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Review Article: Soil Fertility Assessment Using GIS

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ABSTRACT

Application of digital soil mapping process for the prediction of key physicochemical characteristics has been well understood all over the world. Farmers' options depend on soil fertility, which control in Agricultural practices (usage organic matter and fertilizers application) and agricultural production. Therefore, analysis of soil is important for fertility status comprehension to raise production of crops. Soil fertility Evaluation and soil fertility maps can supply information and serious agent for suitable strategies and decisions making to help farmers and improve land management. Applied System for Land Evaluation (ASLE) software and nutrient index (NI) used to evaluate soil fertility. Tracking variations of spatial distribution is significant to know soil fertility state. Subsequently, it is substantial to trace and define status of soil properties and soil fertility study for cultivation of various crops.

Keywords: Fertility evaluation status, soil mapping, ASLE, GIS, Nutrient index.

INTRODUCTION

Definition and Important of soil fertility

One of soil fertility definitions is soil ability to supply the plant with everything it needs during the growing stages. The demand of several crops can be very changing. Wherefore, crops need fertile soil, which varies from one crop to another. Keizaburo and Kazutake, (1975) defined fertility of soil as (Soil fertility can provide the soil with the right components in the right amounts and in the right formula for the growth of specific plants while other factors are favorable such as weather factors (humidity, temperature, light) and soil condition) so, the chemical natural of the soil specifies its fertility of soil. The soil quality is what can it to supply the basic nutrients in amounts and ratios for the plants growth. Mostly, fertility of soil indicate to the capability of the soil to add plant elements and water in enough amount and ratio for plant growth in the nonexistence of toxic materials which that may prevent plant growth (Johnson *et al*. 2000).

Fertility of soil is important item, which that can control soil productivity possibility, and fertility status is affected by administration exercise (Johnson *et al*., 2000). Mulder, (2000); NajafiGhiri *et al*., (2010) and Havlin et.al. (2010) reported that physiochemical properties of soil are important factors, which reflect soil fertility and soil productivity. In addition, plant nutrients availability in soil and their status in soil are critical to excuse the soil fertility (Havlin *et al*., 2010). FAO defined fertility of soil term as the capability of soil to afford nutrients in demand by plants in sufficient amounts and suitable ratios (Jin at el., 2011). Fertility of soil is considered in terms of the highest practical level of yield, with particular assurance on soil physical and chemical aspects. Fertility of soil relates to its ability to preserve production regular with least inputs (Brady and Weil, 1999). Fertility of soil and nutrient administration have important role in modern agriculture, which show in the management fertilizers and crop yield (Bagherzadeh *et al*., 2018). The fertility of soil is large limitation to plant growth and crop production in Egypt and the world, because the low soil fertility means deficiency of nutrients available, inadequate soil moisture and nutrient imbalances for plants growth. Soil fertility of some semi-arid areas are become low due to incorrect management practices, which led to increase chemical and physical properties regression of soils and reduced soil productivity of grain yields per unit area of soil (Tisdale *et al*., 1995). Farmers' options depend on soil fertility, which control in Agricultural production, and fertilizers choices and soil and water keeping. Soil fertility depend on physiochemical properties such as acidity, SOM and ability to conserve nutrients and water (Mulder, 2000). Sushanth *et al*., (2019) mention that soil fertility has relationship with the reactions organic material, nutrient ions and water. Also, the nature and quality of mineral raw materials control fertility of soil.

Evaluation of soil fertility:

Soil analysis is one of several methods for assessing soil fertility, and is important for assessing nutrient status, fertility status and nutrient management. It also enables us to predict and determine the amount of nutrients that plants need. Soil chemical analysis is a method for assessing soil nutrient content and the nutrient-providing strength of soil, so soil tests are much faster than other methods. In addition, the soil's need for nutrients can be determined before planting.

