Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2020, Volume 9, Issue 1, pp. 3331-3349
ISSN 2320 – 0243, Crossref: 10.23953/cloud.ijarsg.473

Research Article

Usage of Geographic Information System for Management of Soil Fertility, Egypt

Ganzour Shimaa, K.[1], Shendi, M. M.[2], Abdallah, A. E. M.[1] and Ismail, M.[1]

[1]Soils, Water and Environment Research Institute (SWERI), Agriculture Research Center (ARC), Egypt
[2]Soils and Water Department, Faculty of Agriculture, Fayoum University, Egypt

Correspondence should be addressed to Ganzour Shimaa K., *sh.ganzour82@gmail.com*

Publication Date: 9 July 2020

DOI: https://doi.org/10.23953/cloud.ijarsg.473

Abstract The current work was implemented to introduce an exclusive description for fertilization of an area equivalent to 50459.04 hectare situated along El Bahria Oasis Road – Giza Governorate, Egypt. GIS and GPS techniques were implicated in this study. Soil survey was carried out where the main physical, chemical properties and fertility parameters were engaged. The studied area was classified into two orders; Aridisols and Entisols. Geographic database for the soil properties and nutrients under study were built up and digital maps were produced. Land evaluation was done according to Storie & Sys and others; Land capability of the studied area showed four classes namely; II, III, IV and V with respect of storie). The land suitability for some crops (winter crops, summer crops and orchard trees) were appraised for the area under investigation and exported to GIS to be displayed in digital maps. Taking into account the contents of the nutrients present in soil the Fertilizer requirements for suitable crops were estimated; spatial analyst tools in Arc/GIS were used to create digital maps for the requirements of key figures nutrients (N, P, K) calculated in kg /hectare; The resulted map for fertilizers needs could be considered of enormous potential for precision farming application.

Keywords *Soil nutrients status; land capability and suitability; crop fertilizer requirements; fertilization maps; Arc/GIS technical*

1. Introduction

Global demand for food is tremendously rising due to higher population growth rate and the developing countries would share the highest percentage of such demand. Therefore, they should swiftly shift from conventional farming to precision one even at the rural districts and land reclamation; in order to boost the cultivation production. Land evaluation provides essential information on land resource, landform, land use, vegetation, climate and soil properties for a defined area. Concepts, definitions and case studies of land evaluation can be found in numerous publications such as (Storie, 1932 and 1978; Sys and Verheye, 1978 and Sys, *et al.,* 1991 and 1993). Land capability classification: USDA, (1973) has provided specific guidelines for land capability classification. This system has been adopted to include eight classes of land designated by Roman numerals. The risks of soil damage or limitations in use become progressively from class I to VIII. Capability grouping of soils is designed *1)* to help landowners and others to use and interpret the soil maps; *2)* to introduce users to the details of the soil map itself and *3)* to make possible broad generalizations based on soil potentialities, limitations in use and management problems. The capability classification provides three major categories of soil groupings: I. capability unit, II. capability subclass and III. Capability class according to USDA, (1961 and 2015) and Office of Environment and Heritage, (2012). The third and broadest category in the capability classification places all soils in eight capability classes. Tideman, (1990) confirmed that land capability is governed by the different land attributes such as types of soil "depth and texture, underlying geology, topography, hydrology… *etc.*" land has a limited resource and with increasing population the demands for land become more competitive. Any given area of land can have a multitude of potential uses and all may need to be considered in planning and management of land resources. As for land suitability classification; Beek and Bennema, (1972) stated that it is a function of crop requirements and land characteristics *i.e.,* it is a measure of how well qualities of land unit match the requirements of a particular form of land use (FAO, 1976 and Sys *et al.,* 1991 & 1993). Suitability analysis can answer the question (what is to grow where?), in order to define suitability of an area for a specific practice, several criteria need to be evaluated (Belka, 2005). Depending on the land use limitations FAO, (1976) classified land suitability into two orders and 4 classes. Land suitability orders indicate whether land is assessed as suitable or not suitable for the use under consideration; Order S suitable "land of which having sustained use and expected to yield benefits which justify inputs, without unacceptable risk of damage to land resources", Order N suitable "land of which have qualities that appear to rule out sustained use". Nonetheless, the 4 classes are class; S1 "highly suitable", class S2 "moderately suitable", class S3 "marginally suitable", class N1 "not suitable" and class N2 "permanently not suitable". Evaluation of land capability for reclamation an area requires data include, chemical and/or physical soil properties and topographic level. One of the sustainable agricultural indicator is to cultivate crops that physically suitable for the soils. Land suitability analysis for crops is a prerequisite to achieve optimum utilization of available land resources for sustainable agricultural production.

Combination of GIS, geospatial mapping and RS technologies is a very powerful tool to achieve such task. Moreover, it helps in building up geographical database, in form of digital maps, for plant nutrients needed for relevant crops. Thereafter, appraisal the actual amounts of various fertilizers needed for the yields would be grown therein; taking into consideration the nutrient levels in soils, the grown plant needs and soil characteristics. Such specific digital maps can rationalize the consumption of the mineral fertilizers used. Egypt pays great attention to the development of its agricultural resources, either through the land reclamation or through maximizing the productivity of soil unit. The current study area is a part of the future promising governmental land reclamation and for developing modern rural districts to interact with the state development plan the current work was accomplished. The ultimate goal of this study is mainly to contribute in achieving the strategic objectives of such plan. In more specific words, this work aims to achieve the following objectives:

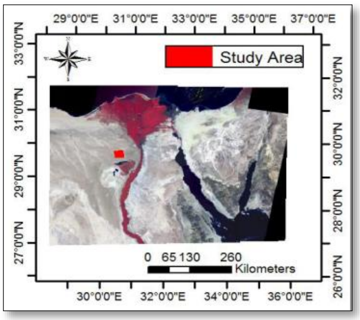
- To execute soil survey for an area suitable for agricultural development of Egypt being incorporated in land reclamation plan.
- To build up a geographic soil database for the main soil physical, chemical properties and nutrient contents of study area and depicting digital maps for the different soil characteristics and nutrients contents.
- To perform the land capability classification and land suitability for some crops.
- To establish a framework of geographical database for calculating fertilizer requirements based on soil characteristics and land use types.

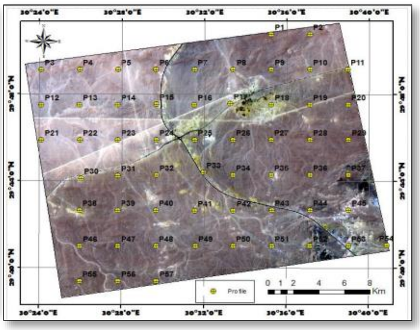
2. Material and Methods

2.1. Study Area

The study area is virgin; it located at the Giza Governorate, Egypt and situated in the Western Desert, at El Baharia Oasis Road, It is in the extend of the south western direction of Wadi El Fargh. The area is bounded by the following four points:

1) 30° 38' 32.64″ E 29° 51' 19.71″ N 2) 30° 23' 18.22″ E 29° 49' 23.30″ N
3) 30° 40' 59.10″ E 29° 40' 50.69″ N 4) 30° 25' 10.88″ E 29° 38' 37.38″ N





Map (1): General location of the study area in Egypt

Map (2): Location map of the tested soil profiles

2.2. Soil survey execution for identifying the main soil physical, chemical properties and Nutrient status in the study area

A grid system was overlaid on the study area with a lag of 3 km distance to identify the location of the observation points. This was followed by a field work to collect representative soil samples; fifty seven soil profiles were allocated to represent the study area, Map (2). The soil profiles were dug to a depth of 150 cm unless opposed by bedrock or extremely hard layer**.** A total number of 178 soil samples were collected from the layers in order to determine the main soil physical and chemical characteristics as well as nutrients levels. The definite locations of the study soil profiles were recorded using GPS (*MODEL GARMYN*), which exported to ARC/GIS. A point map was created to represent the locations of the study soil profiles and used to create the geographic database for the different soil attributes.

