Soil Fertility Evaluation and Fertilizer Requirements of Nitrogen, Phosphorus and Potassium for Wheat Production (Sharq El-Owainat – Western South Egypt)

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ABSTRACT

ElWadi Elgadeed is one of the promising areas for national agricultural projects in Egypt. Soil fertility index and precision farming seek to maximize yield and reduce environmental damage. Therefore, this study aimed to assess the soil fertility of NPK. 25 soil samples (depth 0-50 cm) were collected. The results showed that most of the soil samples were nitrogen moderate fertile (Mf) and high fertile (Hf) with a percentage of (44%). Dissimilar, 64% of soil samples were low soil phosphorus fertility class, which has low wheat potential production (< 500 Kg ha^{-1}). GIS-map of N-soil fertility classes (FN) classified the soil samples into four groups. Relating to the GIS–map of P–soil fertility marked the absence of the very high fertile class, the minority of the high fertile class (92.00 ha, 0.09%), and the dominance of the low fertile class (7352.00 ha, 72.94 %). The potassium very high fertile class occupied the whole of the studied area (10080 ha, 100 %). GIS Maps illustrated that most of the studied area had no need for N application for low wheat production (< 500 Kg ha^{-1}), and 5 kg ha^{-1} N applied to (55. 05%) of the area to moderate wheat production (500–750 Kg ha^{-1}). Attaining high wheat production (750 -1000 Kg ha^{-1}) classified the studied area into nine levels of N requirements. We assigned different eight P application levels to have high wheat production. Finally, the research referred to that there is no need for K fertilizer, even for high wheat production.

Keywords:Fertility Classes, Agricultural Precision, ElWadi Elgadeed.

INTRODUCTION

The world population is expected to reach 9.6 billion in 2050 (Dwivedi *et al.,* 2017). This over increasing population requires the same growing of the food production which needs to convert the extensive methods of agricultural production to the intensive one such as the precision agriculture (Zhang *et al.,* 2002 and Yang *et al.,* 2020).

The real challenge for wheat cultivation in the study area is the high evapotranspiration annual rate (ET_0) that has max. 8.99 mm d^{-1} (June) and min. 2.75 mm d^{-1} (December). Consequently, these soils need high irrigation requirements for wheat planting (17800 m^3 ha^{-1} season^{-1}) (Abd El-Hady, 2015). Agriculture in Egypt is a vital source of livelihood for about 26% of the entire population of Egypt (IFAD, 2021), and it is a major sector in the Egyptian economy for food security achieving, according to the vision 2030 (Kassim *et al.,* 2018). Unfortunately, this sector is dominated by small-scale farmers, which apply traditional agriculture with uneconomic practices such as the overuse of chemical fertilizers, which leads to increasing production costs and reducing yields (USAID, 2022). Despite the Egyptian government's efforts to increase the agricultural lands to achieve self-sufficiency in the main crops such as grain (especially wheat), it remains dependent on food imports (CAPMAS, 2021). So, the current task is to intensify grain crops production like wheat to increase productivity depending on soil fertility.

Soil is a vital component of ecosystems, as many important ecosystem processes occur in its system (Liang *et al.,* 2022). There is a significant relationship between the soil nutrients status and crop productivity (Pang *et al.,* 2018 and Gao *et al.,* 2022). The food and agriculture organization defined soil fertility as the ability of the soil to provide plants with essential nutrients (FAO, 2019) and it is an important factor in plant growth and productivity (Zhang and Xu, 2005). Soil fertility assessment is mainly based on soil analysis (Nafiu *et al.,* 2012) and it is a very important tool for soil management recommendations (Nariyanti *et al.,* 2022). Soil fertility is a comprehensive concept that is not directly measured and assessed through some soil properties such as macronutrients (Du and Zhou, 2009).

DOI: 10.21608/asejaiqjsae.2023.315235

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Received, July 25, 2023, Accepted, August 30,2023.

The nutrient application rates depend on the quantity of the crop element in the soil. In the soil, available nutrient levels are classified into classes as soil indices (Teagasc, 2022). Soil fertility assessment can provide a scientific perspective for soil management. The soil fertility index (SFI) is an important tool to manage field variability and maximize crop yield with minimum environmental impact (Andrews *et al.*, 2004; Munnaf and Mouazen, 2021). Essential nutrient deficiency below the optimal level leads to a decrease in plant productivity, and at the same time, an excess of the optimum level leads to increased negative impacts on the environment (Bongiovanni and Lowenberg-Deboer, 2004).

Precision farming is about doing the right treatment in the right way, in the right place, and at the right time (Liakos *et al.*, 2018), matching it with agro-climatic conditions (Mokaya, 2019), and allowing for site-specific management (Pini *et al.*, 2020). Precision farming refers to the integration between GIS and GPS tools to provide comprehensive information about nutrient levels, soil variability, topography, crop growth, and production. It refers to the management of spatiotemporal variation in crops and soil to reduce inputs, increase outputs, and save the environment (McBratney *et al.*, 2005; Kerry *et al.*, 2010; Abd El-Hady and Abdelaty, 2019).

In Egypt, there are few recent research that dealt with the soil fertility index study (Mohamed *et al.*, 2019; Elseedy, 2019; El-Seedy and Saeed, 2019).

Globally, numerous studies have focused on the soil fertility index. In Indonesia, Nariyanti *et al.* (2022) determined the soil fertility index and classified it as moderate or high. Tunçay *et al.* (2021) assessed the soil fertility index in Turkey using GIS and remote sensing techniques and classified the soil fertility index into three classes: very high and high fertile soils (40.0%), moderately fertile soils (26.7%), and low and very low fertility (33.3%). The visible and near-infrared spectroscopy used to assessment soil fertility index (Yang *et al.*, 2020) and development by Munnaf and Mouazen (2021). Zhao *et al.* (2023) applied a novel weighting method for forest soil fertility index evaluation. There was a significant positive correlation between soil fertility index and soil suitability for Arabica coffee (*Coffea arabica L.*) in Pacitan District, Indonesia (Irawan *et al.*, 2022).

