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# Land Suitability Characterization for Crop and Fruit Production of Some River Nile Terraces, Khartoum North, Sudan

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***Abstract-*** **T**he aim of this study was to evaluate the land suitability of some Nile River terraces for crop and fruit production at Khartoum North, Sudan. Nine soil profiles from three river terraces were selected to cover the different physiographic positions. The land suitability evaluation for annual crops and fruit tress was carried out by matching site conditions with the crop requirement with respect to the characteristics such as: climate condition, topography, drainage, texture, $CaCO_3$, CEC, % O.C, salinity and alkalinity. The suitability for crops, vegetables and fruit were divided into excellent, good, moderate, weak and not suitable. The soils of the study area were classified into: Typic Torrifluvents (unit 1), Entic Haplocambid (unit 2) and Typic Haplocambid (unit 3). The study showed that the soils of the three units were moderately suitable (S2) due to limitations of inundation, fertility, wetness, erosion, and physical limitations. Results indicated that the suitability of units 2 and 3 were weak for *Arachis hypogeal* L, *Alluim cepa*, *Vitis* spp, *Citrus sinensis* and not suitable for *Phaseolus vulgaris.*

***Index Terms***- Nile River terraces, Khartoum North, inundation, erosion.

## I. INTRODUCTION

For the time being, the world population is increasing dramatically (Liu and Chen, 2006). However, the potential of the land for crop production to satisfy the demand of the ever increasing population is declining as the result of sever soil degradation (Lal, 1994).

The land suitability refers to the fitness of a given area of land for a defined kind of land use. Land suitability is usually assessed on the assumption that the defined land use will be sustained and the environmental quality must be preserved or even improved on the site and the surrounding area (FAO, 1976).

The FAO defined that 'The suitability is a function of crop requirements and land characteristics and it is a measure of how will the qualities of land unit matches the requirements of a particular form of land use. Crop land suitability analysis is a prerequisite to achieve optimum utilization of available land resource for agricultural production in a sustainable manner (FAO, 1976).

The land suitability for crops was calculated by matching site conditions with the crop requirement with respect to the following characteristics: topography, drainage, physical soil (texture, structure), calcium carbonate and gypsum, soil fertility (apparent CEC, base saturation and organic carbon), salinity and alkalinity, climatic condition. The methods used based on qualitative evaluation (*Sys et al.*, 1991).

The irrigated intensive crop farming areas for vegetables and fruits in Sudan are largely located within the flooding plains of the Blue, White and River Nile and this is attributed to their high quality soils and water. These soils are used for agricultural production to meet the demands of the densely population capital. However, the selection of crops cultivated is erratic and traditional. Therefore, there is a real need for scientific and sound strategy to put these soils in their optimal use to the best interest of the farmers as well as the population of the capital (Kevie and El-Tom, 2004).

These soils are highly demanded for agricultural production (fruits, vegetables). However, some fruits and vegetables are imported to the capital from other states such as: Gezira, River Nile, North State, Kordofan, Sennar and Blue Nile. This means a high cost of transportation. Therefore, the objective of this study was to evaluate the land suitability of some River Nile terraces for crop and fruit production at Khartoum North, Sudan.

## II. MATERIALS AND METHODS

**Study area and soil sampling:**

The study area is located in the northeastern part of Khartoum North, Sudan between the River Nile at El Khogalab village and extending eastwards till the piedmont plain. The area extends 8.0 km (8,000 ha) along a southeast-northwest direction and extends 4 km (4,000 ha) east west and is located where the grid coordinate is at 451437 to 459503N and 1747982 to 1750070E (Fig. 1). According to Van der Kevie (1973), the study area falls within the semi arid climatic zone. The average annual rainfall varies from 100-225 mm. Mean maximum temperature of the hottest months (May and June) is 40 and 42˚C, respectively. Mean minimum temperature of the coldest month (January) is 13-16˚C. The mean annual relative humidity ranges between 26-21 % (January to February), 15-26 % (March to June) and 41- 48 % (July to September, the wettest three months).