2.2.1. Physical and chemical soil properties

- Particle size distribution was estimated using the International Pipette Method, described by Piper, (1950).
- Total calcium carbonate content was determined volumetrically using Scheibler's Calcimeter (Wright, 1939).
- Organic matter was determined using the Walkley and Black method (Jackson, 1967).
- Soil pH was measured in 1:2.5 soil water suspensions by using a pH meter (Van Reeuwijk, 1993).
- Soil paste extract was prepared for each soil sample, where determinations, Electrical conductivity (ECe), (CONDUCTANCE METER- YSI MODEL 35)&Soluble anions and cations (Jackson, 1967).
- The Gypsum content of soil was determined by precipitation with acetone according to Schoonover, (1952).
- Sodium Adsorption Ratio (SAR) a ratio for soil extracts used to express the relative activity of sodium ions in exchange reactions with soil according to Bower *et al.*, (1952). "SAR=Na/ Ca+Mg /2"

- Exchangeable Sodium Percentage (ESP), it calculated by the formula according to Allison *et al.,* (1954).

"ESP=100(−0.0126+0.01475SAR)1+(−0.0126+0.01475 SAR)"

2.2.2. Nutrient status

- Total nitrogen was determined by Kjeldahl methods using sodium hydroxide and boric acid according to Jackson, (1973).
- Total contents of macronutrients (P and K) in soil samples were extracted through digestion with perchloric-hydrofluoric acids (Hesse, 1971).
- Total phosphorus was determined using ascorbic acid method described by Houba *et al*. (1995). Where light absorbance was measured by Spectro-Photometer at 882 nm. (Model SPECTRONIC 21D).
- Total potassium was measured using Flame Spectro-Photometer (Model JENWAY PFP7).
- Available nitrogen was extracted from 5.0 g soil with 50 mL 2 M KCl (Page *et al*., 1982), and determined using Kjeldahl methods (Jackson, 1973).
- Available phosphorus in soil was extracted using sodium bicarbonate solution, 0.5 M at pH 8.5 according to Olsen *et al*., (1954) and determined used ascorbic acid (Van Reeuwijk, 1993). Absorbance was detected using Spectro-Photometer at 882 nm. (Model SPECTRONIC 21D).
- Available potassium in soil was extracted using 1 N ammonium acetate solution" NH_4OAC "at pH 7 according to Page *et al.,* (1982) and determined using flame spectrophotometer (Model JENWAY PFP7).
- Available Fe, Mn, Zn and Cu were extracted using DTPA method (Lindsay and Norvell, 1978). Available tested micronutrients were determined by Atomic Absorption Spectrophotometer, (Model GBC 932).

2.3. Coding soil database attributes and obtaining digital map

Results of physical, chemical properties and nutrient contents of the tested soils were entered as soil attributes for the soil profiles map. The attributes were coded using Arc/GIS (V., 10.3) as a geographic database. IDW Interpolation type was executed to produce the different soil properties and nutrient contents digital maps.

2.4. Soils classification

Soil classification is carried out according to USDA, (2014).

2.5. Land capability classification maps

Land capability was done using the rating suggested by Storie, (1932 and 1978) where, application in this equation: $\boldsymbol{Ci} = \frac{\boldsymbol{A}}{\mathbf{100}} \times \frac{\boldsymbol{B}}{\mathbf{100}} \times \frac{\boldsymbol{C}}{\mathbf{100}} \times \frac{\boldsymbol{X1}}{\mathbf{100}} \times \frac{\boldsymbol{X2}}{\mathbf{100}} \times \frac{\boldsymbol{X3}}{\mathbf{100}} \times 100$
Where; Ci= Capability index, A= Soil depth, B= Texture, C= Slope, X1= Salinity, X2= $CaCO_3$ content and X3= Gypsum content.

2.6. Mapping land suitability for some crops

Land suitability was done using the rating tables suggested by *Sys et al.,* (1993) for alfalfa and sugar beet (winter crops); where, maize and sorghum (summer crops); olives and citrus (orchard trees).

Current and potential "land capability" and/ or "land suitability for crops" was calculated for the study area. The current "land capability" and/ or "land suitability for crops" indicates that "capability" and/ or "suitability for selected crops" of the area under the prevailing conditions of the soil. Whereas, the potential "capability" and/ or "suitability" reflects the "land capability" and/ or "suitability for the same selected crops " of the area but after curbing and improving limiting factors such as salinity.

The evaluation is carried out by comparing the land characteristics with the limitation levels of the requirement tables. In addition, "capability index" and "suitability index for selected crops" were calculated using Stories equation and were added as open attributes table for the soil profiles point map. The attributes were coded using Arc/GIS as a geographic database for the profiles point map were used for interpolation (natural neighbor) activities then create symbolical/classified to produce capability and suitability digital map of different classes.

2.7. Framework of fertilizer requirements calculation

The fertilizer requirements of the study area were calculated using the geographical database through the capabilities of Arc/GIS then fertilizer requirement maps were produced according to the prevalent soils characteristics and the proposed land use type.

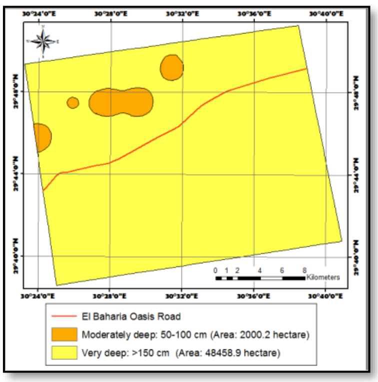
3. Results and Discussion

*All Maps represent physical, chemical and nutrient content for average surface and subsurface layers of the study area.

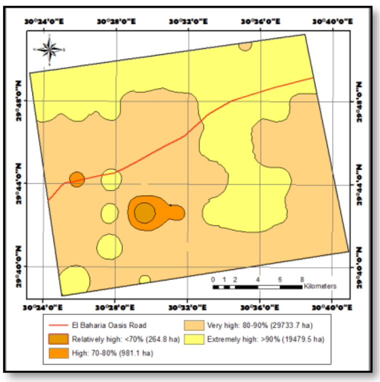
3.1. Descriptions of study soils physical and chemical properties

3.1.1. Soil depth: The study area is considered in terms of land use as virgin area with flat to undulating desert formations. Some of normal faults with strike slip movements seem to have affected the location. As indicated from Map (3), an area of approximately 2000 hectare there are moderately deep profiles, e.g., profiles 7, 13, 14, 15 and 21. According to the proposed limits after FAO (1990), while, 96.04% of the study area is considered very deep soils that could be suitable for either shallow and deep rooted cultivation.

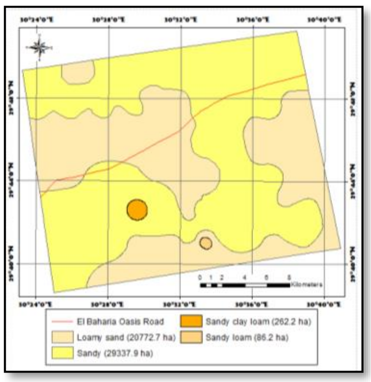
3.1.2. Soil texture: Soil texture is considered one of the most important soil criteria affecting soil behavior and land management, and it influences a number of physical and chemical soil characteristics. The obtained results showed that sand fractions dominated the soil particles in all the study soil samples, Map (4). Particle size distributions for the study soils are presented in Maps (5). The results revealed that most of the study area exhibits coarse sand texture, especially in the surface layers samples, and sometimes with medium to coarse textured as the texture varies between sand to sandy loam excluding profile 40 which possess sand clay loam due to the occurrence of shale deposits in that location. It appears that the soils under consideration may reflect multi- depositional regimes throughout soil profile layers. Desert pavement is commonly observed in the study area as high gravel contents were concentrated on the soil surface.