The food security is still a very critical issue, especially in arid and semiarid regions like Egypt. Therefore, this study aims to manage and distribute macronutrient fertilizer inputs (NPK) at specific locations for wheat cultivation according to soil fertility index to reduce cultivation costs, increase yield, reduce the use of macronutrient fertilizer (NPK), and decrease soil and environmental pollution.

MATERIALS AND METHODS

Soil sampling and analysis:

Twenty-five surface soil samples (depth 0-50 cm) were collected, which is located between 668000 E, 669000 E and 2520000 N, 2532000 N (UTM, Zone 35N), ElWadi Elgadeed Governorate. The studied area (100 km^2) was sampled by nested centroid grid soil sampling design (5*5 samples), spacing (4 km) (Figure 1). UTM coordinates were recorded using the global positioning system (GPS), (Table 1). The samples were air-dried, crushed, and sieved through a 2 mm sieve. The fine soil (less than 2 mm diameter) carried the routine physical and chemical analyses, as well as the available plant macronutrients determination according to FAO (1970) and Page *et al.* (1982).

Table 1. Soil samples UTM coordinates

Sample No.	UTM coordinates E	UTM coordinates N	Sample No.	UTM coordinates E	UTM coordinates N	Sample No.	UTM coordinates E	UTM coordinates N
1	669709	2530733	10	677709	2528733	19	675709	2524733
2	671709	2530733	11	669709	2526733	20	677709	2524733
3	673709	2530733	12	671709	2526733	21	669709	2522733
4	675709	2530733	13	673709	2526733	22	671709	2522733
5	677709	2530733	14	675709	2526733	23	673709	2522733
6	669709	2528733	15	677709	2526733	24	675709	2522733
7	671709	2528733	16	669709	2524733	25	677709	2522733
8	673709	2528733	17	671709	2524733			
9	675709	2528733	18	673709	2524733			

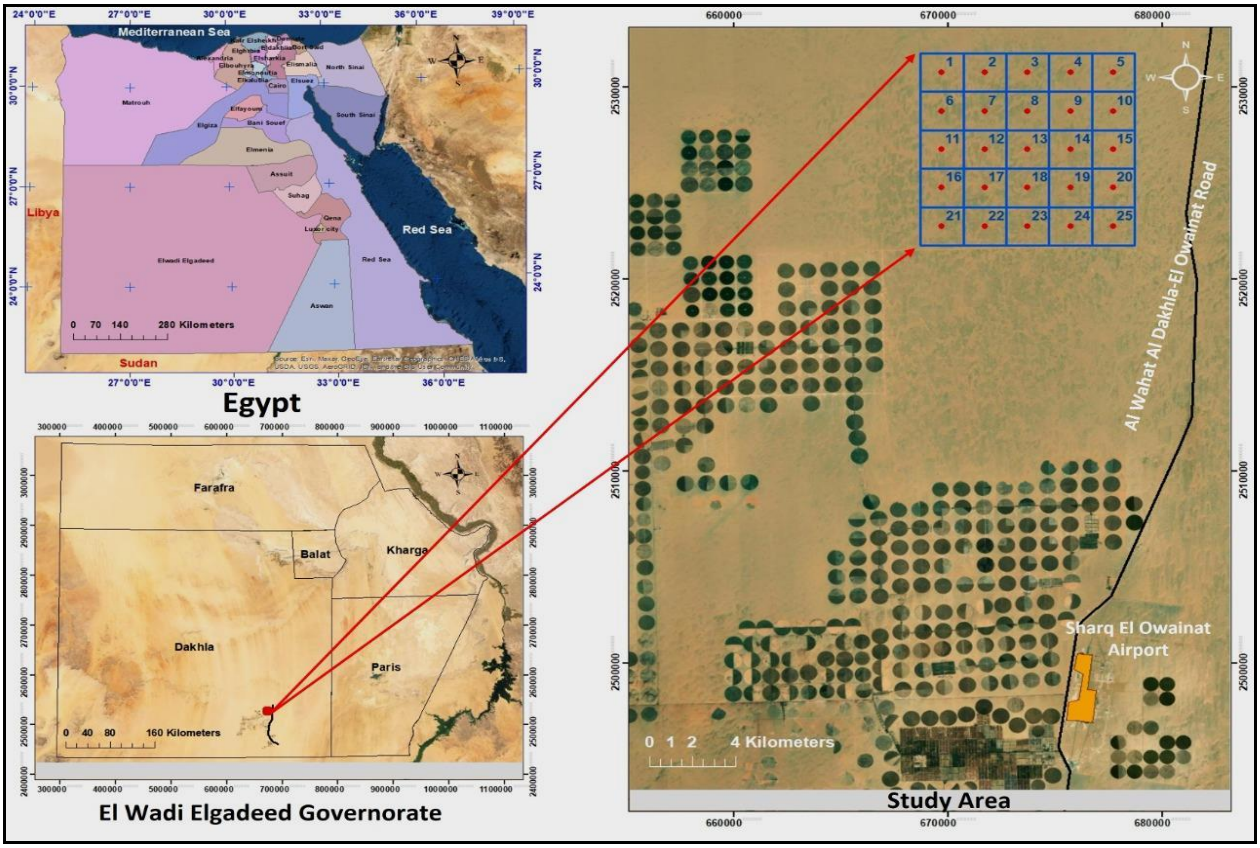

Fig. 1. Location of the study area and spatial distribution of soil samples

Determination of Soil Fertility Classes:

The soil content of available macronutrients (ppm) was determined and was converted to (kg root zone^{-1} ha^{-1}) (Liu and Gazula, 2019). Then, soil fertility macronutrient indices were determined according to the interpretive ranges of macronutrients (kg root zone^{-1} ha^{-1}), for winter and spring wheat production (Common Wheat, *Triticum aestivum L. subsp. aestivum*) (Teagasc, 2022). These indices classified the soil samples into four categories: low fertile (LF), moderate fertile (MF), high fertile (HF) and very high fertile (VHF).

