Distribution and Land Capability Classification of Soils in Wadi Watir Delta, Gulf of Aqaba, Sinai, Egypt

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ABSTRACT

Recently, the political leadership in Egypt focused on all state agencies concerned with the development of Sinai, with the need to achieve an economic dimension parallel to the security one. Hence, the Egyptian government always is seeking land resources potentially suitable for agriculture in Sinai. Especially, after establishing three stations of sanitary and agricultural wastewater treatment that pumping huge amounts of irrigation water annually inside Sinai. The scientists recommended that the delta of Wadi Watir, south-eastern of Sinai is a promising area for cultivation. Therefore, the purpose of this paper is to: (1) identify and mapping the soils of Wadi Watir delta, (2) determine the dominant agricultural limitations, and (3) assess soils capability and their priorities for agricultural land use. The studied soils were characterized and distributed into; (i) almost flat deep coarse-textured soils that had 37.13% of the total studied area, (ii) gently undulating deep coarse-textured soils which covered most of the research site; 49.09%, and (iii) undulating deep coarse-textured soils that comprised the minimum portion 13.78%. Six agricultural limitations could be distinguished within the studied site as wind erosion, texture, content of gravel, topography, alkalinity, and soil fertility. The soils were evaluated into class III, indicating that the researched area are good for agriculture with special conservation practices. Soils of Wadi Watir delta was divided into two parts according to their priority for agriculture, i.e. priority (I) which had 54.52% of the total area, and priority (II) which had the rest portion of the considered soils.

Keywords: mapping, soils, agricultural limitations, land capability and use, Sinai

1. Introduction

It is certain that a comprehensive development in Sinai has become one of the necessary requirements to maintain Egyptian national security, where it represents a dream for millions of Egyptians as the main gateway to economic growth. For this reason, the political leadership in Egypt focused on all state agencies concerned with the development of Sinai, with the need to achieve an economic dimension parallel to the security one. This can surely be achieved with sustainable agricultural development in Sinai which depends on the soil capability and availability of water resources.

Previous studies of geology and geomorphology referred that Wadi Watir basin is one of the most remarkable and promising drainage basins in the south-eastern part of Sinai. The main channel of Wadi Watir and its tributaries drain into the Gulf of Aqaba forming alluvial fan of dry delta which is a promising cultivated area (Hassan and Farag, 2008).

Hassan and Farag, (2008) mentioned that delta of Wadi Watir comprises the flood plain which defines the downstream part of its main channel and is filled with badly sorted deposits. Fan-delta is derived from eroded calcareous materials and has almost flat to slightly undulating surfaces.

As delta of Wadi Watir is considered a heartening portion for agriculture development especially after establishing three stations of sanitary and agricultural wastewater treatment inside Sinai will pump huge amounts of irrigation water annually. Additionally, few publications were being found in the literature that addresses the issue of soil distribution and its evaluation for agricultural use in the area of delta Wadi Watir.

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Hence, this study is to propose; (1) identifying and mapping the soils of delta of Wadi Watir, (2) determining the dominant agricultural limitations, and (3) assessment the soils capability and their priorities for agricultural land use.

2. Material and Methods

2.1. Study Area

Wadi Watir delta exists in the downstream portion of Wadi Watir on the south-eastern part of the Sinai Peninsula, Egypt, between longitudes 34° 38’ and 34° 41’ E and latitude 28°59’ and 29° 03’ N, and covering an area of 5150 fed., (Fig. 1). Nuweiba city which is a tourist destination is situated on delta of Wadi Watir itself while Nuweiba Harbor is located on the delta coast where ships sailing from Nuweiba Harbor link Egypt with Saudi Arabia and Jordan. This gives the study area economic importance, especially with optimally exploited agriculture.

2.2. Geology

Geologically, Wadi Watir consists of rocks ranging in age from Precambrian to Quaternary (CONOCO, 1987). The Wadi Watir delta is composed mainly of Quaternary deposits that constitute the main water-bearing formation in the Nuweiba District. These deposits formed essentially of fine-to-coarse sands, gravels, and boulders of carbonate, sandstone, and granitic rock embedded in a silt and clay matrix (El-Shazly, et al., 1974; Eyal, et al., 1980; El Kiki, et al., 1992), as shown in (Fig. 2).