Map (3): Depth of soils in the study area



Map (4): Sand contents

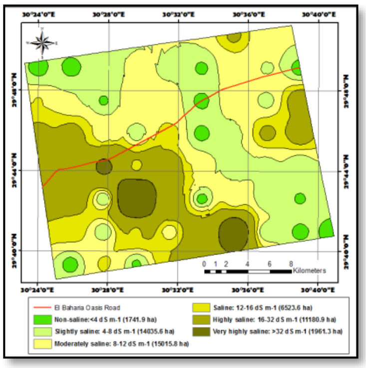


Map (5): Distribution pattern of textural classes

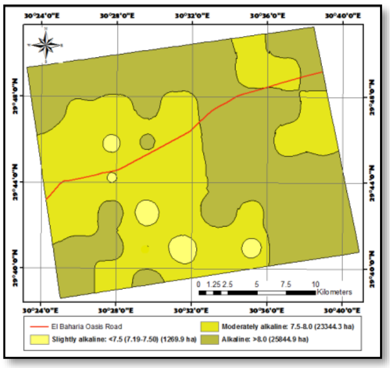
3.1.3. Soil salinity and alkalinity: Salinity is one of the main factors which limits the distribution of plant communities in their natural habitats and is causing increasingly severe agricultural problems. The study soils are characterized by different salinity levels ranged between non-saline (0.79 dS m^{-1}) to extremely highly saline (110.40 dS m^{-1}). The highly saline values may be related mostly to salinity inherited from dominating Eocene limestone. Whereas, the lowest EC values were more related to the permeable coarse textural soils. The distribution pattern of soil salinity in the study area, Map (6) shows that more than 31% of the area is non-saline, 1741.86 hectare to slightly saline soils, 14035.59 hectare. This confirms the potentiality of the study area for agriculture. The highly saline and very highly saline soils constitute only 22.16 % and 3.89 %, respectively.

3.1.4. Soil reaction- pH: Having the correct soil pH is crucial for the healthy plant growth as it affects the amount of nutrient available to plants (Nur *et al.,* 2014). Soil pH is considered as one of the most essential factors influencing plant uptake of trace element (Kabata-Pendias, 2001). The variation in soil pH usually is related to parent material, rainfall, topography and organic matter. From the obtained pH data in the current study, Map (7), the study soils are slightly alkaline to alkaline with pH values between 7.23 to 9.16. The alkaline pH values indicate that the soils are saturated with basic exchangeable cations besides the occurrence of free $CaCO_3$ in the soil. The most majority of the investigated soils have pH values in the range of 8.00 to 8.38.

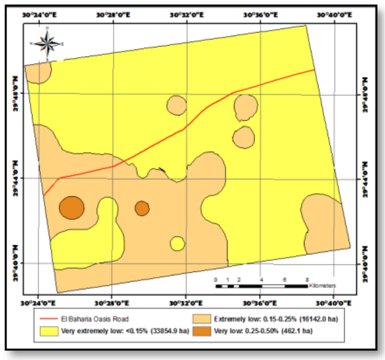
3.1.5. Organic matter content: Organic matter influences many soil characteristics including color, nutrient retaining or turnover and stability, holding capacity and soil aggregations (Tagwirg *et al,* 1992). The data of OM% exhibited in, Map (8), show that the study area have general extremely low content of organic matter as the values are ranged from 0.02 to 0.34%. This is mainly could be related to the non-arable desert nature with no vegetation cover due to scarcity of precipitation and to the common coarse texture prevailing in the area.



Map (6): Soil salinity "ECe"



Map (7): Soil pH levels



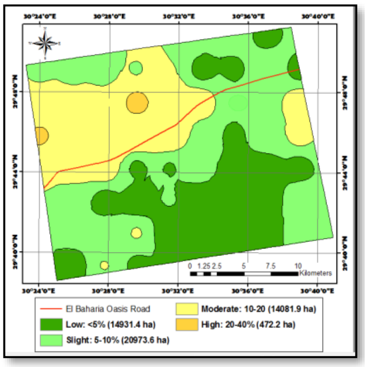
Map (8): Total organic matter

3.1.6. Calcium carbonate content: Soil $CaCO_3$ is an important soil criterion for agricultural cultivation of crops. This criterion affects soil moisture regime and availability of nutrients to plants, pH and organic matter stabilization (Schoeneberger *et al.,* 2011). Generally, calcium carbonate contents are mostly associated with coarse and moderately coarse textured soils. The data illustrated in Map (9) revealed that calcium carbonate values ranged between 0.17 to 31.39%; suggesting a possible relationship between $CaCO_3$ content and soil parent material in the area. It could be inferred from this Map, approx. 99% of the study area has low, slight and moderate $CaCO_3$ contents. There three categories cover 14931.36, 20973.60, 14081.85 hectare, respectively, whereas the highly calcareous soils (20-40 %) constitute only approx. 1% of the study area (472.23 hectare).

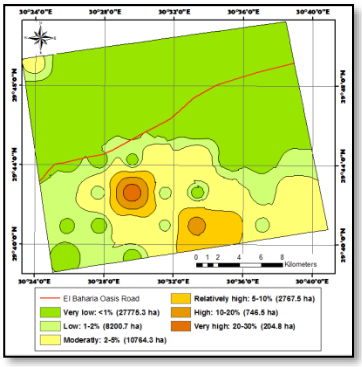
3.1.7. Gypsum content: Gypsum presence imparts to soils properties and affects soil development including soil morphology, water holding capacity, nutrient, water availability for plants, root growth and the standard concepts of soil texture and rapture resistance,(Susan *et al.,* 2014).

Gypsum accumulates in soil in a process similar to carbonate accumulation. However, since $CaSO_4.2H_2O$ is more soluble than $CaCO_3$ and SO_4 is not as abundant as carbonate, gypsum deposits are less common and generally found in drier climates where very little leaching occurs (Lindsay, 1979). Soil gypsum contents in the study area are presented in Map (10). It ranged between < 0.01 to 33.11%. However, it could be classified into 6 classes: very low <1% (27775.20 hectare); low content 1-2% (8200.71 hectare); moderate content 2-5% (10764.27 hectare); relatively high content 5-10% (2767.50 hectare); high content 10-20% (746.46 hectare) and very high content 20-30% (204.84 hectare).

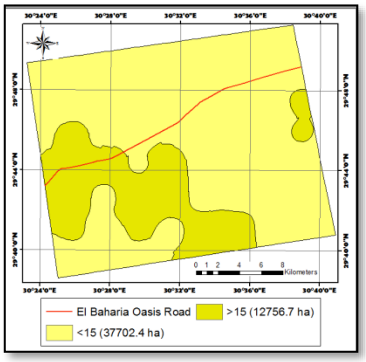
3.1.8. Exchangeable Sodium Percentage (ESP): The detrimental effect of sodium in soils has been widely investigated. It has been reported, for example that high ESP may enhance chemical dispersion of soils, which leads to crust formation and decreases infiltration rate (Robinson and Phillips, 2001). Soils ESP and SAR are positively related because soils solution cations and exchangeable cations are nearly always in equilibrium with each other (Singer and Munns, 1996). Dispersion problems may appear at a greater ESP or SAR. A limit beyond which the ESP is harmful to the soil structure is difficult to assess especially in sandy soils. In general, no problems are experienced in soils with ESP<15 under arid climate. However, the ESP is not the only indicator of soil stability because the salt concentration of the soil solution also affects soil dispersion. The distribution pattern of the obtained ESP values is illustrated in Map (11). It is clear, approx. 74.7% of the study area, (37702.35 hectare), have low ESP values <15 while the remaining parts possess higher ESP values. The highest values are associated with high salinity and dominance of soluble sodium in the soil paste extract.



Map (9): Total $CaCO_3$ contents



Map (10): Gypsum contents



Map (11): ESP

3.2. Nutrients contents in the study soils

3.2.1. Total macronutrients contents: Many investigators concluded that a soil system is a function of soil potentiality for essential plant nutrients, which was usually, related to the nature of soil parent material. This may result from combination of compositional differences between the physical and chemical conditions in soils (Officer *et al*., 2006). The soil factors which influence the contents of the primary macronutrients (NPK) are mineralogical composition, soil texture, organic matter content, soil reaction, calcium carbonate and soil depth. The following discussion will be devoted to discuss the contents of NPK; the key players for the plant product.

a. Nitrogen; The obtained results are illustrated; the soils are very poor in total N content as it ranges between 30.5 to 140.0 mg kg^{-1}, apart from profile 40 that recorded 350 mg kg^{-1}, in top soil. The lowest total N value (0.02%) was recorded in a profile bottom, whereas the highest value (0.34%) was recorded in a profile surface.

b. Phosphorus; Values of total P differed widely in the study soils depending on the type of deposits. Total P contents mostly vary between 88.7 to 191.6 mg kg^{-1}, apart from the shale deposits in profile 40 that have 327.5, 356.2 and 342.3 mg kg^{-1} in its successive layers respectively. In general it seems that marine and lacustrine deposits present in the study area played a substantial role in elevating total P content in the soils.