GIS-Mapping of Soil Fertility Classes:

The NPK soil fertility indices and samples UTM coordinates were used to elaborate GIS- soil fertility maps for each macronutrient by Arc_GIS-10 software (ArcMap 10.8, 2011). The maps determined the area (ha and %) of the different soil fertility classes. These areas were used as a parameter to calculate the soil fertility classes.

Determination of Soil Fertility Classes for the Whole Studied Soils (NFIarea):

The soil nutrient fertility index (**NFI**) for whole studied area calculated by the following equation (Chase & Singh, 2014 and El-Seedy & Saeed, 2019):

$$\text{Nutrient Fertility Index (NFI)} = NL * 1 + NM * 2 + NH * 3 \ / \ NT \qquad \text{(Eq-1)}$$

Where:

(NFI) refers generally to the soil macronutrient fertility.

NL, NM and NH are the number of samples falling in low, moderate, and high fertile classes of macronutrient that are multiple by each classes number.

NT is the total number of samples analyzed.

The study modified equation (1) by introducing the fourth soil fertility class (very high fertile, (VHF) to be complied with the interpretative scale of fertility classes (El-Seedy and Saeed, 2019). Thus, equation (1) modified to the following formula:

$$\text{Nutrient Fertility Index (NFIarea)} = ALF*1+AMF*2+AHF*3+AVHF*4/100\ (\%) \qquad \text{(Eq- 2)}$$

Where:

ALF, AMF, AHF and AVHF are the areas (%) of the soil fertility classes; low fertile (LF), moderate fertile (MF), high fertile (HF), and very high fertile (VHF), respectively.

In equation (2), each soil fertility class was weighted by its spreading area. This modification was elaborated because there is no relation between the category of soil fertility category and soil sampling (except the gridding design of soil sampling). So, the introduced method substitutes the soil samples number, of each soil fertility class, by its area that is determined by GIS technique. This modification validated the fertility index determination under all soil sampling designs.

Determination of NPK Fertilizers Precise Requirements (FRi):

The concentration of the soil available plant nutrients (the residual fertilizers of the previous potato; crop) was converted from ppm to be expressed as kg root zone^{-1} ha^{-1} (Qi). NPK fertilizers precise requirements were determined by the following equation:

$$(FRi) = (FTi) – (Qi) \quad (Eq- 3)$$

Where:

(FRi): fertilizer precise requirements, for each soil fertility class, for fertilizer (i)

(i): plant macronutrient

(FTi): upper threshold of the interpretive ranges of plant macronutrients (kg root zone^{-1} hectare^{-1}) that leads to an expected wheat production (kg ha^{-1}).

(Qi): residual fertilizers from the previous potato crop (Kg root zone^{-1} ha^{-1}) (El-Seedy and Saeed, 2019).

These procedures of fertilizers management consisted of an approach farm precision that was based of GIS technique and georeferenced data. The produced GIS–maps delineated soil fertility classes. This conducted to determine NPK fertilizers precise requirements for each soil fertility class to get three levels of wheat production: low wheat production (< 500 kg ha^{-1}), moderate wheat production (500 – 750 kg ha^{-1}) and high wheat production (750 -1000 kg ha^{-1}). Practically, the midpoint substituted the requirements range. For example, the midpoint of 10 kg ha^{-1} switches its range of (0 -20 kg ha^{-1}).

RESULTS

Chemical and Physical Characterization:

The chemical and physical characterization showed that the soil was non-saline, except for samples (1) and (2) that had the values of 4.07 and 4.00 ds cm^{-1} (Table 2). Most of the soil had pH range thresholds of 7.9-8.4 to locate them in the moderately alkaline class. Only samples no. (3, 4, 5) laid in the class of strongly alkaline that had pH range of 8.5-9.0 (Sarkar, 2015). The SAR values located all soils samples in the class of excellent (non-sodic) (Ravikumar, 2014). As soils of arid regions, they had low organic matter and moderate calcium carbonate. Like most of the soils of the Egyptian western desert, they had sandy texture and low bilk density (Table 2).

Determination of NPK Soil Fertility Classes of Each Soil Sample:

The soil content of available macronutrients (kg root zone^{-1} ha^{-1}) assigned fertility index to each soil sample, (Table 3) (Teagasc, 2022). The soil fertility indices were used as criteria to classify soil samples into soil fertility groups (Table 4).

The table showed that most of the soil samples occupied the nitrogen moderate fertile (MF) and high fertile (HF) classes with percent of (44%) and (36%). It was expected that these soil fertility groups could give moderate wheat production (500 – 750 Kg ha^{-1}) and high wheat production (> 750 – 1000 Kg ha^{-1}) without any nitrogen fertilizer application. Contrary, most soil samples (64%) located in the class of low soil phosphorus fertility to be low wheat potential production (< 500 Kg ha^{-1}). Phosphorus fertilizers applications are required to obtain more moderate wheat production (500 – 750 Kg ha^{-1}). In the case of non-phosphorus application, a percent of (24%) of soil samples had moderate P status that may contribute to gain (500 – 750 Kg ha^{-1}). It is obvious, there is no need at all to soil K fertilizers application hence the soil was enriched by K by the overdose application during the cultivation of the previous crop (potato).