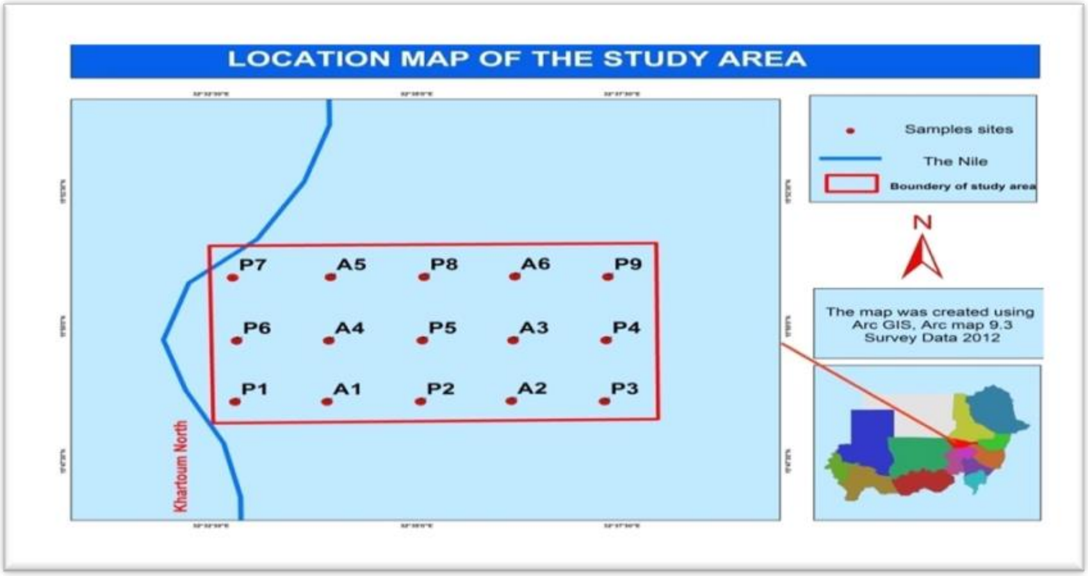


**Figure (1): The study area and sites of the soil samples**

Tundub (*Capparis decidua*), Seyal (*Acacia tortilis*), Usher, Musket (*Prosopis chilensis*), Heglig (*Balanites aegypiaca*) and Seder (*Zizyphus spina-christi*) are the predominant species among the natural vegetation. Table 1 presents the UTM coordinates of the sampling sites.

**Table 1:** Coordinates of the sampling sites within the study area.

| Profile No. | Coordinates (UTM) | |
|---|---|---|
| | **N** | **E** |
| P1 | 451437 | 1747982 |
| P2 | 453437 | 1747982 |
| P3 | 455468 | 1747982 |
| P4 | 459462 | 1747982 |
| P5 | 457440 | 1747997 |
| P6 | 451478 | 1750070 |
| P7 | 453478 | 1750070 |
| P8 | 455509 | 1750070 |
| P9 | 459503 | 1750070 |

According to the Soil Taxonomy (2014), the calculated soil temperature regime is hyperthermic and soil moisture regime is variable from arridic/torric to ustic depending on local topographical conditions. Nine soil profiles located in different physiographic units were selected for soil sampling with a distance of 2 km in all direction (Fig. 1). Each horizon or layer was then fully described according to the FAO Guideline for Soil Profile Description (FAO, 2006).

## III. METHODOLOY

Enhanced Thematic Mapper Plus (ETM+) Scene (173/49) was used as a base map. A preliminary reconnaissance soil survey was carried out in order to outline the soil distribution pattern in the study area. All soil profiles were fully described according the FAO Guideline for Soil profile Description (FAO, 2006). The land evaluation was determined based upon topography and soil characteristics include (Sys *et al.,* 1993). Soil properties such as pH, N%, P%, organic matter (%OM) and Cation Exchange Capacity (CEC) were considered in terms of soil fertility (Sys *et al.,* 1991). Particle size distribution was determined by the hydrometer method after removal of organic matter using $H_2O_2$ and stirring in a sodium hexametaphosphate solution (Soil Survey Staff, 2004). The soil pH was determined in the saturated soil paste using a Digital pH Meter Model (Jenway 3510). The electrical conductivity was determined in the saturated soil paste extract using a conductivity meter Model (Jenway 4510 U.S. Salinity Lab Staff, 1954). % CaCO3, %N and %P were determined according to Richards (1954). The exchangeable sodium percentage was calculated according to the formula: % ESP = {Exch $Na^+$}*100/CEC. Organic matter in the soils was determined using the Walkley and Black wet digestion method (Van Lagen, 1993). The CEC by the 1M $NH_4OAC$ standard method ($CEC_{SM}$) was determined using continuous leaching of 5 g of soil with 100 ml of 1 M NH4OAC (at pH 7) and the concentrations of the exchangeable bases were determined using the atomic absorption spectrophotometer. Requirements for each crop recommended by *Sys et al.,* (1993) were used.