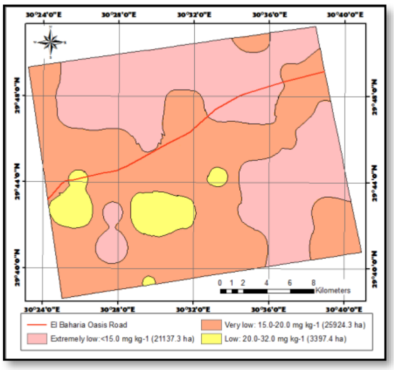
c. Potassium; Concerning the data of total K recorded in the different study soil, it ranged between 1160.2 to 9431.6 mg kg^{-1} with no obvious distribution pattern trend through the profiles depth. The majority of study area soils possess total K values ranged between 3000-5000 mg kg^{-1}. Such higher value could be ascribed to the mineralogical composition. In this respect Ibrahim (2001) demonstrated that higher K value could be related to occurrence of feldspars arising from the recent lacustrine sediments.

3.2.2. Available macronutrients contents: Macronutrients status of the soils is an important aspect in context of sustainable agriculture production and it play a vital role in maintaining soil health and also productivity of crops. Regarding the available N, P and K data presented in the following is a brief description.

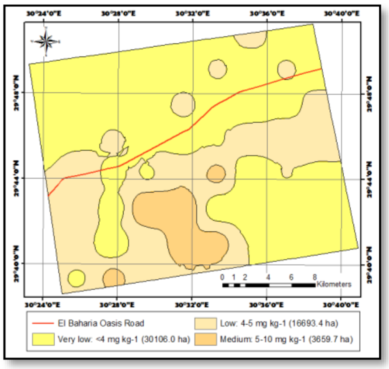
a. Nitrogen; Data of available N show that the available contents are generally low and do not exceed 18.8% of the total contents and it tends to decrease in coarse textured soils and organic matter. Data demonstrate that the distribution of available N range between 6.58 to 33.76 mg kg^{-1}. As clear from Map (12), the whole study area has low contents of available nitrogen that are grouped into one class, low (<40 mg kg^{-1}) and the maximum recorded value is 33.76 mg kg^{-1}.

b. Phosphorus; Data of the available P values, revealed that they did not exceed 3.8% of the total content, presumably due to either adsorption on the surface of $CaCO_3$ particles and/or precipitation due the reaction with soluble Ca that may available from the relatively high gypsum contents in the study area. This finding is consistent with the results reported by (Borhamy, 2001) as he indicated that the available content of P usually do not exceed 5% of the total content. The relatively high values of soil pH and adsorption of P on Mn and Fe oxides may also reduce P availability in the study area. As indicated in Map (13), the recorded values of available P in the study area ranged between 1.60 to 7.23 mg kg^{-1} and allocated in different categories; low content (<5 mg kg^{-1}), and medium content (5-10 mg kg^{-1}) occupied 46799.37 and 3659.67 hectare, respectively.

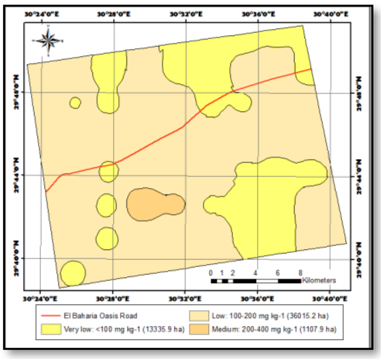
c. Potassium; Data in Map (14) show that the available K does not exceed 4.3% of the total K contents, the values ranged between 52.24 to 367.8 mg kg^{-1}. However, only limited area possess medium available K values range between 200-400 mg kg^{-1} (2.19 % of total area), while the majority of study area possess low available K values less than 200 mg kg^{-1} (97.80 % of total area).



Map (12): Available nitrogen.



Map (13): Available phosphorus.



Map (14): Available potassium.

3.2.3. Available micronutrients contents: There are many essential factors that may affect the contents of such micronutrients among them organic matters, soil pH, lime content, sand, silt and clay contents.

a. Iron; Fe is largely present in soils as insoluble Fe (III) oxides and its solubility greatly affected by the redox potential. The obtained data indicated that more than 99% of the study soils possess very low to low available Fe; ranged between 1.02 to 5.56 mg kg^{-1}.

b. Manganese; Available amounts of Mn ranged between 0.36 to 2.19 mg kg^{-1}. The lowest available Mn values are associated with the coarse texture higher content of $CaCO_3$ in similar results were obtained by **(Ibrahim, 2001)**.However, the study area has low in available Mn content.

c. Zinc; Available Zn values in most of the study area are very low to low, these values ranged between 0.16 to 1.33 mg kg^{-1}. Approx. 78.66% of the study area has very low value <0.5 mg kg^{-1}.

d. Copper; The obtained data revealed that 97.85 % of the study soils possess very low to low amounts that range from 0.10 to 0.94 mg kg^{-1}. The lowest values attributed to the relatively coarse skeletal texture grade with low OM contents being of a very poor ability for Cu retention.

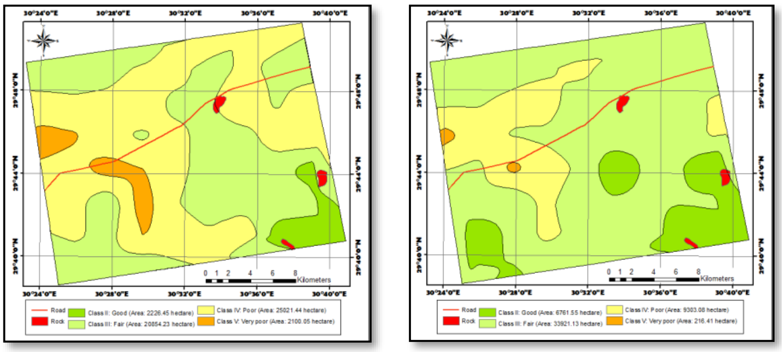
3.3. Soil classification

The purpose of soil classification is to provide basis for grouping and memorizing, to integrate knowledge of soils, to relate soils to each other and to their environments and to enable predictions of the soils behavior and response to anthropogenic intervention in its natural development. In the light of these results it could be concluded that the study area possesses two main soil Orders namely; Aridisols and Entisols covering 21168.49 and 29031.14 hectare; respectively, in addition, rock is covering 259.33 hectare.

3.4. Land capability assessment

3.4.1. Current land capability: Land capability assessment is considered one of the most important outputs of soil studies. Estimation of current land capability is illustrated in Map (15). The results revealed that the studied area possesses 48102.12 hectare of capable soils with classes II, III, IV, *i.e.* 95.33 % of the studied area, whereas the remaining areas are of very poor capability and/or of rocky in nature. The capability of the studied area varies from "good to very poor "according to some existing limiting factors as salinity, coarse texture, gravels content, calcium carbonate content, gypsum content and shallow soil depth. Part of these limiting factors could be corrected with time as salinity and gypsum while, texture, gravels content, calcium carbonate and shallow soil depth are considered economically not correctable. Results show that 2226.45 hectare, (4.41% of the evaluated soils) have good capability, Class II (without serious limiting factors). Fair capability class III is recorded in 20854.23 hectare, *i.e.* 41.33% of the studied area, with one limiting factor; texture in most cases and salinity or gravels in some soil profiles. Poor capability (class IV) is recorded in 25021.44 hectare, *i.e.* 49.59% of the studied area. These soils exhibit more limiting factors as; salinity, texture, gravels, soil depth and calcium carbonate content. Very poor capability Class V, 2100.05 hectare, constitutes approx. 4.16% of the studied area with more limiting factors as salinity, texture, gravels, depth and calcium carbonate.

3.4.2. Potential land capability: Land capability of the studied area is governed by different limiting factors. Some of these factors can be improved through appropriate soil management practices to enhance its land capability, Map (16). These management practices include leaching of salinity of some profiles where salinity leaching could drop soil salinity to 4 dS m^{-1} as these of profiles having coarse fraction and very deep besides they are lacking the impact of higher gypsum or calcium carbonate aggregate in their layers. While other profiles are affected by gypsum and calcium carbonate content so prediction for salt leaching is moderate. On the other hand, the presence of petrocalcic horizon sand layers with high gypsum content are expected to hinder salt leaching process in four profiles. By applying salt leaching management, the potential capability classes of the studied area are expected to be developed as Potential Class II, III, IV and V as presented in Map (16). Potential class II covers an area of approx. 6761.55 hectare (13.40% of the studied soils). This area is located in the eastern south and western south of the studied area. Potential class III covers an area of approx. 33921.13 hectare (67.22% of the studied area). Potential class IV covers an area of approx. 9303.08 (18.43% of the studied area). Very poorly potential class V covers a limited area of approx. 216.41 (0.43% of the studied area).