GIS Maps of NPK Soil Fertility Classes:

UTM soil samples coordinates and samples fertility indices were input to Arc-GIS-10.8 software to produce GIS maps of soil samples fertility classes (Figure 2). The GIS-map of N-soil fertility classes classified the soil samples into four classes: low, moderate, high, and very high nitrogen fertility (Figure 2-A). These classes were presented by areas; low fertile (904.80 ha, 8.98%), moderate (5128.0 ha, 50.87 %), high fertile (3336.16 ha, 33.10 %), and very high fertile (711.20 ha, 7.06 %) (Figure 2-A). This spatial distribution soil samples clarified that most of the studied samples laid in moderate and high fertile classes. GIS-map of P-soil fertility marked the absence of the very high fertile class, and minority of high fertile class (92.00 ha, .09 %) (Figure 2-B). In addition, it referred to the dominance of low fertile class (7352.00 ha, 72.94 %). The potassium very high fertile class occupied whole of the studied area (10080 ha, 100 %) (Figure 2-C). This is due to the huge K application during the cultivation of previous crop (potato).

Table 2. Chemical and physical properties characteristics of the studied soils

Sample No.	pH	EC dS m^{-1}	SAR %	$CaCO_3$ %	OM %	Textural Class	Bulk Density g cm^{-3}
1	8.4	4.07	9.2	6.1	0.2	Slightly Gravely Sandy	1.59
2	8.4	4	7.9	6.2	0.2	Slightly Gravely Sandy	1.59
3	8.5	1.47	4.7	7.2	0.3	Slightly Gravely Sandy	1.59
4	8.6	1.46	4.9	7	0.4	Sandy	1.56
5	8.5	1.45	5.1	7.1	0.3	Sandy	1.57
6	8.4	1.57	5.2	6.7	0.2	Sandy	1.56
7	8.4	1.61	4.3	6.3	0.4	Sandy	1.67
8	8.4	1.6	4.3	6.5	0.4	Sandy	1.69
9	8.4	1.55	5.2	6.3	0.2	Sandy	1.7
10	8.3	1.7	4.6	7.5	0.4	Slightly Gravely Sandy	1.59
11	8.4	1.56	5.2	7.8	0.4	Sandy	1.69
12	8.3	1.66	4.7	7.3	0.4	Sandy	1.58
13	8.3	1.75	3.9	5.4	0.5	Slightly Gravely Sandy	1.58
14	8.3	1.4	4	5.6	0.5	Slightly Gravely Sandy	1.59
15	8.4	1.44	2.9	5.8	0.2	Sandy	1.6
16	8.5	0.64	2.1	6.7	0.4	Sandy	1.59
17	8.5	0.78	2.2	6.4	0.3	Sandy	1.59
18	8.1	2.13	4.5	6	0.4	Slightly Gravely Sandy	1.61
19	8.1	2.22	4.5	6.3	0.2	Slightly Gravely Sandy	1.59
20	8.4	2.05	4.4	7	0.2	Slightly Gravely Sandy	1.55
21	8.4	2.01	4.4	6.6	0.2	Slightly Gravely Sandy	1.54
22	8.3	2.04	4.6	6.3	0.2	Slightly Gravely Sandy	1.66
23	8.2	1.24	3.2	2.7	0.3	Slightly Gravely Sandy	1.49
24	8.2	1.3	3.3	3	0.4	Slightly Gravely Sandy	1.49
25	8.4	1.66	5.6	6.7	0.2	Sandy	1.52

Table 3. Macronutrients interpretive ranges and wheat goal (expected) production (Kg ha^{-1}) Vs soil fertility classes (Teagasc, 2022)

Soil Fertility Classes		Macronutrients Interpretive Ranges (kg root $zone^{-1}$ ha^{-1})			Expected Wheat Production (Kg ha^{-1})
No.	Designation	N	P	K	
1	Low Fertile (LF)	< 75	< 60	< 50	Low (< 500)
2	Moderate Fertile (MF)	75 - 118	60 - 88	50 - 55	Moderate (500 - 750)
3	High Fertile (HF)	118 -160	88 -110	55 - 60	High (> 750 - 1000)
4	Very High Fertile (VHF)	>160	>110	>60	Very high (> 1000) *

*With simple modification by adding the fourth K fertility class

Table 4. Soil samples classification according to soil fertility indices

Soil Fertility Classes		Macronutrients					
		N		P		K	
NO.	**Designation**	**Samples No.**	**Samples %**	**Samples No.**	**Samples %**	**Samples No.**	**Samples %**
1	Low fertile (LF)	16, 17	2	6, 7, 8, 9, 12, 13, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25	64	--	0
2	Moderate fertile (MF)	3, 4, 5, 7, 8, 9, 10, 11, 20, 21, 22	44	1, 2, 10, 11, 14, 15	24	--	0
3	High fertile (HF)	1, 2, 6, 12, 18, 19, 23, 24, 25	36	3, 4, 5	12	--	0
4	Very high fertile (VHF)	13, 14, 15	12	--	0	All soil samples	100