Fig. 1: Location of the study area

Fig. 2: Geology of the study area, after (Hammad, 1975)
2.3. Geomorphology
Hassan and Farag, (2008) considered the Wadi Watir delta as one of the geomorphic units of Wadi Watir. They described the surface of the delta as almost flat to slightly undulating and formed of weathered calcareous materials.

2.4. Hydrology setting
The Wadi Watir basin is the main water source for the groundwater aquifer of the study area and is facing increasing demands for groundwater due to the rapid development (Himida, 1994). Groundwater in the Wadi Watir delta flows as a thin layer of fresh water, and the groundwater here is very sensitive to pumping because of its location near the coast and consequent seawater intrusion (in particular, it is affected by the upwelling of deep saline deep groundwater, (Ismail, 1998; Shalaby, 1997).

2.5. Soil Mapping and GIS Processing
Digital Elevations Model (DEM) was produced using Shuttle Radar Topography Mission (SRTM) 90 m, and then a toposequence model was generated from the DEM using Global Mapper 17 (2016) as shown in Fig. (3). A digital database for the site was generated using Arc-GIS 9.2 software (ESRI, 2006). Sites of soil observations were digitized, as a unique identifier for every location connected to correlated attribute data using the Database Management System (DBMS). Soil mapping units were produced by overlapping the most variable soil data where final soil types and capability maps were generated.

Fig. 3: Digital elevation model (A), along with the generated toposequence model (B) of the study area and locations of soil profiles

2.6. Field and laboratory methods
Ten soil profiles were selected on basis of a toposequence model represents most of the topographical variations. This model was generated from the DEM which showed ground elevations 5 to 20 m A.S.L within the area of study Fig. (3). The profiles were dug out up to 150 cm depth then morphologically described and sampled for the chemical and physical analyses, according to Soil Survey Manual (Soil Survey Staff, 2017). Soil laboratory analyses performed according to (Page, et al., 1982) including soil texture, total calcium carbonates, electrical conductivity of soil extracts (EC), and soil reaction (pH).
2.7. Soil classification and Land capability evaluation

Soils were classified according to the USDA (2014) and appraised to estimate its potential of capability using the rating of soil properties adapted after USDA System of land capability classification (Klingebiel and Montgomery, 1961). Six main characteristics are considered in this system: soil depth, soil texture, slope, erosion, permeability, and surface runoff. The research area categorized into classes based on the general guide for selecting land capability classes as shown in table (1).

| Soil Factor | Description                        | Best Land Class |
|-------------|------------------------------------|-----------------|
| Texture (1):| Coarse textured                    | III             |
|             | Moderately coarse, medium          | I               |
|             | Moderately fine and fine           | I               |
| Depth (2):  | Deep or moderately deep            | I               |
|             | Shallow                            | III             |
|             | Very shallow                       | VII             |
| Slope (3):  | Nearly level (0 to 1%)             | I               |
|             | Gently sloping (1% to 3%)          | II              |
|             | Moderately sloping (3% to 5%)      | III             |
|             | Strongly sloping (5% to 8%)        | IV              |
|             | Steep and very steep (8% to 15%+)  | VI              |
| Erosion (4):| None to slight erosion             | I               |
|             | Moderate                           | II              |
|             | Severe or very severe              | VI              |
| Permeability (5):| Rapid                   | III             |
|                | Moderate and slow               | I               |
|                | Very slow                         | II              |
| Runoff (6):  | Rapid                             | III             |
|             | Moderate and slow                 | I               |
|             | Very slow                         | II              |

3. Results and Discussion

3.1. Morphological characteristics

The morphological characteristics of the studied soils are presented in Table 2. Topography diversified between almost flat to undulating with a slope described as nearly level to sloping. The soils are deep (150 cm), and thickness of surface soil horizons varied between 15 and 50 cm reflecting the differences in topography of the research site. Soil colour exhibited a range of hue from 10YR to 2.5Y, and 6 to 8 for value while chroma varied between 4 to 8. The soils are classified as coarse-textured with a gravel content not exceeded 50%. Most of the soil structure is massive; however subangular blocks were noticed as little.