Soil fertility evaluation is a part of land capability evaluation but for specific physicochemical properties. Soil fertility is a complicated operation that includes nutrient elements cycle of between organic and inorganic component. When plant and animal wastes decompose they release nutrients to the solution of soil, which that an operation referred to as mineral fertilization. (Sims and Wander, 2002 and Sims, 2006). There are several techniques are commonly used to estimate soil fertility status such as soil analysis, Nutrient-deficiency symptoms of plants, biological tests in which the growth of either higher plants or certain micro-organisms is used as a measure of soil fertility and analysis of tissue from plants growing on the soil. (Tisdale *et al*. 2003). Soil testing is important to observe changes in soil fertility over time to specify if modifications in management are needed. Moreover, by knowing the soil fertility of the area, nutrient deficiency will be revealed. Fertilizer cost and amount will be properly prescribed (Villanueva *et al*. 2008). It becomes

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necessary to evaluate soil fertility management practice of rice farmers with the aim of improving fertility status of the soil on a sustainable basis in order to boost the production of rice in the country. (Adesanwo *et al*. 2009). Based on the difference of landform, Khadka *et al*., (2017) collected 81 soil samples (0-20cm) Using soil sampling auger based for evaluation of soil fertility in the study area. Periodically estimate changes in spatial variance to know soil fertility status is very important, where cultivation of the different crops depend on Tracking and evaluation of soil fertility and determine soil properties (El-Seedy, 2019).

According to Ismail *et al*. (1994), Ismail & Ismail *et al*., (2001) and Morsi, (2001) program of ASLE (The Applied System of Land Evaluation) is a helpful instrument for evaluating soil fertility, it based on is a computer as program for arid and semi-arid soils as shown in Fig. (1). Ganzorig and Adyasuren (1995) explain that evaluation of land can be used by various models such as LECS (land evaluation for capability), GIS (geographic information system) ALES (agricultural land evaluation system), description. Sayed, (2006) illustrate that land evaluation is an explanation of the soil characteristics, cover of cropping, conditions of climatic, the aim of land use and diagnosing the optimal use of the land. ASLE-program contrast the properties and interactivity of the soil units to classify soil fertility into six classes from C1, to C6 (Sayed *et al*., 2016) as shown in Table (1). In order to evaluation of soil fertility classes it is being done using these expressions (Excellent-C1, Good-C2, Fair-C3, Poor-C4, Very poor-C5 and Non agriculture-C6) applying ASLE program for contrasts the soil properties and interaction of the land units (Sayed *et al*., 2016). There are several models and patterns were applied in the field to determine soil fertility (Bijanzadeh and Mokarram, 2017). SFI (soil fertility index) of the study area was classified as very low, low and moderate (Bagherzadeh, 2018). Fertility of soil evaluation applied ASLE program in some soils of Dakahlia Governorate, he found that data (Good and Fair) classes of soil fertility index were classified as two Indicators for evaluation of soil fertility (C2 and C3, respectively) at the studied area. Calculation of fertility Index and soil fertility evaluation status were carried out by ASLE program. (Elseedy, 2019). Using ASLE to evaluate and calculate soil fertility and fertility Index (FI) for some soils North Nile Delta, Egypt, tracing fertility status now compared with it evaluation 9 years ago. According to fertility Index, the study area currently has four classes as (Fair-C3, Poor-C4, Very poor-C5 and Non agriculture-C6), while the results studied before showed only three classes as (Fair-C3, Poor-C4, Very poor-C5). Comparing fertility Index mapping in the two studies show that some soils in the studied area were degradation in soil fertility while others were increase in soil fertility (El-Seedy and Saeed, 2019). Hafif, (2021) founded that soil fertility of the study area -sandy loam to sand clay loam soil texture- was low to moderate, this indicated by low pH, P, K, and total-N. While soil organic carbon was low to moderate. Also he found that Ca, Mg, K, and CEC were low to very low.