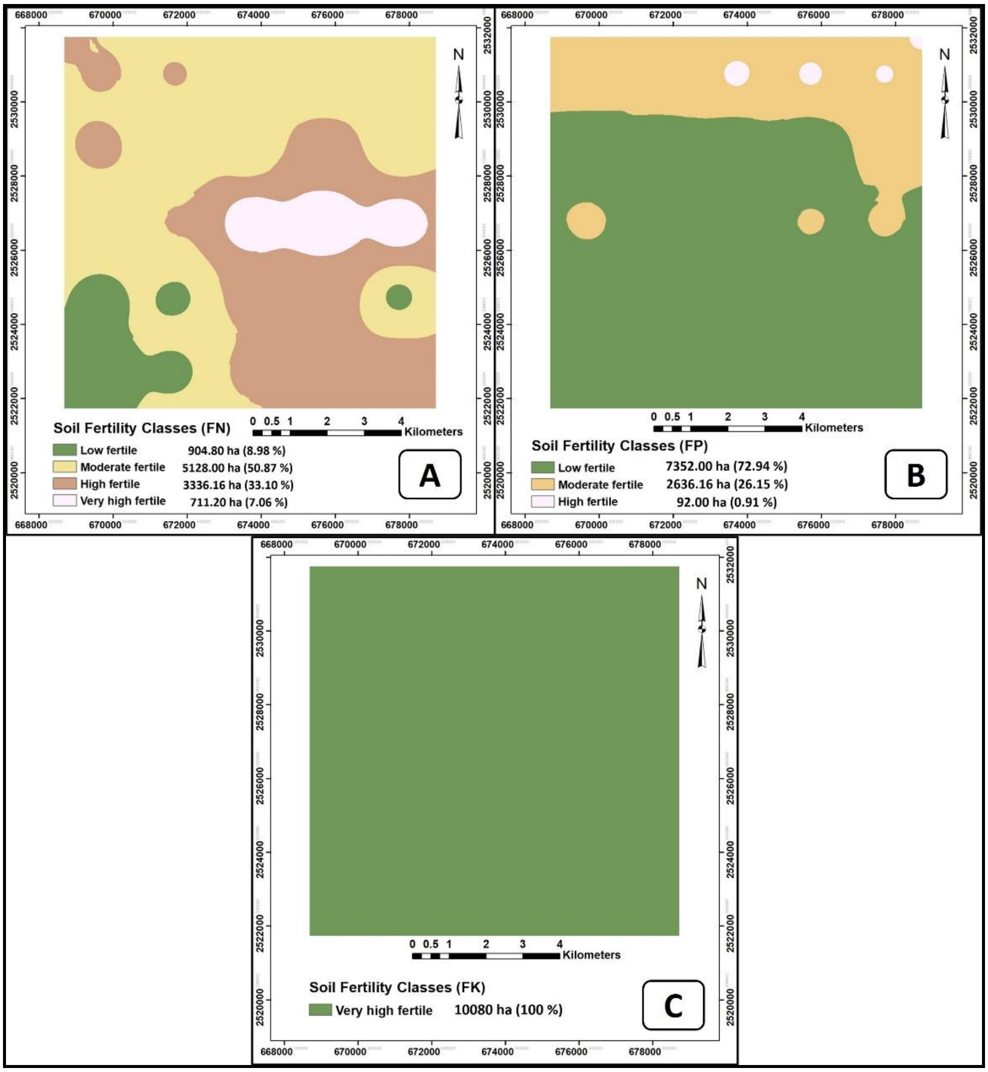

Fig. 2. NPK- soil fertility classes; A: nitrogen (FN), B: phosphors (FP), and C: potassium (FK)

A New Method to Determine the Soil Fertility Classes of the Whole Studied Area (NFI_{area}):

The study introduced an amendment to the equation of soil fertility classes of the whole studied area (Chase & Singh, 2014 and El-Seedy & Saeed, 2019). In equation 1, the soil fertility index of each class was weighted by using its soil samples number. This was down without any arguments, i.e., this operation is non-compiled with logic because there is no relation between the category of soil fertility category and its soil samples. Therefore, we strongly believe that the determination of (NFIarea) will be more accurate by weighing the index of each soil fertility class by its representative mapped area (%). Consequently, the area of each soil fertility class substituted its soil samples numbers in Eq-1 to obtain Eq -2. Therefore, Eq -2 was reliable to calculate soil fertility classes of the whole studied area (NFIarea). The results of the of Eq-2 indicated that the studied soils had 59.57 % (NFINarea), 31.87% (NFIParea) and 100% (NFIKarea) to describe the studied soil as high for nitrogen, moderate for phosphor and very high for potassium.

GIS – mapping of NPK Fertilizer Precise Requirements (FR_i):

NPK fertilizer precise requirements were calculated, for each soil sample, by applying Eq - 3, for three levels of expected wheat production table (5):

- low wheat production (< 500 kg ha^{-1})
- moderate wheat production (500 – 750 kg ha^{-1})
- high wheat production (750 -1000 kg ha^{-1})

The results of table (5) indicated that zero value generally referred to as there is no need to fertilizer application, whiles the negative (-) values of sign specified that there is an excess of NPK nutrients.

The georeferenced NPK fertilizers requirements enabled to map N and P precise requirements for three levels of expected wheat production (Figures 3, 4, 5). The negative (-) values of table (5) pointed out that there an excess of (K) and there no need to (K) fertilizer, even for obtaining the higher wheat production. For this reason, we could not map (K) precise requirements for all the three levels of wheat production. Generally, potassium has a significant effect on improving leaf photosynthesis ability, especially under stress conditions. Increasing of (K) application increase grains, wheat (*Triticum aestivum* L), production, but application over 100 (Kg ha^{-1}) has an inverse effect (Wang *et al.*, 2020). Figure (3-A) illustrated that most of the studied area had no need to N application for low wheat production (< 500 Kg ha^{-1}). 5 kg ha $^{-1}$ N must be applied to (55. 05 %) of the area to obtain moderate wheat production (500 – 750 kg ha^{-1}) (Figure 4-A). The objective of attainment high wheat production (750 -1000 kg ha^{-1}) classified the studied area into nine levels of N requirements (Figure 5-A). The minimum and maximum N applications were 10 and 95 kg ha^{-1} for the first and ninth level, respectively.

As for phosphorus, all levels of wheat production required P fertilizer applications. The low and moderate wheat production design five and six levels of P application, figures (3-B) and (4-B), respectively. Different eight P applications levels were assigned to have the high wheat production (Figure 5-B). The greater application was at a midpoint of 95 kg ha^{-1} its range of (80 -100 kg ha^{-1}). These results show that moderate and high wheat production leads to more different levels of NP fertilizers requirements (Table 6).

