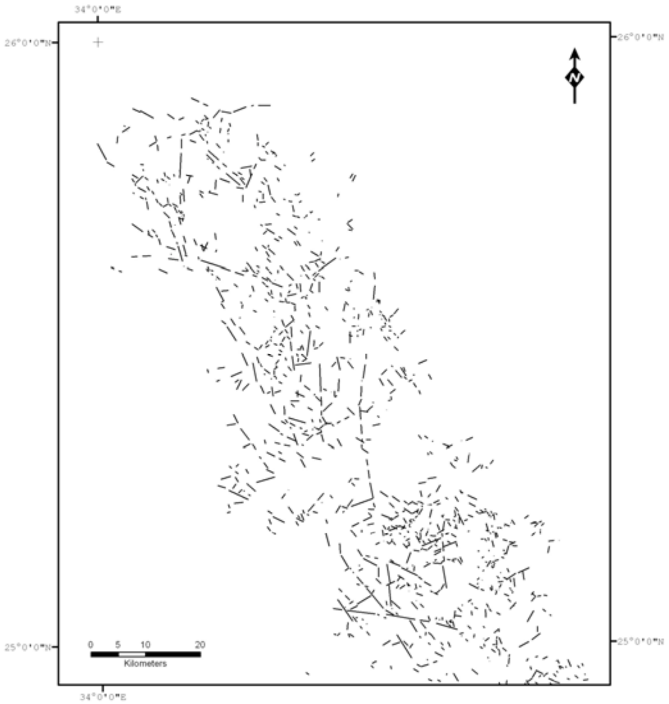


Fig. (10-a): Structure lineament of the northern sector.

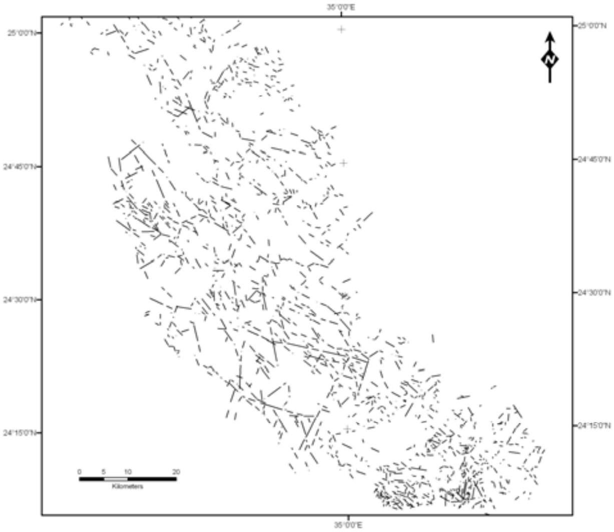


Fig. (10-b): Structure lineament of the Southern sector.