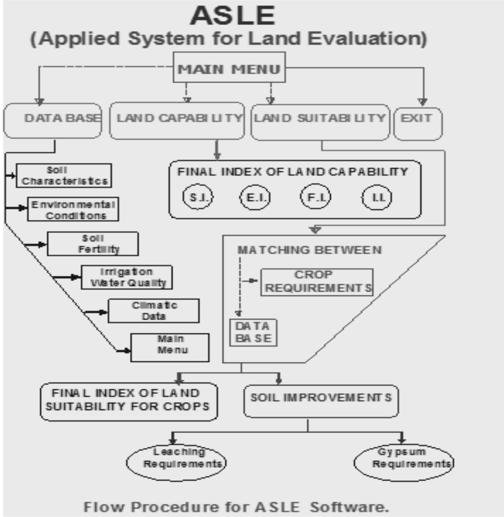

Fig. 1. Flow chart ASLE- program (El-Seedy, 2019)

Table 1. Ranges for soil fertility index classes according to Storie (1944)

classes	soil fertility index	Range (%)
C1	Excellent	> 80
C2	Good	60 - 80
C3	Fair	40 - 60
C4	Poor	20 - 40
C5	Very poor	10 - 20
C6	Non agriculture	< 10

There are broad variances in status of soil fertility improved on diverse land forms. NI (Nutrient index) for available N was low, while available P was low to high and available K was high to medium. (Verma *et al*., 2005). Status of soil fertility estimated using NI (available potassium, available phosphorus and organic carbon) and soil pH index. According to rating chart using pH index, OC index, P and K, based on organic carbon, soil fertility was evaluated and classified from medium to high. While, based on available phosphorus and potassium it were classified as low (Abah and Petja 2015a). NI of nutrient status was a ratio of allocation and soil samples evaluation using three grades were low class, medium class and high class (Willy *et al*. 2019).

Based on the ranking of confines fertility standard as shown Table (2 and 3), and in order to analyze the state of soil fertility, there are several indices as pH index and nutrient index (e.g. EC, available NPK and organic carbon) were calculated. NI of soil samples were studied applying equation 1 and the soils rating chart. (Ramamurthy and Bajaj, 1969):

$$NI = ((NL \times 1) + (NM \times 2) + (NH \times 3)) / NT \longrightarrow \text{Equation 1}$$

where,

NI is Nutrient Index. NL is the number of samples classified low.
NM is the number of samples classified as mean.
NH is the number of samples classified as high.
NT is the total number of samples.

Table 2. Critical fertility levels and categories of NI

Parameters		Unit	Critical fertility level Low	Medium	High
Soil pH 1			< 6	6 - 8	> 8
EC 3		(dSm-1)	< 4	4 – 8	> 8
Organic matter 1		(%)	< 0.86	0.86 - 1.29	> 1.29
Available N 2		(mg kg-1)	< 108	108 - 217	> 217
Available P 2		(mg kg-1)	< 5	5 - 9	> 9
Available K 2		(mg kg-1)	< 45	45 - 112	> 112
Total (N) 3		(%)	< 0.125	0.125 - 0.225	> 0.225
C/N ratio 3			> 14 = poor	10 - 14 = medium	< 10 = good
Exchangeable cations 3	K+	(cmol kg-1)	> 0.3	0.3 – 0.6	> 0.6
	Na+		> 0.3	0.3 – 0.7	> 0.7
	Ca2+		> 5	5 -10	> 10
	Mg2+		> 1.5	1.5 - 3	> 3
CEC 3		(cmol kg-1)	> 12	12 - 25	> 25

1 (Ravikumar and Somashekar, 2013), 2(Verma *et al.* 2005), 3 (Enang *et al.*, 2016).

Table 3. Classification categories of nutrient index

Nutrient index and Categories	Range
I =Low-L	< 1.67
II =Medium-M	1.67 - 2.33
III =High-H	> 2.33

Ramamurthy and Bajaj, (1969) and Ravikumar and Somashekar, (2013)

GIS and mapping of soil fertility

Dharumarajan *et al*., (2022) illustrate that soil nutrient mapping is important for determining regions of fertile status and aiding farmers' agricultural management practices to improve crop yields. They evaluated a mapping of soil for predictions of Phosphorus, Potassium, Sulfur, Zink, Boron, Copper, Manganese and Iron nutrients with other soil properties as soil pH, EC, and SOC in the study area.