Table 5. NPK fertilizer precise requirements (FR_i)

Sample No.	Plant Nutrients											
	N				P				K			
	(Q_N) (kg root one $^{-1}$ha^{-1})	(FR_N) Wheat Production (kg ha^{-1})			(Q_P) (kg root one^{-1} ha^{-1})	(FR_P) Wheat Production (kg ha^{-1})			(Q_K) (kg root one^{-1} ha^{-1})	(FR_K) Wheat Production (kg ha^{-1})		
		Low	Moderate	High		Low	Moderate	High		Low	Moderate	High
1	119.41	-44.41	-1.41	40.59	82.92	-22.92	5.08	27.08	461.10	-411.10	-406.10	-401.10
2	119.57	-44.57	-1.57	40.43	81.89	-21.89	6.11	28.11	453.15	-403.15	-398.15	-393.15
3	88.64	-13.64	29.36	71.36	91.66	-31.66	-3.66	18.34	413.40	-363.40	-358.40	-353.40
4	86.74	-11.74	31.26	73.26	90.48	-30.48	-2.48	19.52	413.40	-363.40	-358.40	-353.40
5	86.74	-11.74	31.26	73.26	89.02	-29.02	-1.02	20.98	417.62	-367.62	-362.62	-357.62
6	124.96	-49.96	-6.96	35.04	32.21	27.79	55.79	77.79	436.80	-386.80	-381.80	-376.80
7	87.76	-12.76	30.24	72.24	42.92	17.08	45.08	67.08	417.50	-367.50	-362.50	-357.50
8	85.60	-10.60	32.40	74.40	42.33	17.67	45.67	67.67	422.75	-372.75	-367.75	-362.75
9	136.94	-61.94	-18.94	23.06	34.00	26.00	54.00	76.00	472.60	-422.60	-417.60	-412.60
10	88.64	-13.64	29.36	71.36	66.46	-6.46	21.54	43.54	365.70	-315.70	-310.70	-305.70
11	93.80	-18.80	24.20	66.20	70.14	-10.14	17.86	39.86	386.17	-336.17	-331.17	-326.17
12	120.00	-45.00	-2.00	40.00	38.71	21.29	49.29	71.29	442.40	-392.40	-387.40	-382.40
13	201.69	-126.69	-83.69	-41.69	59.17	0.83	28.83	50.83	539.81	-489.81	-484.81	-479.81
14	208.29	-133.29	-90.29	-48.29	63.68	-3.68	24.32	46.32	535.91	-485.91	-480.91	-475.91
15	188.72	-113.72	-70.72	-28.72	64.00	-4.00	24.00	46.00	400.00	-350.00	-345.00	-340.00
16	64.16	10.84	53.84	95.84	6.68	53.32	81.32	103.32	295.26	-245.26	-240.26	-235.26
17	65.35	9.65	52.65	94.65	7.00	53.00	81.00	103.00	286.20	-236.20	-231.20	-226.20
18	129.52	-54.52	-11.52	30.48	13.77	46.23	74.23	96.23	466.90	-416.90	-411.90	-406.90
19	124.58	-49.58	-6.58	35.42	13.20	46.80	74.80	96.80	453.39	-403.39	-398.39	-393.39
20	62.47	12.53	55.53	97.53	18.68	41.32	69.32	91.32	465.00	-415.00	-410.00	-405.00
21	60.21	14.79	57.79	99.79	18.79	41.21	69.21	91.21	447.29	-397.29	-392.29	-387.29
22	66.98	8.02	51.02	93.02	24.07	35.93	63.93	85.93	481.48	-431.48	-426.48	-421.48
23	127.77	-52.77	-9.77	32.23	54.01	5.99	33.99	55.99	387.40	-337.40	-332.40	-327.40
24	128.07	-53.07	-10.07	31.93	54.46	5.54	33.54	55.54	395.00	-345.00	-340.00	-335.00
25	133.30	-58.30	-15.30	26.70	8.97	51.03	79.03	101.03	468.69	-418.69	-413.69	-408.69

Note: zero value refers to there is no need to fertilizer application, and the negative, (-) indicated there is an excess of plant nutrient.