Soil consistence was either soft to very hard or sometimes friable to firm. Pedological features weren’t observed, except in subsurface soils of profiles 4 and 9 in forms of lime segregations and salt crystals. Fine to coarse-sized dead roots were found in different quantities within 48% of the estimated soils. Reaction with HCl was either strongly or violently effervescent reflecting the high percentage of lime. Boundaries between soil horizons ranged between abrupt to clear smooth, which is referring to possibility of heterogeneity in sedimentation between the pedological layers.

3.2. Physical and chemical characteristics

As shown in (table 3), soil texture class ranged between fine sand (fs) and medium sand (ms), where the minimum content of total sand was not less than 94.35% within the considered area. It was found that soil texture wasn’t showed regular distribution with depth. As soil texture is sand, this indicates the prevalence of good conditions for aeration and ease of penetration of plant roots and water drainage. However, at the same time it signalizes a decrease in the ability of the soil to retain irrigation water due to the low proportions of the clay fraction and the attendant capacity of the soil to hold and exchange nutrients, which results in a decrease in soil fertility.
Table 2: Main morphological characteristics of the studied soils

| Topography, Slope | Profile No. | Depth (cm) | Colour | Texture (USDA) | Coarse Fragments | Structure | Consistence Dry | Consistence Wet | Pedological features | Roots | Reaction with HCl | Boundary |
|-------------------|------------|------------|--------|----------------|------------------|-----------|-----------------|-----------------|---------------------|-------|-------------------|----------|
| Almost flat, Nearly level | 1 | 0-40 | 10YR 7/6 | ms | ff & ffg | m | sh | so, po | - | - | es | cs |
| | | 40-90 | 10YR 7/8 | ms | m var.g | m | sh | so, po | - | - | es | cs |
| | | 90-150 | 10YR 7/6 | ms | ff & ffg | m | s | so, po | - | - | es | - |
| Almost flat, Nearly level | 2 | 0-40 | 10YR 7/8 | fs | mfg & m | m | sh | so, po | - | cm & f | es | cs |
| | | 40-60 | 2.5Y 8/4 | ms | m var.g | m | sh | so, po | - | - | es | as |
| | | 60-90 | 10YR 7/6 | fs | - | m | sh | so, po | - | - | es | cs |
| | | 90-150 | 10YR 7/8 | ms | ff & ffg | m | sh | so, po | - | - | es | - |
| Almost flat, Nearly level | 3 | 0-30 | 10YR 6/6 | fs | ffg & ffg | m | sh | so, po | - | cm & f | es | cs |
| | | 30-70 | 10YR 7/8 | ms | ffg | m | sh | so, po | - | vff & v | es | cs |
| | | 70-150 | 10YR 7/6 | ms | mf & mg | m | sh | so, po | - | - | es | - |
| Almost flat, Nearly level | 4 | 0-30 | 10YR 7/6 | ms | - | m | h | so, po | - | cm & f | ev | as |
| | | 30-60 | 2.5Y 8/4 | fs | ffg & sbk | vh | sh | so, po | cf lime seg. | ff & v | ev | as |
| | | 60-90 | 10YR 6/6 | ms | ffg | m | s | so, po | - | - | es | cs |
| | | 90-150 | 10YR 7/6 | ms | mfg | m | s | so, po | - | - | es | - |
| Almost flat, Nearly level | 5 | 0-30 | 2.5Y 8/4 | ms | - | m | sh | so, po | - | fl & m | ev | as |
| | | 30-60 | 10YR 6/6 | fs | ffg & sbk | h | sh | so, po | - | vff & v | ev | as |
| | | 60-100 | 10YR 7/6 | ms | f var.g | m | sh | so, po | - | ff & v | es | cs |
| | | 100-150 | 10YR 7/6 | fs | ffg | m | sh | so, po | - | ff | es | - |
Continued,