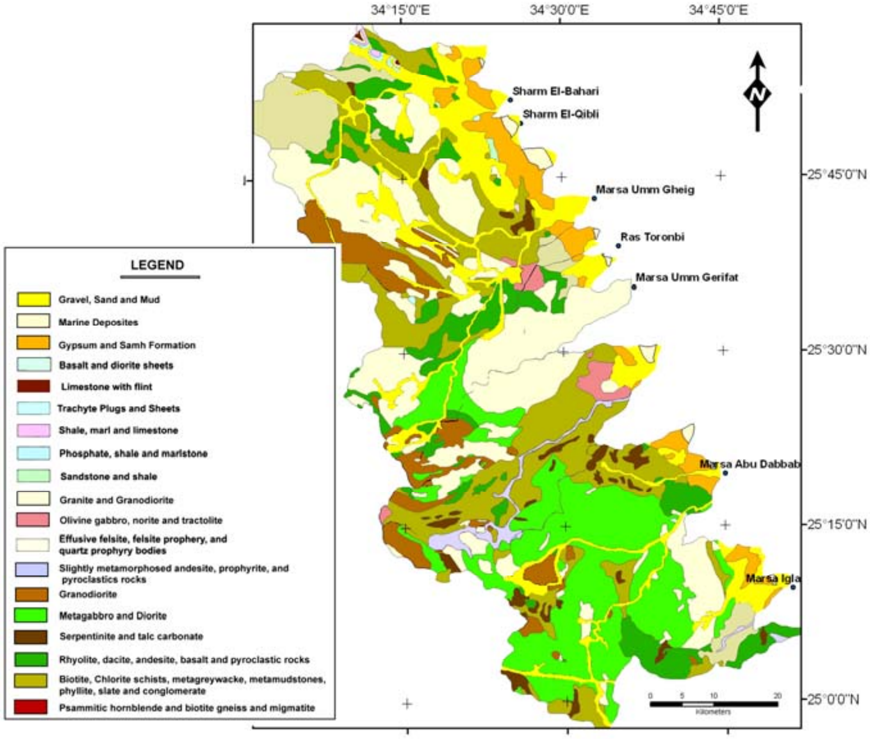


Fig. (11-a): Lithological map of the northern sector.

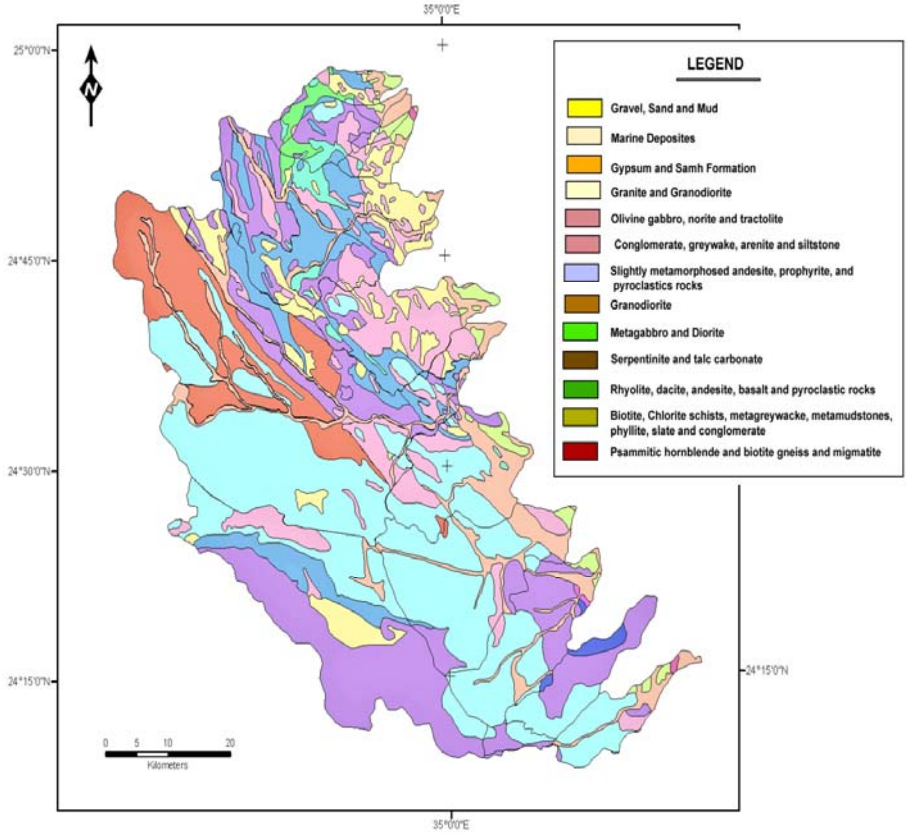


Fig. (11-b): Lithological map of the southern sector.

Table (3): Ranking of the Lithological composition of the formations and groups exposed on the study area.

Lithology	**Rank**
Biotitew, Chlorite schists, metagreywacke, metamudstones, phyllite, slate and conglomerate	1
Gypsum and Samh Formation	1
Limestone with flint and Shale	1
Serpentinite and talc carbonate	1
Tarawan Chalk and lower part of Esna shale	1
Psammitic hornblende and biotite gneiss and migmatite	1
Conglomerate, brecia, graywacke, arenite and siltstone	2
Marine Deposites	2
Metagabbro and Diorite	2
Olivine gabbro, norite and tractolite	2
Slightly metamorphosed andesite, prophyrite, and pyroclastics rocks	2
Coarse brecia and fine lacustrine	3
Effusive felsite, felsite prophery, and quartz prophyry bodies	3
Granite and Granodiorite	3
Gravel, Sand and Mud	3
Rhyolite, dacite, andesite, basalt and pyroclastic rocks	3
Granodiorite	4
Sandstone with some shale	4

Table (4-a): Soil suitability factor for Northern sector basins.