## IV. RESULTS AND DISCUSSION

**Physical and chemical properties:**

Table 2 presents some physical and chemical properties of selected soil profiles of the study area. Generally; the soils of the three units in the study area were alkaline with a pH value ranged between 7.6 to 8.18. The soils were non saline at all depth except at depth more than 70 cm in units 2 and 3 were slightly saline, non sodic with maximum value of SAR 7.58. The soils were moderately calcareous, low in nitrogen, organic carbon and available phosphorus. The CEC was low and ranged between 13.7 to 31.63 Cmol+/kg. The texture varied from sandy loam to clay.

**Table 2:** Some physical and chemical properties of selected soil profiles of the study area

| Profile No. | Depth (cm) | pH | ECe (dS/m) | SAR [1] | CaCO3 (%) | N (%) | O.C (%) | P (mg/kg) | CEC[2] (Cmol+/kg) | Particle size distribution (%) | | | Textural class[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Clay | Silt | Sand | |
| | **Unit 1** | | | | | | | | | | | | |
| **P 1** | 0-30 | 7.69 | 0.66 | 1.66 | 5.7 | 0.95 | 1.36 | 3.85 | 21.68 | 33.56 | 52.4 | 14.06 | SiC |
| | 30-80 | 7.6 | 0.45 | 1.78 | 5.04 | 0.89 | 1.28 | 3.64 | 20.16 | 38.32 | 33.3 | 28.34 | SiC |
| | 80-130 | 7.68 | 0.5 | 1.72 | 5.85 | 0.78 | 1.12 | 3.2 | 13.7 | 33.56 | 42.9 | 23.58 | SiC |
| | **Unit 2** | | | | | | | | | | | | |
| **P 5** | 0-20 | 7.9 | 0.88 | 1.27 | 4.74 | 1.22 | 1.76 | 4.95 | 14.95 | 33.56 | 11.9 | 54.53 | SC |
| | 20-45 | 7.8 | 2.08 | 5.94 | 6.15 | 0.72 | 1.04 | 2.99 | 20.60 | 35.94 | 11.9 | 52.15 | SC |
| | 45-80 | 7.6 | 5.62 | 4.02 | 6.00 | 0.72 | 1.04 | 2.99 | 23.10 | 52.61 | 11.9 | 35.49 | C |
| | 80-120 | 7.6 | 7.03 | 6.28 | 6.67 | 1.00 | 1.44 | 4.07 | 22.34 | 40.7 | 9.52 | 49.77 | C |
| | **Unit 3** | | | | | | | | | | | | |
| **P 9** | 0-15 | 7.97 | 0.38 | 2.09 | 3.93 | 0.72 | 0.64 | 1.91 | 20.82 | 16.9 | 33.3 | 49.77 | SL |
| | 15-40 | 8.18 | 0.97 | 2.40 | 4.30 | 0.11 | 1.04 | 2.99 | 31.63 | 26.42 | 59.5 | 14.06 | SiC |
| | 40-70 | 7.90 | 4.70 | 7.58 | 4.81 | 0.11 | 0.16 | 0.65 | 23.21 | 24.04 | 28.6 | 47.39 | SL |
| | 60-120 | 7.86 | 5.41 | 4.29 | 4.59 | 0.55 | 0.80 | 2.34 | 22.99 | 24.04 | 28.6 | 47.39 | SL |

Note: [1] Sodium adsorption ratio, [2] Cation exchangeable capacity, [3] SiC; Silty clay, SC; Sandy clay, C; Clay, Sl; Sandy loam

**Soil classification:**

Table 3 illustrates the classification of soils of the three units in the study area. According to the American system of soil classification (Soil Survey Staff, 1975), the soils of unit 1 (first terrace) belong to the order Entisols and classified as Typic Torrifluvents. This due to absence of pedogenic horizons. While the soils of units 2 and 3 (second and third terraces respectively) belong to the order Aridisols and classified as Entic Hplocabmids (unit 1) and Typic Haplocambids (unit 2), this due to lack available water of most time for plant growth and presence of cambic subsurface horizon

**Table 3: Classification of soils of the study area**

| Unit No. | Profile No. | Classification | Area (ha) | (%) |
|---|---|---|---|---|
| 1 | 1,6,7 | Fine loamy, mixed, active (non calcareous), hyperthermic, Typic, Torrifluvents | 400 | 25.00 |
| 2 | 2,5,8 | Fine, mixed, active (non calcareous), hyperthermic, Entic, Haplocambids | 700 | 43.75 |
| 3 | 3,4,9 | Fine, mixed, superactive (non calcareous), hyperthermic, Typic, Haplocambids | 500 | 31.25 |