We can also characterize locative Patterns by GIS and prediction of soil values features at locations which are not sampled by some statistical tools by geostatistics. For evaluating the value of variable in locations which are not sampled, locative fulfillment techniques have been utilized in soil science. El-Sirafy *et al*., (2011) utilized GIS as technique to estimate the locative patterns of differences for some of soil characteristics at an extent of scales and with various sizes of sampling grids Differences in soil formation factors and soil management lead to spatial variation of soil properties; spatial variations of soil characters result from distinction in soil formation factors and soil arrangement, which is a great determinant of competence of farm inputs and yield. Therefore, locative distributions enable us to use important techniques in using nutrients and fertilizers arrangement and water in agricultural yield (Sağlam *et al*., 2011).

It is become has been world widely understood to apply the digital soil mapping (DSM) to predict the main physical and chemical properties like soil depth, available water content, textural fractions, organic carbon and pH (McBratney *et al*. 2003; Hengl *et al*. 2015; Minasny *et al*. 2013; Dharumarajan *et al*. 2020a, 2020b). The key to successful soil administration for prospective crop yield is planning spatial distribution of soil characteristics. It also enables us to improve agricultural exercise, can boost making decisions and resolution with more precise information we need in improving management of fertility programs. (El-Sirafy *et al*., 2011, (Behera *et al*. and Elnaggar *et al*., 2016), and Elseedy, 2019) according to Fig (2). The relationship between soil formation agents and soil administration practices through spatio-temporal standards produces about the spatial several of soil characteristics, and is locally modified by corrosion and sedimentation processes. (Iqbal *et al*., 2005 and Hu *et al*., 2019). Moore *et al*., (1993), Park and Vlek, (2002), Lian *et al*., (2009) and Jiang *et al*., (2017) explained based on soil characteristics that spatial distribution and variance characteristics of soil are important for Expecting land use changes on soil characteristics. So, the loss of soil values at a detailed spatial accuracy greatly raises the doubt of model products and becomes a fundamental limitation for evaluation of land quality and use of soil.

Despite the determination of soil texture using conventional methods, the information about soil texture is very benefit for designing, drawing, and administrating of the soils. Maps of soil are created at big measures to adequately appear their spatial allocation. (Scull *et al*., 2005). Spatial soil information depends on reaction between ecological variables and soil characteristics. Detailed spatial soil information is fundamental for evaluation and resolution making for Soil problem solving (Forkuor *et al*., 2017). Tools of Geographic information systems improved Expecting for clay amount with characteristics of soil studied. In addition, spatial variability output showed that soil characteristics were medium to good in the study soil (Saleh, 2018).

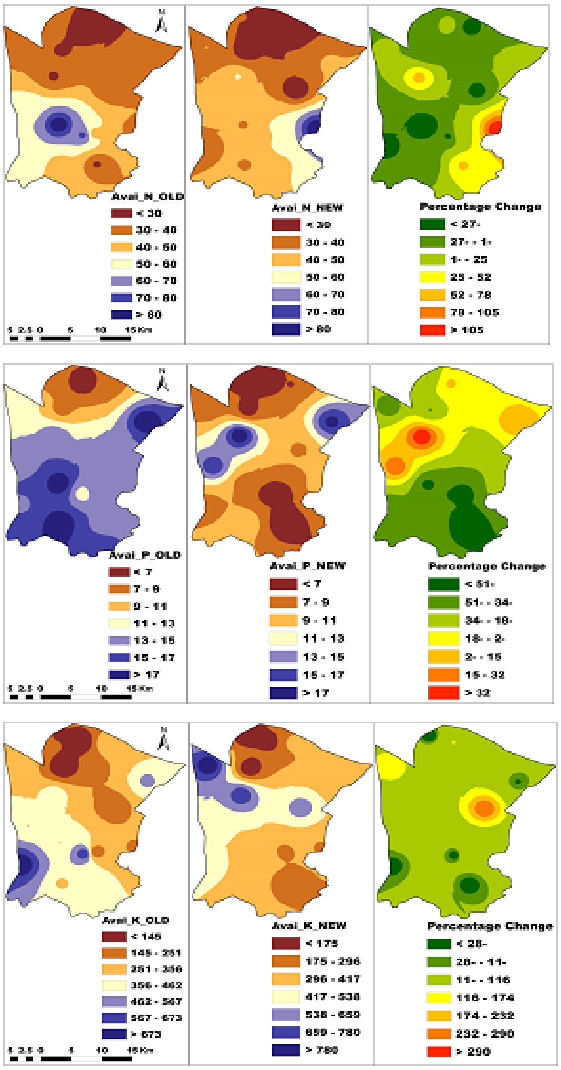

Fig. 2. Spatial distribution mapping of Available NPK (Elseedy, 2019).