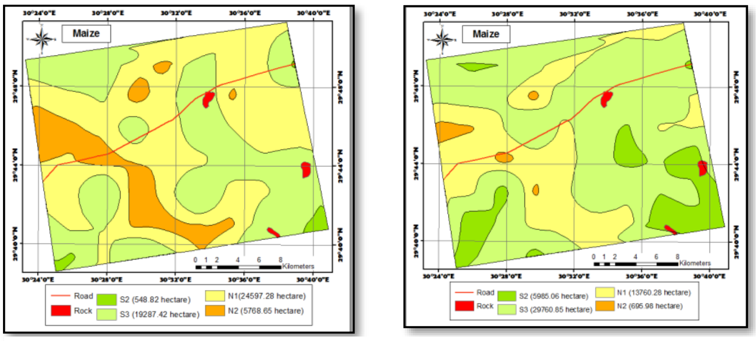
Maps (15, 16): Current and potential land capability classes in studied area

3.5. Land suitability for crops

Land suitability for crops is considered a very important issue in the reclamation of desert area and predicts the suitable land use in the area. Physical land suitability emphasizes the potential success of cultivating a specific crop in this area. Therefore, current and potential land suitability digital maps were produced for the studied soils. Current land suitability maps reflecting the soil suitability for selected crops under the current soil properties. While, the potential suitability is representing the crops suitability for the area after leaching salinity. Brief discussion of the tested crops is given below:

Maize (Zea Mays L.):.Current suitability areas for maize is shown in Map (17), which indicate that, small area; approx. 548.82 hectare (1.09%) have moderate suitability due to the coarse texture limiting factor; approx. 19287.42 hectare (38.22%) have marginally suitable; limiting factors mostly; texture and salinity, approx. 24597.28 hectare (48.75%) are currently not suitable, approx. 5768.65 hectare (11.43%) are permanently not suitable due to presence of more limiting factors for agricultural use.

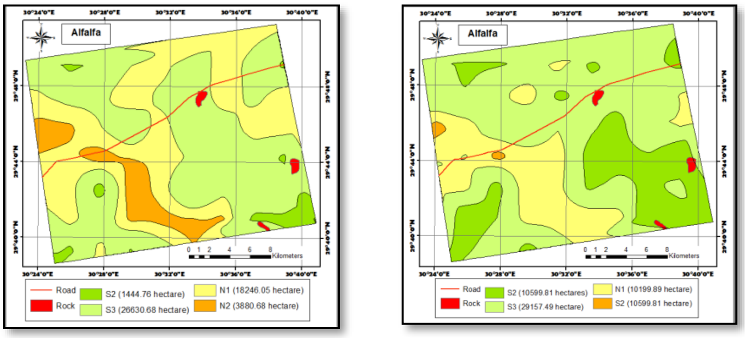
While, the potential suitability shown in Map (18); approx. 5985.06 hectare (11.86%) have moderately suitable, approx. 29760.85 hectare (58.98%) have marginally suitable, approx. 13760.28 hectare (27.27%) have currently not suitable and small area of approx. 695.98 hectare (1.38%) are permanently not suitable



Maps (17, 18): Current and Potential suitability classes for maize

Alfalfa (Medicago Sativa L.): The statistics manipulation of current suitability for Alfalfa, Map (19) indicate that approx. 1444.76 hectare (2.86%) are classified as moderately suitable S2, approx. 26630.68 hectare (52.78%) are classified as marginally suitable S3, approx. 18246.06 hectare (36.16%) are considered currently not suitable N1, approx. 3880.68 hectare (7.69%) are permanently not suitable N2. The observed limiting factors were mainly salinity and coarse texture.

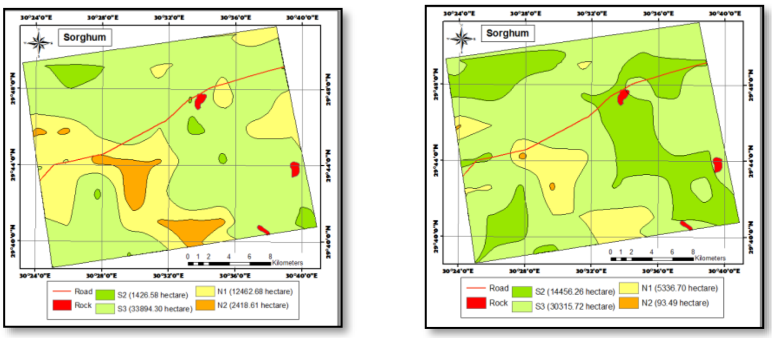
As shown in Map (20), the potential suitability shows that, moderately suitable class (S2) covers an area of approx. 10599.81 hectare , *i.e.* 21.01% of the studied area whereas, the marginally suitable areas (S3) constitute approx. 29157.49 hectare (57.78% of the studied area). On the other hand, the currently not suitable class (N1) covers approx. 10199.89 hectare, *i.e.* 20.21% of the tested soils and the permanently not suitable areas constitute small area of approx. 244.98 hectare (0.49 %).



Maps (19, 20): Current and potential suitability classes for alfalfa

Sorghum (*Sorghum Bicolor L.*): The current suitability for sorghum, Map (21) indicate that a small area of approx. 1426.58 hectare (2.83%) have moderate suitability with texture as a limiting factor, approx. 33894.30 hectare (67.17%) have marginally suitability (with salinity and/or texture as mostly limiting factors), approx. 12462.68 hectare (24.70%) are currently not suitable (with salinity and texture limiting factors),approx. 2418.61 hectare (4.79%) are permanently not suitable with more limiting factors.

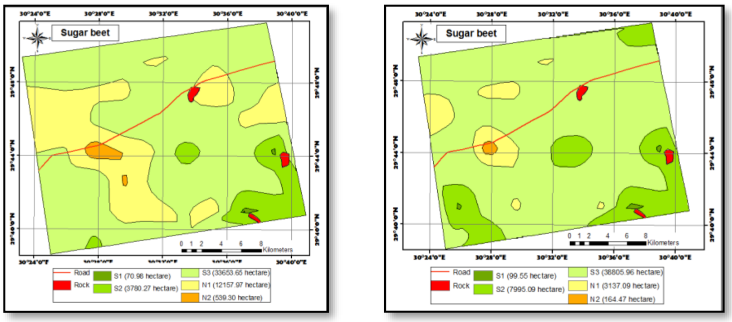
The potential suitability for sorghum, Map (22) indicate that approx. 14456.26 hectare (28.65 %) have moderately suitable class, approx. 30315.72 hectare (60.08%) have marginally suitable class, approx. 5336.70 hectare (10.58 %) are considered currently not suitable and limited area approx. 93.49 hectare (0.18 %) are considered permanently not suitable.



Maps (21, 22): Current and potential suitability classes for sorghum

Sugar beet (*Beta Vulgaris*): Distribution of current suitability is exhibited in, Map (23). A very limited area is approx. 70.98 hectare (0.14%) have highly suitable without limiting factor, approx. 3780.27 hectare (7.49%) have moderately suitable without limiting factor or salinity, the most majority of area approx. 33653.65 hectare (66.69%) have marginally suitable, approx. 12157.97 hectare (24.09%) is currently not suitable and small areas (approx. 539.30 hectare, 1.07%) have permanently not suitable with several limiting factors.

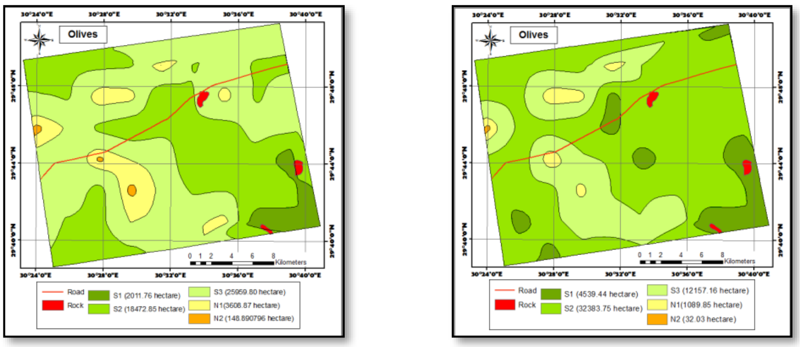
Potential suitability could be categorized into five classes, Map (24). Approx. 99.55 hectare (0.20%) have highly suitable, approx. 7995.09 hectare (15.84%) have moderately suitable one. However, the most majority of area approx. 38805.96 hectare (76.91%) have marginally suitable, approx. 3137.09 hectare (6.22%) have currently not suitable one and small area approx. 164.47 hectare (0.33%) are permanently not suitable.