| Topography, Slope | Profile No. | Depth (cm) | Colour | Texture (USDA) | Coarse Fragments | Structure | Consistence | Pedological features | Roots | Reaction with HCl | Boundary |
|-------------------|-------------|------------|--------|----------------|------------------|-----------|-------------|---------------------|-------|-------------------|----------|
| Gently undulating, Gently sloping | 6 | 0-50 | 2.5Y 7/4 | fs | ffg | m | sh, so, po | - | - | es | as |
|  | 50-75 | 10YR 7/8 | ms | - | sbk | h | so, po | - | vff | ev | cs |
|  | 75-150 | 2.5Y 8/4 | fs | - | m | s | so, po | - | - | es | - |
| Undulating, sloping | 7 | 0-15 | 10YR 7/6 | ms | - | sbk | vh | so, po | - | - | ev | as |
|  | 15-70 | 10YR 7/8 | fs | - | m | s | so, po | - | ffr | ev | cs |
|  | 70-100 | 10YR 7/6 | ms | - | sbk | h | so, po | - | ff&vfm | ev | cs |
|  | 100-150 | 2.5Y 7/4 | fs | - | m | s | so, po | - | vff | es | - |
| Almost flat, Nearly level | 8 | 0-30 | 10YR 8/4 | ms | ffg | m | sh, so, po | - | cvf | es | cs |
|  | 30-110 | 2.5Y 8/4 | ms | - | m | sh, so, po | - | - | es | cs |
|  | 110-150 | 2.5Y 7/4 | fs | - | m | fr | so, po | - | - | ev | - |
| Almost flat, Nearly level | 9 | 0-20 | 10YR 7/8 | ms | ffg | m | s | so, po | - | - | es | as |
|  | 20-45 | 10YR 7/6 | fs | - | m | fr | so, po | - | - | es | as |
|  | 45-80 | 2.5Y 7/4 | ms | - | m | f | so, po | cf lime & salt | - | ev | as |
|  | 80-150 | 10YR 7/8 | ms | - | m | f | so, po | - | vff | ev | - |
| Almost flat, Nearly level | 10 | 0-30 | 2.5Y 8/4 | ms | ffg | m | sh, so, po | - | vff | es | cs |
|  | 30-110 | 10YR 8/4 | fs | - | m | s | so, po | - | ff&m&vf | es | as |
|  | 110-150 | 2.5Y 8/4 | ms | mf&mg | m | sh, so, po | - | - | es | - |

Abbreviations

- **Texture (USDA):** ms-medium sand; fs-fine sand; ffg-few fine gravel; m var.g-many varized gravel; mfg-many fine gravel; mf&mg-many fine and medium gravel; fmg-few medium gravel; f var.g-few varized gravel
- **Structure:** m-massive; sbk-subangular blocky
- **Consistency:** sh-slightly hard; s-soft; h-hard; vh-very hard; fr-friable; f-firm; s-so sticky; p-non plastic
- **Pedological features:** cf lime seg.-common fine lime segregations; cf lime & salt- common fine lime segregations & salt crystals
- **Reaction with HCl:** es-very vigorous effervescence; ev-violently effervescence

- **Roots:** cf-common fine; cm&f-common medium and fine; vff-very few fine; ff-few fine; ff&m-few fine & medium; vff&m-few very fine & very fine; ff&vfm-few very fine & very fine; vff&vf-very few fine & very fine; ff&vfm-few very fine & very fine; vff&m&vfm-few very fine & very fine; cvf-common very fine; ff&m&vf- few fine & medium & very few coarse
- **Boundary:** es-clear smooth; as-abrupt smooth
Table 3: Some Physical and chemical characteristics of the studied soils