Bakhshandeh *et al*. (2019) and Zeraatpisheh *et al*. (2019) mention that mapping the spatial distribution of soil nutrients is important for mapping deficient areas and for planning more efficient management decisions. Spatial distribution for Soil nutrients is normally created by interpolation techniques as local ordinary kriging, inverse distance weighted and polynomial interpolation. El-Sayed *et al*. (2020) evaluated and mapped some soils in Sohag using geostatistical analysis tool in GIS whereas they found that the study area included four capability classes ranged between Good, Fair, Poor and Nonagricultural lands. The spatial distributions of soil properties and soil management practices, helps in understanding soil characteristics changes and timely amendment management patterns. Further, evaluation of soil fertility within farmland is Urgent need for comprehension level of soil fertility and obviating degradation of soil (Chen, *et al* 2020). A soil fertility index maps can supply decision-makers with information like spatial designing for soil management. The establishment of fertility maps depend on basic soil properties that can be modeled for spatial mapping. (Hounkpatin, *et al* 2022).

CONCLUSION

Fertility of soil and nutrient management have a direct impact on crop quality and yield. Plant nutrition with nutrients amount at the quite time is important to crop production. So, must be observing soil nutrient levels through soil tests to determine soil electrical conductivity, OM, pH, CEC, and macronutrients and micronutrients. Also, estimate and apply soil improvers such as lime or sulfur application rates are necessary to treat soil pH.

Using ASLE and the nutrient index to assess soil fertility can support decision-making to improve soil fertility management programs, and help advance agricultural practices to raise soil agricultural productivity using ASLE and nutrient index to evaluate soil fertility enable help decision makes to improve management of soil fertility, and assistance us in advancement agricultural work to raise productivity of soil agricultural. A soil fertility index maps can supply decision-makers with information like spatial designing for soil management. The establishment of fertility maps depends on basic soil properties that can be modeled for spatial mapping. Soil testing is important for soil fertility management, subsequently, methods soil fertility evaluation is an efficient tool for rising the soils production from crops. GIS mapping have a high degree of spatial variation resulting from physiochemical processes of soils. So, study of soil fertility using GIS and determine situation of soil properties it is very important to cultivate different crops

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دراسة مرجعية :تقييم خصوبة التربة باستخدام نظم المعلومات الجغرافية

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الملخص

رسم الخرائط الرقمية للتربة للتنبؤ بالخصائص الفيزيائية والكيميائية الرئيسية تم فهما جيدًا في جميع أنحاء العالم. تعتمد خيارات المزارعين على خصوبة التربة، والتي تتحكم في الممارسات الزراعية (استخدام المواد العضوية واستخدام الأسمدة) والإنتاج الزراعي. لذلك ، يعد تحليل التربة مهمًا لفهم حالة خصوبة التربة لزيادة إنتاج المحاصيل والعائد المستدام. يمكن أن يوفر تقييم خصوبة التربة وخرائط خصوبة التربة معلومات وعاملًا جادًا لاتخاذ القرارات والاستراتيجيات المناسبة لمساعدة المزارعين وتحسين إدارة الأراضي. يستخدم برنامج النظام التطبيقي لتقييم الأراضي ((ASLEومؤشر المغذيات ((NIلتقييم خصوبة التربة. يعد تتبع التغيرات في التوزيع المكاني أمرًا مهمًا لمعرفة حالة خصوبة التربة. وبالتالي ، من المهم للغاية تتبع ودراسة خصوبة التربة وتحديد حالة خصائص التربة لزراعة المحاصيل المختلفة.