Maps (23, 24): Current and potential suitability classes for sugar beet.

Olives (*Olea Europacea*): Results of current suitability for olive are presented in Map (25) which indicate that; 2011.76 hectare (3.99 % of the area) have highly suitable, 18472.85 hectare (36.61%) are moderately suitable due to texture or salinity limiting factors, 25959.80 hectare (51.45%) are marginally suitable(with limiting factors from texture and/or salinity), 3608.87 hectare (7.15%) are currently not suitable (with salinity and/or texture limiting factors;) and 148.89 hectare (0.30%) are permanently not suitable.

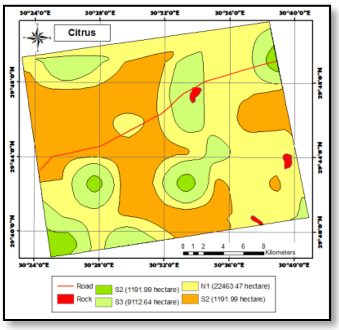
Potential suitability for olive is shown in Map (26) indicating that 4539.44 hectare have highly suitable class and the majority of the area, (32383.75 hectare)are classified as moderately suitable, 12157.16 hectare have marginally suitable class, 1089 hectare are currently not suitable and only approx. 32.03 hectare are permanently not suitable.

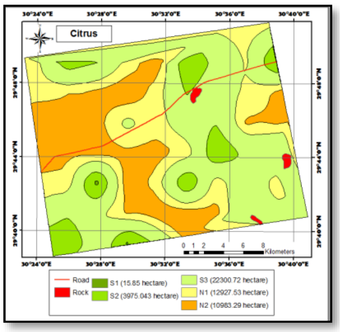


Maps (25, 26): Current and potential suitability classes for olives

Citrus (*Citrus Spp*): The spatial distribution of current suitability is illustrated in Map (27). Approx. 1191.99 hectare (2.36%) has moderately suitable. Approx. 9112.64 hectare (18.06%) have marginally suitable one and mostly salinity is the limiting factor Nonetheless, approx. 22463.47 hectare (44.52%) are currently not suitable; approx. 17434.07 hectare (34.55%) are permanently not suitable due to the effect of salinity and $CaCO_3$ as limiting factors.

Potential suitability could be divided into four classes as shown in Map (28). Very small area approx. 15.85 hectare is of highly suitable, approx. 3975.04 hectare (7.88%) have moderately suitable one, approx. 22300.72 hectare (44.20%) are marginally suitable. However, approx. 12927.53 hectare (25.62%) has currently not suitable and areas approx. 10983.29 hectare (21.77%) are permanently not suitable for agricultural use.





Maps (27, 28): Current and potential suitability classes for citrus

3.6. GIS fertilizer requirements digital maps for the selected crops

The resulted available nutrients status maps (expressed in mg kg^{-1}) were used later for the calculation of fertilizer requirements for the proposed crops according to the recommended fertilizer requirements for each specific crop. This was done by simple subtract operation between the existing nutrients contents map and the recommended quantity of fertilizers to the proposed crops. The resulted fertilizers needs digital maps could be multiplied by simple conversion factors to have maps displaying the needed fertilizers in any commercial fertilizer forms.

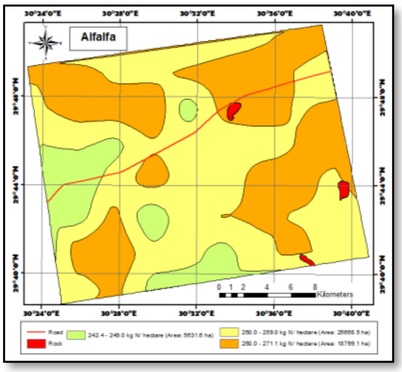
3.6.1. Fertilization maps for some winter crops.

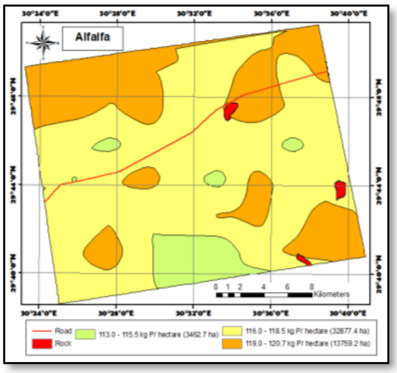
Alfalfa (*Medicago Sativa L.*):

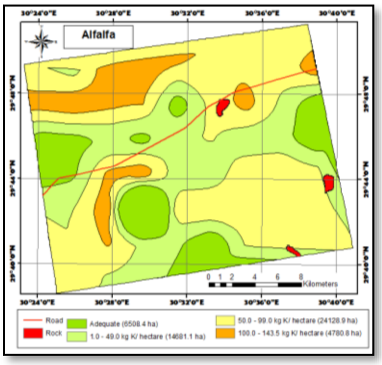
➢ Blanket N fertilizer for alfalfa grown in the newly reclaimed soil is 285.60 kg N/hectare (ARC-Ministry of Agriculture-Egypt, brochure No.764). The N fertilization needs is displayed in Map (29). It indicates that approx. 5631.6, 25668.5 and 18799.1 hectare in need for N fertilization requirements equivalent to 242.4-249.0, 250.0-259.0 and 260-271.1 kg N/hectare, respectively; needed to be applied for one year to the studied soil .

➢ P fertilization, as super phosphate is added at a rate of 833 kg/hectare just prior cultivation starting then added at a rate of 357 kg/hectare every 4 months. In Map (30), more than 32877 hectare of the studied area is in a need approx. 116- 189.5 kg P/hectare, whereas approx. 3462.7 hectare show needs approx. 113-115.5 kg P/hectare. The recorded average needed for phosphorus fertilization reached to 117.6 kg P/hectare.

➢ K fertilizer is added at a rate of 238 kg/ hectare of potassium sulfate with land preparation before planting, then being added 119 kg/ hectare every 4 months. The distributions of potassium fertilization requirements in the studied area is exhibited in, Map (31). More than 6508 hectare of the studied soils show adequate potassium contents for alfalfa requirements, whereas, approx. 14681.1, 24128.9 and 4780.8 hectare need potassium fertilization ranges from 1.0-49.0, 50.0-99.0 and 100.0-143.5 kg K/hectare, respectively.







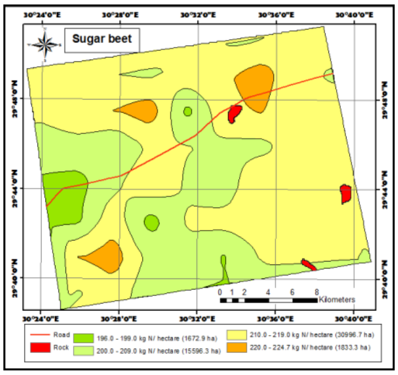
Maps (29, 30, 31): Nitrogen, phosphorus and potassium fertilizer requirements (kg N, P, K /hectare) for alfalfa.

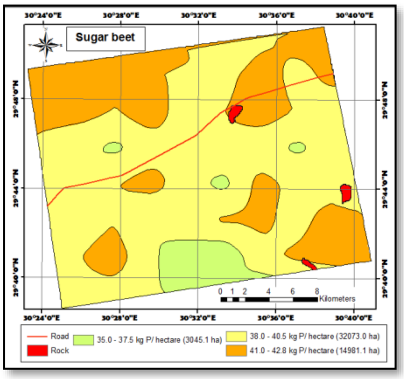
Sugar beet (*Beta Vulgaris*)

➢ N fertilization is considered as one of the limiting factors for sugar beet crop. It needs approx. 714 kg/hectare of ammonium nitrate 33.5% in the reclaimed lands and sandy soils. Applying of N should not be delayed for 90 days of plant age as it causes the delay in the maturation of the crop and also reduces sugar (ARC- Ministry of Agriculture-Egypt, brochure No.696). As shown in Map (32), the distribution pattern of N fertilization needs is exhibited for the studied area. The maximum estimated value is 224.7 kg N/hectare, while the average value is 210.3 kg N/hectare. Approx. 15596.3 hectare of soils is in need to 200.0-209.0 kg N/hectare. Whereas, approx. 30996.7 hectare need fertilization with a rate ranged from 210.0-219.0 kg N/hectare.