| Profile No. | Depth/cm | Gravel % | EC dS m⁻¹ | pH | CaCO₃ % | Particle Size Distribution % | Particle Size Distribution % | Texture (USDA)³ |
|-------------|----------|----------|-----------|----|---------|------------------------------|-------------------------------|-----------------|
|             |          |          |           |    |         | 1-2 (mm)                     | 1-0.5 (mm)                  |                 |
|             |          |          |           |    |         | 0.5-0.25 (mm)                | 0.25-0.125 (mm)             |                 |
|             |          |          |           |    |         | 0.125-0.063 (mm)             | <0.063 (mm)                 |                 |
|             |          |          |           |    |         |                              |                              |                 |
| P1          | 0-40     | 8.33     | 0.29      | 7.73 | 18.10  | 2.20                         | 6.90                        | 83.19           | 5.62            | 1.95            | 0.14            | MS              |
|             | 40-90    | 50.00    | 0.20      | 8.14 | 15.29  | 10.23                        | 24.12                       | 43.55           | 18.63           | 3.21            | 0.26            | MS              |
|             | 90-150   | 7.14     | 0.06      | 8.42 | 10.86  | 3.09                         | 8.64                        | 81.50           | 5.53            | 1.13            | 0.11            | MS              |
| P2          | 0-40     | 21.43    | 0.59      | 7.68 | 20.52  | 4.60                         | 10.15                       | 31.65           | 47.65           | 2.79            | 3.16            | FS              |
|             | 40-60    | 21.43    | 0.15      | 8.27 | 11.67  | 15.09                        | 33.55                       | 44.24           | 5.80            | 1.27            | 0.05            | MS              |
|             | 60-90    | 0.00     | 0.09      | 8.48 | 12.87  | 0.12                         | 1.76                        | 47.10           | 48.11           | 1.71            | 1.20            | FS              |
|             | 90-150   | 2.31     | 0.13      | 8.27 | 18.91  | 5.91                         | 11.10                       | 70.85           | 8.00            | 3.79            | 0.35            | MS              |
| P3          | 0-30     | 5.26     | 0.98      | 6.97 | 20.36  | 1.87                         | 5.77                        | 27.15           | 54.16           | 7.40            | 3.65            | FS              |
|             | 30-70    | 6.67     | 0.08      | 8.44 | 15.69  | 4.67                         | 8.91                        | 71.81           | 9.86            | 4.45            | 0.30            | MS              |
|             | 70-150   | 28.57    | 0.09      | 8.55 | 13.28  | 9.96                         | 27.72                       | 47.15           | 13.44           | 1.28            | 0.45            | MS              |
| P4          | 0-30     | 1.88     | 1.83      | 7.42 | 26.95  | 8.50                         | 9.66                        | 70.90           | 6.44            | 4.40            | 0.10            | MS              |
|             | 30-60    | 2.31     | 0.35      | 7.74 | 26.95  | 4.46                         | 5.37                        | 19.56           | 57.19           | 10.80           | 2.62            | FS              |
|             | 60-90    | 2.27     | 0.13      | 8.13 | 16.09  | 1.93                         | 5.31                        | 83.06           | 7.86            | 1.78            | 0.06            | MS              |
|             | 90-150   | 7.69     | 0.15      | 8.03 | 12.07  | 0.72                         | 7.90                        | 62.96           | 26.76           | 1.11            | 0.55            | MS              |
| P5          | 0-30     | 0.00     | 1.11      | 7.39 | 28.16  | 3.68                         | 4.73                        | 79.70           | 6.41            | 4.77            | 0.71            | MS              |
|             | 30-60    | 2.73     | 0.33      | 7.80 | 28.56  | 6.15                         | 4.76                        | 16.86           | 50.67           | 15.91           | 5.65            | FS              |
|             | 60-100   | 5.26     | 0.11      | 8.14 | 16.90  | 3.51                         | 8.39                        | 74.46           | 8.26            | 4.75            | 0.63            | MS              |
|             | 100-150  | 2.00     | 0.12      | 8.14 | 17.30  | 2.67                         | 7.96                        | 38.00           | 45.57           | 3.98            | 1.82            | FS              |
## Continued,