Basin	Soil Suitability Factor
North Abu Dabbab	9.85
South Sharm El-Qibli	13.74
Wadi Umm Gerifat	2.17
Ras Toronbi	11.62
South Umm Gheig	5.03
El-Nabaa	99.22
Sharm el-Bahari	30.78
Sharm el-Qibli	19.22
Umm Gheig	131.62
Wadi Abu Dabbab	23.87
Wadi Abu Eriki	12.12
Wadi al-Ejlah	24.31
Wadi Esel	75.56
Wadi Jabal El-Rasas	8.23
Wadi Mubbarak	100.69
Wadi Sifayn	6.95

Table (4-b): Soil suitability factor for Southern sector basins.

Basin	Soil Suitability Factor
Wadi Iriar	36.54
Wadi Umm El-Abas	26.87
Wadi El-Radah	5.75
Wadi an-Nakari	12.24
Wadi El Gemal	121.68
Wadi El-Anba'ut	21.40
Wadi Ghadir	92.33
Wadi Hamata	18.11
Wadi Khashir	25.11
Wadi Shawab	20.60
Wadi Sibikhay	6.21
Wadi Umm Tundubah	27.21

Based on the slope, flood potentiality and soil suitability factor of those basins with an outlet drained to the pre-selected sites (Fig. 4) were categorized according to their suitability for Mangrove plantation into three categories: good, fair and poor (Table 5) (Figure 12).

Table (5): Site suitability.

Name	**Slope**	**Flood Potentiality**	**Soil Suitability**	**Site Suitability**
El-Nabaa	1.84	Low	99.218	Good
North Abu Dabbab	1.39	Low	9.850	Poor
Ras Toronbi	1.35	Low	11.618	Fair
Sharm el-Bahari	2.27	High	30.777	Poor
Sharm el-Qibli	1.64	Moderate	19.222	Poor
South Sharm El-Qibli	1.18	Moderate	13.739	Poor
South Umm Gheig	1.05	Low	5.032	Poor
Umm Gheig	1.82	Low	131.619	Good
Wadi Abu Dabbab	1.63	Low	23.871	Poor
Wadi Abu Eriki	1.50	Moderate	12.115	Poor
Wadi al-Ejlah	1.63	Moderate	24.310	Fair
Wadi Esel	1.87	Low	75.563	Fair
Wadi Jabal El-Rasas	1.44	Moderate	8.232	Poor
Wadi Mubbarak	1.77	Moderate	100.691	Good
Wadi Sifayn	1.30	High	6.951	Poor
Wadi Umm Gerifat	1.50	Low	2.169	Poor

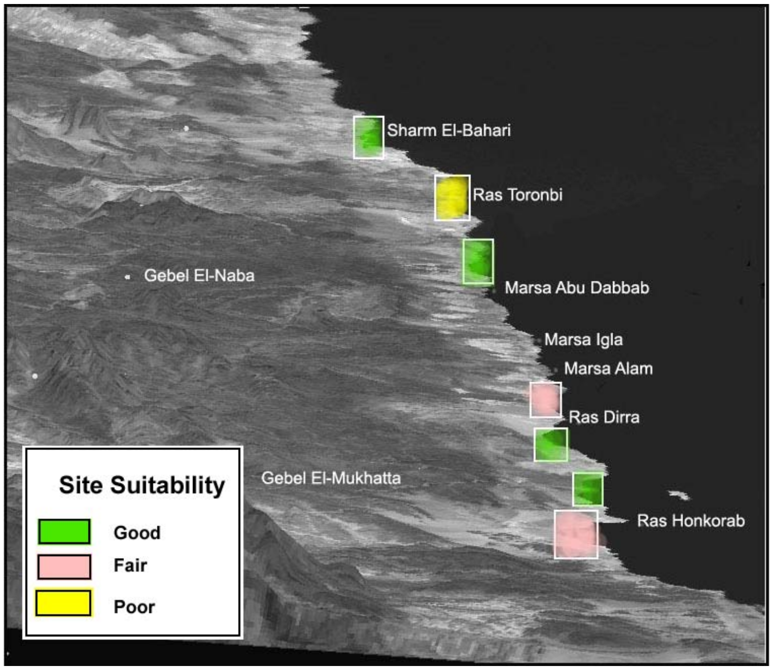


Fig. (12): Site Suitability for Mangrove plantation.

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