➢ We should pay attention to P fertilization of the reclaimed land. The estimated need for this land is approx. 714 kg/hectare in the form of superphosphate (15.5%). The spatial distribution of the needed P fertilization is exhibited in Map (33). P fertilization map shows that the maximum needed P reached 42.8 kg P/hectare, whereas the average need for the whole studied area 39.7 kg P/hectare. Most of the studied area in needs to P fertilization 38.0 40.5 kg P/hectare (32073.0 hectare).

➢ K fertilization is recommended to be added at a rate of 238 kg/hectare of potassium sulfate (48%) during servicing or with the first batch of adding nitrogen fertilizer. However, the total studied soils show adequate potassium contents for sugar beet requirements; only just bio-fertility could be utilized.





Maps (32, 33): Nitrogen and phosphorus fertilizer requirements (kg N, P, /hectare) for sugar beet

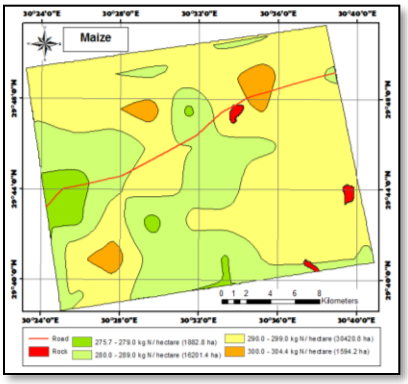
3.6.2. Fertilization maps for some summer crops.

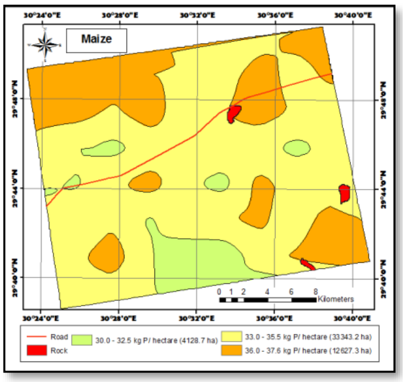
Maize (*Zea Mays L.*)

➢ N fertilization needed is 952 kg/ hectare in the form of ammonium nitrate 33.5%. In three doses they should be applied the first at cultivation, the second after thinning and the third batch before the second irrigation (ARC- Ministry of Agriculture-Egypt, brochure No.962). The distribution pattern of N fertilization needs of the studied area is shown in Map (34). The maximum estimated value is 304.4 kg N/hectare, while the average value is 290.0 kg N/hectare. Approx. 1882.8 hectare of area is needed 275.7.0-279.0 kg N/hectare. While, approx. 30420.8 hectare need N fertilization at a rate ranged from 290.0-299.0 kg N/hectare.

➢ P fertilization in the form of super phosphate (P_2O_5 15%) is recommend to be added at a rate of 714 kg P/hectare before plowing. The spatial distribution of the needed P fertilization is confirmed in Map (35). P fertilization map show that the maximum needed P reached 37.6 kg P/hectare, whereas the average (66.6%) need for the whole studied area is 34.5 kg P/hectare. Most of the studied area (66.6 %) in need to P fertilization ranges 33.0-35.5 kg P/hectare.

➢ As for high-yield varieties or in the reclaimed land Addition of 238 kg potassium sulfate (48% K_2O) per hectare is recommended after thinning the plants. However, total studied area show adequate potassium contents for maize cultivation, only just bio-fertility could be utilized.





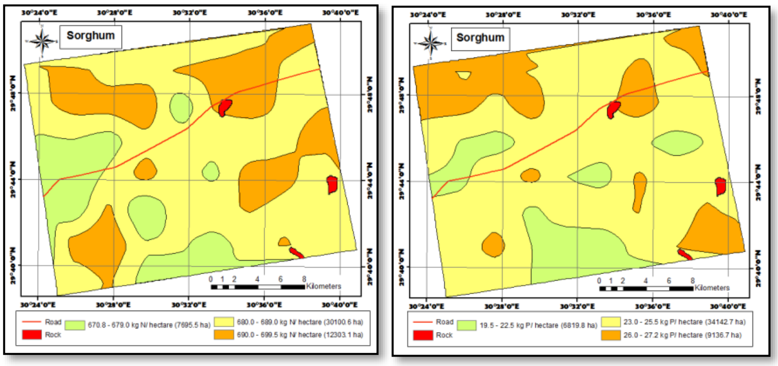
Maps (34, 35): Nitrogen and phosphorus fertilizer requirements (kg N, P, /hectare) for maize

Sorghum (*Sorghum Bicolor L.*)

➢ Sorghum needs 143 N-units/hectare in beginning of cultivation, to be added at the first irrigation, then application of 143 N-units/ hectare after the second irrigation. More 72 units of nitrogen would be added after each cut (ARC- Ministry of Agriculture-Egypt, brochure No.907). As for the organic fertilizers it as also recommended to add 48-72 m^3/hectare composted organic manure with the land preparation. The calculated nitrogen fertilization need is illustrated in Map (36). Data indicate that the maximum fertilization need is 699.5 kg N/hectare (12303.1 hectare). Most of the studied area (60.1%) is in need to 680.0-689.0 kg N/hectare. The estimated average of nitrogen fertilization needs for sorghum if it would be cultivated in the studied area reached to 685.1 kg N/hectare.

➢ Recommended addition of P fertilization in the form of super phosphate is approx. 476 kg/hectare during land preparation for planting. As indicated in Map (37), in the studied area, approx. 34142.7 hectare (68.15%) needs approx. 23.0-25.5 kg P/hectare. The recorded average needed of phosphorus fertilization reached to 24.1 kg P/hectare.

➢ The recommended addition of potassium sulfate during the land preparation is a rate of 238 kg/hectare. The total studied soils show adequate amounts potassium for sorghum cultivation.



Maps (36, 37): Nitrogen and phosphorus fertilizer requirements (kg N, P, /hectare) for sorghum.

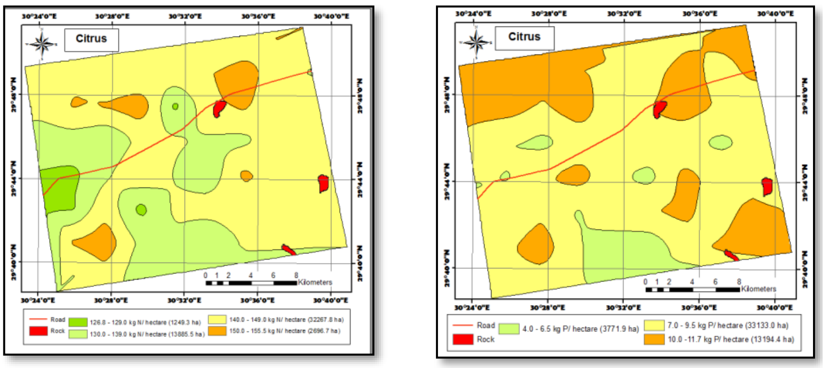
3.6.3. Fertilization maps for some orchard trees.

***Citrus (*Citrus Spp*):** The following is a proposed program to fertilize citrus trees of age 1-3 years in the reclaimed lands (ARC- Ministry of Agriculture-Egypt, brochure No.366).

➢ Trees need N fertilization is 833 kg ammonium sulfate (20.5%) per hectare, for one year, where this amount is added through 21 dosages added from the second half of February and ending June. In addition, is recommending to be added 47.6-59.5 m^2 of manure per hectare. As Map (38), illustrates the distribution pattern of N fertilization needs for the studied soils. The maximum estimated value is 155.5 kg N/hectare for year, while the average value is 141.1 kg N/hectare. A few areas approx. 1249.3 hectare of soils is needed 126.8-129.0 kg N/hectare. Whereas most of studied soils, approx. 32267.8 hectare, need fertilization at a rate ranged from 140.0-149.0 kg N/hectare for year.