| Profile No. | Depth/cm | Gravel % | EC dS m⁻¹ | pH | CaCO₃% | Particle Size Distribution % | Texture (USDA)¹ |
|-------------|----------|----------|-----------|----|--------|-------------------------------|----------------|
|             |          |          |           |    |        | 1-2 (mm) | 1-0.5 (mm) | 0.5-0.25 (mm) | 0.25-0.125 (mm) | 0.125-0.063 (mm) | <0.063 (mm) |
| P6          | 0-50     | 2.00     | 0.36      | 7.70 | 18.91  | 1.67 | 3.61 | 25.76 | 53.65 | 14.61 | 0.70 | FS    |
|             | 50-75    | 0.00     | 0.41      | 8.01 | 32.99  | 6.65 | 7.48 | 60.52 | 15.98 | 8.92 | 0.45 | MS    |
|             | 75-150   | 0.00     | 0.28      | 8.58 | 22.13  | 3.06 | 7.63 | 39.46 | 44.88 | 3.84 | 1.13 | FS    |
| P7          | 0-15     | 0.00     | 0.48      | 7.67 | 29.37  | 4.86 | 5.21 | 76.14 | 9.00 | 4.45 | 0.34 | MS    |
|             | 15-70    | 0.00     | 0.14      | 8.40 | 25.75  | 0.51 | 1.70 | 17.37 | 68.62 | 6.50 | 5.30 | FS    |
|             | 70-100   | 1.43     | 0.34      | 8.54 | 30.17  | 7.77 | 10.58 | 69.64 | 8.49 | 3.50 | 0.02 | MS    |
|             | 100-150  | 0.00     | 0.33      | 7.81 | 24.94  | 1.32 | 1.75 | 23.21 | 67.89 | 4.87 | 0.96 | FS    |
| P8          | 0-30     | 2.00     | 0.80      | 7.86 | 22.93  | 6.44 | 10.33 | 74.99 | 5.44 | 2.73 | 0.07 | MS    |
|             | 30-110   | 0.00     | 0.57      | 8.18 | 8.85   | 1.43 | 5.26 | 70.66 | 21.12 | 0.86 | 0.67 | MS    |
|             | 110-150  | 0.00     | 0.23      | 7.84 | 28.56  | 0.22 | 1.11 | 11.00 | 81.54 | 3.72 | 2.41 | FS    |
| P9          | 0-20     | 2.50     | 0.29      | 6.97 | 20.52  | 4.89 | 7.67 | 78.78 | 5.48 | 3.17 | 0.01 | MS    |
|             | 20-45    | 0.00     | 0.63      | 7.60 | 22.93  | 3.51 | 9.50 | 20.07 | 60.57 | 3.95 | 2.40 | FS    |
|             | 45-80    | 0.00     | 1.00      | 7.77 | 30.98  | 12.53 | 27.65 | 45.57 | 11.99 | 1.66 | 0.60 | MS    |
|             | 80-150   | 0.00     | 0.50      | 7.93 | 30.57  | 6.03 | 7.82 | 48.93 | 33.18 | 3.98 | 0.06 | MS    |
| P10         | 0-30     | 5.00     | 0.76      | 7.84 | 24.14  | 0.98 | 3.43 | 77.63 | 12.19 | 5.39 | 0.38 | MS    |
|             | 30-110   | 0.00     | 0.09      | 8.70 | 17.30  | 0.08 | 0.57 | 25.13 | 62.47 | 10.15 | 1.60 | FS    |
|             | 110-150  | 25.00    | 0.24      | 8.70 | 17.70  | 9.88 | 25.21 | 55.22 | 8.20 | 1.40 | 0.09 | MS    |

Abbreviations: ¹: MS-medium sand; FS-fine sand
The quantities of gravel in most layers of profiles (1, 2, 3, and 10) varied between 5 and 50%, while the rest of the investigated soils showed contents between 0.0 to 8.33%. The soil layers which are free of gravel are a good indicator for this type of land which gives it an appropriate degree of validity for agriculture due to absence of rock fragments. Also, the height of the gravel magnitudes in some of the subsurface layers makes it as natural drains for water leakage under the surface layer.

Values of electrical conductivity (EC) ranged between 0.06 and 1.83 dS m⁻¹, indicating that the soils can be classified as non saline, and there was no specific trend for EC results with depth. The analytical data of EC referred to presence of high suitable soils for agriculture. Soil reaction values assorted between neutral to strongly alkaline tendency, where pH ranged from 6.97 to 8.70 for the whole area. Feedbacks of pH illustrated that the soil of the investigated area might be affected by a decrease in the solubility of nutrients with a limited to a moderate degree. Total calcium carbonate distributed between 8.85 to 32.99% and displayed irregular trend with depth in most of soil profiles. The resulted proportions of CaCO₃ qualified the studied soils to be classified between moderately to extremely calcareous.

3.3. Soil classification

The studied area belongs to Entisols order without any diagnostic horizons, and classified as Typic Torripsamments, and Typic Torriorthents subgroups.

3.4. Soil bodies identification and mapping them

Based on soil analyses, three soil bodies in the study area were differentiated and mapped according to soil texture, depth, and topography as in the following; (1) almost flat deep coarse-textured soils which represented 37.13% of the total studied area, (2) gently undulating deep coarse-textured soils which covered most of the research site; 49.09%, and (3) undulating deep coarse-textured soils that comprised the minimum portion and covered 13.78% of Wadi Watir delta, Fig. (4).