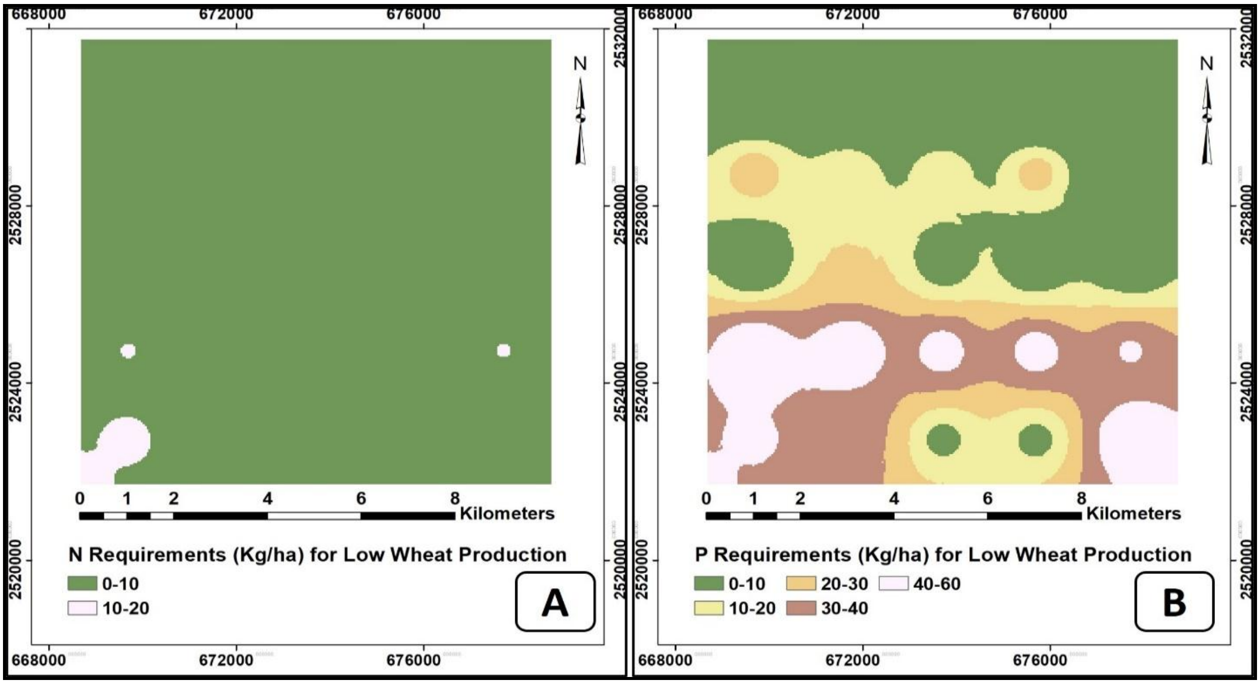

Fig. 3. N and P precise requirements (A: (FR_N) and B: (FR_P) for low wheat production (< 500 kg ha^{-1})

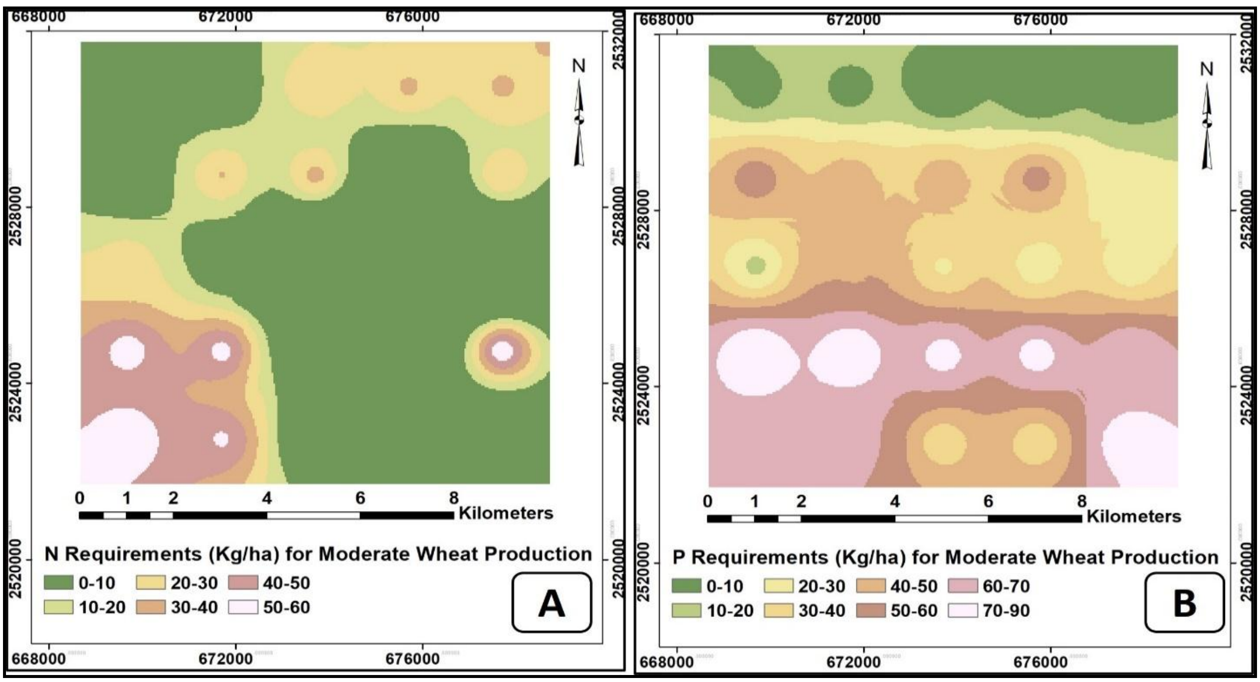

Fig. 4. N and P precise requirements (A: (FR_N) and B: (FR_P) for moderate wheat production (500-750 kg ha^{-1})