**Land Suitability for Agricultural Purpose:**

The soils of the study area were classified with respect to their suitability after rating the different qualities (Kevie and Eltom, 2004) as shown on Table 4. The suitability classes of all units recognized were moderately suitable (S2), (land which is expected to be moderately productive for the defined use, yielding moderate benefits, with limitations which are moderately to reduce crop yields and/or increase recurrent inputs. The limitation includes; inundation (i), fertility (f), wetness (w), erosion (e) and physical limitations. The soil fertility of the area was assessed using pH, %O.C, %N, available P and CEC. The soils of the area were non saline ($EC_e$ less than 4 dS/m), non sodic (SAR 0-30 cm <8) and (SAR 30-120 cm <18 Rating 1). Erosion hazards of the study area were negligible because there were no evidences of sheet erosion. However some water erosion may be happened during high flood. The soils were non calcareous. The topography for gravity irrigation of the study area is smooth to promote uniform distribution of water and provide surface drainage to the all parts of the study area (Rating 1). The workability of the study area was loose to hard because it had silty clay loam, sub angular blocky structure, and coarse gravels (<3% of the surface coverage Rating 1) (Stori, 1964).

**Table 4: Land suitability of different physiographic units**

| Land qualities | Unit 1 | Unit 2 | Unit 3 |
|---|---|---|---|
| **Soil moisture availability** | 1 | 2 | 2 |
| **Chemical soil fertility** | 3 | 3 | 3 |
| **Condition for seedling establishment** | 1 | 2 | 3 |
| **Drainage condition in grow season** | 1 | 2 | 2 |
| **Workability** | 1 | 2 | 3 |
| **Possibility of mechanization** | 1 | 2 | 2 |
| **Salinity** | 1 | 1 | 1 |
| **Alkalinity** | 1 | 1 | 1 |
| **Erosion hazards** | 2 | 2 | 2 |
| **Capability for maintain surface water** | 1 | 2 | 2 |
| **Topography for gravity irrigation** | 1 | 2 | 2 |
| **Soil drainability** | 3 | 2 | 1 |
| **Land cover** | 2 | 2 | 1 |
| **Suitability classes** | S2 | S2 | S2 |
| **Suitability sub classes** | S2iw (f) | S2fe | S2ef (p) |
| **Kind of limitations** | iwf | fe | ifp |

Note: S2 = moderately suitable i = inundation; w = wetness; f = fertility; e = erosion; p = physical limitations

**Land Suitability for Crops and Fruit Trees:**

In applying systems of crops suitability to the soils of the study area, the ranking of the suitability of the different physiographic units of the study area was found as indicated in Table 5 bearing in mind that these ratings were based on the weighted average. The suitability of the land to different crops was determined for field and horticultural crops (vegetables and fruits) according to Sys (1993). The land suitability for crops was calculated by matching site conditions with the crop requirement with respect to the following characteristics: topography, drainage, physical soil (texture, structure), calcium carbonate and gypsum, soil fertility (apparent CEC, base saturation and organic carbon), salinity and alkalinity, climatic condition. The methods used were based on qualitative evaluation (Sys *et al.*, 1991 PART I, II, and III). The suitability for the field crops, vegetables and fruit were divided into excellent, good and moderate; For example the suitability of the unit 1 for Alfa alfa (*Medicago sativa)* was excellent for that crop; slope 0-2, moderate drainage, silty clay loam texture, with pH 7.4-8. ECe between 0-3 dS/m and SAR 0-8 and other requirements (Oluwatosin *et al.*, 2002).

**Table 5: Land suitability for the common crops & fruits grown in the study area.**

| **Crop type** | **Land unit** | | |
|---|---|---|---|
| | **1 (Typic Torrifluvents)** | **2 (Entic Haplocambids)** | **3 (Typic Haplocambids)** |
| **Wheat** | excellent | excellent | good |
| **Barley** | excellent | excellent | good |
| **Maize** | good | moderate | moderate |
| **Sorghum** | good | good | good |
| **Alfa Alfa** | excellent | good | moderate |
| **Sunflower** | good | good | good |
| **Chick pea** | excellent | moderate | moderate |
| **Onion** | good | weak | weak |
| **Potato** | moderate | weak | weak |
| **Date palm** | moderate | moderate | moderate |
| **Grapes** | good | weak | weak |

| | | | |
|---|---|---|---|
| **Orange** | moderate | weak | weak |
| **Haricot beans** | good | not suitable | not suitable |

## V. CONCLUSION

Acoording to the American system for soil classification the soils of the study area were belong within order Entisols (unit 1) and Aridisols (units 2 and 3). The study revealed that the suitability classes of the three units in the study area were moderately suitable for agricultural purpose, and the most important limitations include: inundation, wetness, low fertility, erosion and physical limitation such as soil moisture availability

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