3.5. Land Capability classification

In consonance with the data in tables (2 and 3), soils of the studied site could be classified according to their capability into class III, (Table 4). This is referring that these soils are good for cultivated crops, but have severe limitations that reduce the choice of plants and/or require special conservation practices that are more difficult to apply. Therefore, soils of profiles (4, 5, 6, 8, and 9) representing almost flat to gently undulating deep coarse-textured were selected for agricultural priority (I) and covered 54.52% of the total area. While, soils of profiles (1, 2, 3, 7, and 10) which are almost flat to undulating gravelly deep coarse-textured, were nominated for agricultural priority (II), and covered the rest of the studied area, Fig (5).
Table 4: Calculated land capability indices for different soil mapping units

| Profile No. | Surface Texture | Depth | Slope¹ | Erosion² | Permeability³ | Surface Runoff⁴ | Capability class |
|-------------|-----------------|-------|--------|----------|--------------|-----------------|-----------------|
| 1           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 2           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 3           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 4           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 5           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 6           | Coarse          | Deep  | GS     | N        | R            | S               | III             |
| 7           | Coarse          | Deep  | S      | N        | R            | S               | III             |
| 8           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 9           | Coarse          | Deep  | NL     | N        | R            | S               | III             |
| 10          | Coarse          | Deep  | NL     | N        | R            | S               | III             |

Abbreviations
¹: NL - nearly level; GS - gently sloping; S - sloping ²: N - none ³: R - rapid ⁴: S - slow

Fig. 5: Priorities of agricultural land use in the studied area

3.6. Agricultural land use limitations in the investigated site

On basis of field and laboratory analyses related to delta Wadi Watir, it could be determined the most important limitations factors that had negatively impact on the agricultural land use and hence land productivity. These limitations were summarized as follows:

1) Exposure to the risks of wind erosion, as the delta of Wadi Watir, is located in the coastal area on the Gulf of Aqaba, and it is one of the areas exposed to wind gusts, which exhibits crops and growing trees to the destructive effect of air erosion.

2) Existing of some limited areas with undulating topography and a high degree of slope represented in soil profile 7, which greatly affect the formation and properties of the soil, and then the method and economics of its reclamation and exploitation for agriculture.

3) Prevailing sandy texture in the studied soils reflects the low ability of the land to retain water, whether at the field capacity or the wilting point, which affects the decrease in the water available for absorption by plants, as this calls for the inevitability of applying advanced irrigation systems and adding precisely defined water regulations for each proposed crop to achieve maximum benefit of irrigation water.

4) The high contents of gravel in some soils of delta Wadi Watir as in profiles (1, 2, 3, and 10), especially with subsurface and deep layers, represents a medium-severity limit on the productivity of soil in these sites.

5) Relatively high values of pH, which may affect the reduction of nutrients solubility for plants, necessitates the need to pay attention to organic fertilization to reduce soil alkalinity through programs, reclamation, and management of these lands.

6) The apparent poverty in the soil fertility component of organic matter, macro, and micronutrients, as well as the weak ability of the soil to retain nutrients, are among the most important determinants of agricultural exploitation in the studied portion.
4. Conclusions

From this research, it is possible to conclude that the studied soils were characterized and distributed into; (i) almost flat deep coarse-textured soils which represented 37.13% of the total studied area, (ii) gently undulating deep coarse-textured soils which covered most of the research site; 49.09%, and (iii) undulating deep coarse-textured soils that comprised the minimum portion and covered 13.78% of Wadi Watir delta.

The dominant agricultural limitations were represented in; (a) exposure to the risks of wind erosion, (b) existing of some limited areas with undulating topography and a high degree of slope, (c) prevailing sandy texture in the studied soils, (d) the high contents of gravel in some soils of delta Wadi Watir, (e) relatively high values of pH, (f) the apparent poverty in the soil fertility component of organic matter, macro, and micronutrients. The soils could be evaluated into class III, which are good for cultivation, but have severe limitations and require special conservation practices.

Therefore, Wadi Watir delta was divided into two portions on basis of agricultural land use priority, the first occupied the eastern and western sides with 54.52% of the total area; (priority I). While, the second one covered the middle slice of the research area and comprised of 45.48% as geographical area; (priority II).

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