➢ P fertilization at a rate of 238 kg super phosphate (15.5%) per hectare is recommended. The spatial distribution of the needed P fertilization is illustrated in Map (39). P fertilization map show that the maximum needed P reached 11.7 kg P/hectare for one year, whereas the average need for the whole studied area 8.5 kg P/hectare. Most of the studied area (13194.4 hectare). in need to P fertilization ranges 7-9.5 kg P/hectare.

➢ Recommendation for K fertilization is adding 190 kg/ hectare of potassium sulfate per year divided into two batches, the first installment in March and the second in August. However, the total studied soils show adequate potassium contents for citrus cultivation; only just bio-fertility could be applied.



Maps (38, 39): Nitrogen and phosphorus fertilizer requirements (kg N, P, /hectare) for citrus

It is worthy to mention that digital maps for micronutrients fertilizer requirements to the selected crops could be produced. But, it should be bearing in mind that it is not advisable to correct deficiency of micronutrients dominating in sandy and calcareous soils through soil addition but through foliar application.

4. Conclusions

The current study concluded that: Incorporation of GIS methodology could be very helpful to produce accurate digital maps for the different soil characteristics, total and available nutrients status, land capability, land suitability for crops and the adequate fertilizer recommendation requirements for them. The resulted fertilizers needs maps are considered very potential for precision farming application. Therefore, it is recommended to apply such scientific methodology, depending on the most advanced recent technology, on the other new agricultural extension areas. Furthermore, in order to achieve much more benefit of the current work or similar one, it is advisable to monitor and update the available nutrients status for the tested point (that identified by GPS).This is suggested to be done twice a year before winter and summer cultivations to retrieve updated fertilization maps. This guide could be used by the decision makers for strategic fertilization plans.

References

Allison, L., Richards, L., Reeve, R., Bernstem, L., Bower, A., Brown, J., Fireman, M., Hatcher, J., Hayward, H., Pearson, G. and Wilcox, L. 1954. Diagnosis and improvement of saline and alkali soils. Untied staff salinity laboratory staff. L.A. Richards (Editor). Agriculture Handbook: 60. U.S. Department of Agriculture.

Beek, K.J. and Bennema. 1972. Land evaluation for agricultural, land use planning. An ecological methodology. pp: 61. (Memeograph). Dept. Soil Sci. and Geol., Agric. Univ., Wageningen, the Netherlands.

Belka, K.M. 2005. Multi criteria analysis and GIS application in the selection of sustainable motorway corridor. Master’s thesis submitted to Linkopings University Institutional for data vetenskap.

Borhamy, S.E. 2001. Pedo-genetic aspects as related to soil fertility status at El-Fayoum. Egypt. Ph. D. Thesis. Fac. Agric. El-Fayoum, Cairo Univ., Egypt.

Bower, C., Reitemeiyer, R. and Fireman, M. 1952. Exchangeable cation analysis of saline and alkaline soils. Soil Sci., 73, pp.251-261.

FAO. 1976. A framework for land evaluation. Soils Bulletin 32. Rome, Italy.

FAO. 1990. Guidelines for Soil Description. 3rd (Ed.) Revised, Soil Resources, Management and Conservation Service Land and Water Development Division, Rome, Italy.

Hesse, P.R. 1971. A Text book of Soil Chemical Analysis. John Murray Publ., William Clowes and Sons Limited, London, Beccels and Colchester.

Houba, V.J., Van Der Lee, J.J. and Novozamsky, I. 1995. Soil and Plant Analysis. Part 5 B., 6th Ed., Dept. of Soil Sci. and Plant Nutrition, Wageningen Agricultural Univ.

Ibrahim, S.E. 2001. Pedo- genetic aspects as related to soil fertility status at EL Fayoum, Egypt. Ph. D. Thesis, Fac. of Agric. El Fayoum, Cairo Univ., Egypt.

Jackson, M.L. 1967. Soil chemical analysis. Prentic Hall, Ladia Private, LTD., New Delhi.

Jackson, M.L. 1973. Soil chemical analysis. Pretice-Hall, Inc., Englewood Cliffs, New Jersey, U.S.A.

Kabata-Pendias, A. 2001. Trace elements in soil and plants. 3rd (Ed). CRC Press, Boca Roton, FL. USA.

Lindsay, W. 1979. Chemical equilibrium in soils. John Wiley and Sons, Inc. New York. p.449.

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese, and copper. *J. Soil Sci. Soc. Amer.,* 42, pp.42-428.

Nur, A., Ezrin, M. and Aimrun, W. 2014. Relationship between soil apparent electric conductivity and pH value of Jawa series in oil palm plantation. 2nd International Conference on Agricultural and Food Engineering. 2, pp.199-206.

Office of Environment and Neritoge. 2012. The land and soil capability assessment scheme second Approximator. Dep. of Premier and Cabinet NSW. *www.environment.nsw.gov.au*

Officer, S; Tillman, R.; Palmer, A. and Whitton, J. 2006. Variability of clay mineralogy in two New Zealand steep-land top soils under pasture. *Geoderma*, 132, pp.13-28.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dept. Agric. Circular No. 939.

Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of Soil Analysis. Part 2.Chemical and Microbiological Properties. 2nd (Ed.) Amer. Soc. of Agronomy. Madison, Wisconsin, USA.

Piper, C.S. 1950. Soil and Plant Analysis. International Science Publisher, Inc., New York, USA.

Robinson, D. and Phillips, C. 2001. Crust development in relation to vegetation and agricultural practice on erosion susceptible, dispersive clay soils from central and southern Italy. *Soil and Tillage Research,* 60, pp.1-9.

Schoeneberger, P., Wysocki, D. and Benham, E. 2011. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Schoonover, W. 1952. Examination of soils for alkali. University of California Extension Service, Berkeley, California (Mimeographed).

Singer, M. and Munns, D. 1996. Soils: an introduction. 3rd ed. Prentice- Hall. Saddle River, NJ.

Storie, R.E. 1932. An index for rating the agricultural values of soil. Bulletin 556, Berkeley: California Agricultural Experiment Station.

Storie, R.E. 1978. Storie index soil rating (revised). Special Publication 3203, Division of Agricultural Science, University of California, Berkeley, CA.

Susan, C., Juan, H. and Nelson, A. 2014. Gypsum soils their morphology, classification, function and land scaps. Chapter 4 Advances in Agronomy, 130.

Sys, C. and Verheye, W. 1978. An Attempt to the Evaluation of Physical Land Characteristics for Irrigation According to the FAO Framework for Land Evaluation. International Training Center for Post Graduate Soil Scientists, Chent, Belgium, pp.66-78.

Sys, C., Van Ranst, E., Debaveye, J. and Beernaert, F. 1993. Land Evaluation Part III: Crop requirements. Agricultural Publication No. 7. GADC, Brussels, Belgium, pp.12-173.

Sys, C., Van Ranst, E. and Debaveye, J. 1991. Land Evaluation. Part 1: Principles in Land Evaluation and Crop Production Calculations; Part 2: Methods in Land Evaluation; Part 3: Crop Requirements (in press). Agricultural Publications no. 7, General Administration for Development Cooperation, Brussels.

Tagwirg, F., Piha, M. and Mugwira, L. 1992. Effect of pH, phosphorus and organic matter contents on zinc availability and distribution in two Zimbabwean soils. Commun. Soil Sci. Plant Anal., 23, pp.1485-1500.

Tideman, T.N. 1990. Integrating land value taxation with the internalization of spatial externalities. Land Econ. 66, pp.341-355.

USDA. 1961. Soil survey Stanton County, Kansas. Soil Conservation Service in Cooperation with Kansas Agricultural Experiment Station. Series 1958, pp.1-41.

USDA. 1973. Soil conservation service, land capability classification, Agriculture Handbook No. 210.

USDA. 2014. Keys to Soil Taxonomy. Soil Survey Staff, Natural Resources Conservation Service (NRCS). Twelfth Edition, 2014.

USDA. 2015. Soil study and land evaluation handbook. Natural resources conservation service. *https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm*

Van Reeuwijk, L.P. 1993. Procedures for soil analysis. CIP-Gegevens Koninklijke Bibliotheek, Den Haag: international soil reference and information centre. (Technical Paper/ International Soil Reference and Information Centre. ISSN 0923-3792: No.9) Trefw: Bodemkunde. ISRIC. Fourth Edition.

Wright, C. 1939. Soil Analysis. Thomas Murby Co., London.