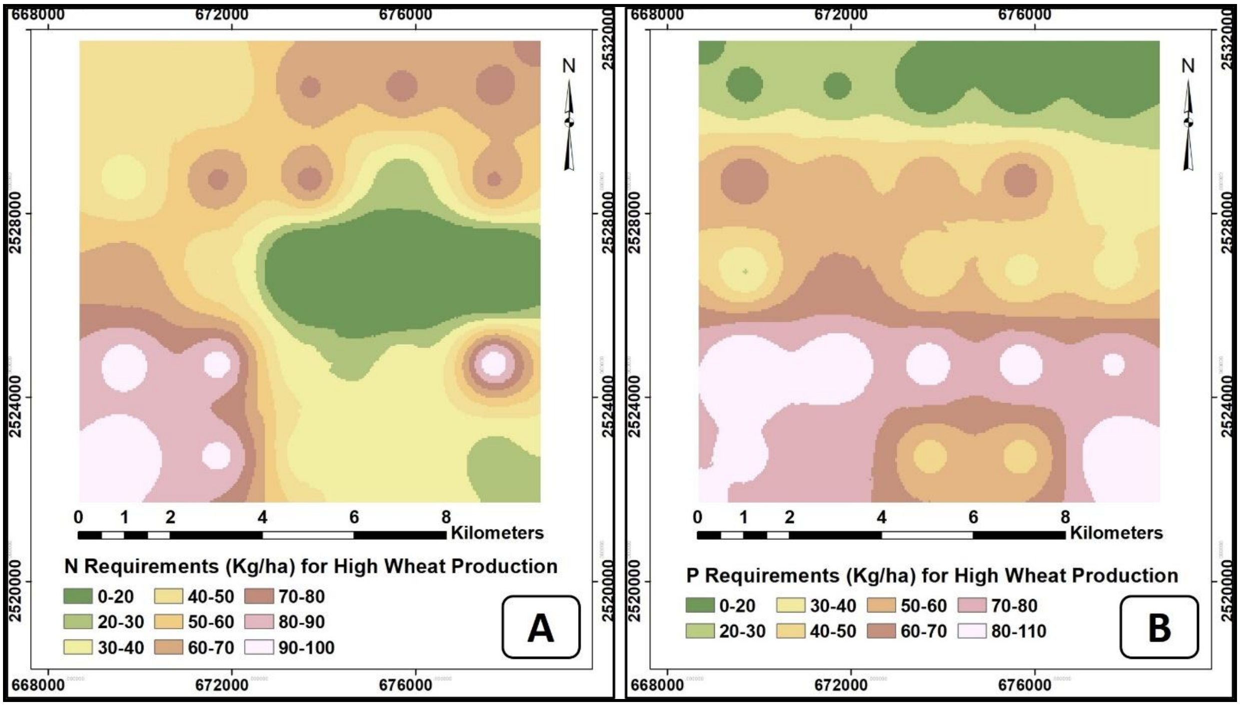

Fig. 5. N and P precise requirements (A: (FR_N) and B: (FR_P) For high wheat production (750-1000 kg ha^{-1})

Table 6. Precise Requirements of N and Fertilizers for different level of wheat production (kg ha^{-1})

Fertilizer Precise Requirements (FR_i)					
Class No.	N Precise Requirements (FR_N)		Class No.	P Precise Requirements (FR_P)	
	(kg ha^{-1})	(kg $Area^{-1}$)		(kg ha^{-1})	(kg $Area^{-1}$)
Low Production (< 500 Kg ha^{-1})					
1	0-10	49585.6	1	0-10	20763.2
2	Oct-20	2445.6	2	Oct-20	29640
			3	20-30	25916
			4	30-40	60838.4
			5	40-60	58832
Moderate Production (500 – 750 kg ha^{-1})					
1	0-10	27949.6	1	0-10	5736.8
2	Oct-20	21256.8	2	Oct-20	12129.6
3	20-30	37584	3	20-30	25212
4	30-40	15036	4	30-40	55972
5	40-50	36777.6	5	40-50	82425.6
6	50-60	17758.4	6	50-60	53882.4
			7	60-70	130457.6
			8	70-90	55846.4
High Production (750 -1000 kg ha^{-1})					
1	0-20	12795.2	1	0-20	9244.8
2	20-30	17340	2	20-30	22784
3	30-40	58363.2	3	30-40	31231.2
4	40-50	77040	4	40-50	64101.6
5	50-60	74712	5	50-60	108680
6	60-70	104124.8	6	60-70	67381.6
7	70-80	38832	7	70-80	130368
8	80-90	67428.8	8	80-110	111780.8
9	90-100	43335.2			

CONCLUSION

The determined concentration of soil available macronutrients (ppm) must be converted to (kg root zone^{-1} ha^{-1}) to correctly assign the fertility index to each soil sample. GIS –mapping of NPK soil fertility classes required georeferenced - UTM soil sampling. The approach of mapping the precise fertilizers requirements greatly saves the fertilization costs. In addition, this determination enables us to avoid the harmful effect of overdose fertilizer on the plant. For the economic viewpoint, the precise fertilizers requirements must be determined for the different crop production levels.

The equation of determination of soil fertility classes of the whole studied area of (NFIarea), weights soil fertility index of each class by multiplied by its soil samples number. This approach had no arguments, and it is non-compiled with logic because there is no relation between the category of soil fertility category and soil sampling (except the gridding design of soil sampling). So, the introduced mothed substituted the soil samples number, of each soil fertility class, by its area that is determined by GIS technique. This modification validated the (NFIarea), determination under all soil sampling designs. Finally, the paper concluded that moderate and high wheat productions lead to more levels of NP fertilizers requirements to make the precise determination of requirements soil fertilizers more vital.

REFERENCES

Abd El-Hady, A.M. 2015. Soil Fertility, (Sharq El-Owainat – Western South Egypt) , Technical Report, El-Zehra Comp. Cairo, pp. 1–15.

Abd El-Hady, A.M. and E.F. Abdelaty. 2019. GIS - Comprehensive Analytical Approach for Soil Use by Linking Crop Soil Suitability to Soil Management and Reclamation. Alex. Sci. Exch. J. 40: 60-81.

Andrews, S.S., D.L. Karlen and C.A. Cambardella. 2004. The soil management assessment framework: A quantitative evaluation using case studies, Soil Sci. Soc. Am. J., vol. 68, no. 6, pp. 1945–1962.

ArcMap 10.8. 2011. ESRI, Environmental Systems Research Institute,. U.S. Copyright 2008 ESRI Inc..

Bongiovanni, R and J. Lowenberg-Deboer. 2004. Precision Agriculture and Sustainability , . Precis. Agric. https://doi.org/10.1023/B:PRAG.0000040806.39604.aa

CAPMAS. 2021. Central agency for public mobilization and statistics (CAPMAS)." Egypt.

Chase, P and O.P. Singh. 2014. Soil nutrients and fertility in three traditional land use systems of Khonoma, Nagaland, India, Resour. Environ., vol. 4, no. 4, pp. 181–189.

Du, C and J. Zhou. 2009. Evaluation of soil fertility using infrared spectroscopy: a review, Environ. Chem. Lett., vol. 7, pp. 97–113.

Dwivedi, A., R.K. Naresh, R. Kumar, R.S. Yadav and R. Kumar. 2017. Precision Agriculture. Promoting agri-hortucultural, technological innovations. Parmar Publishers & Distributors.

Elseedy, M. 2019 .Soil fertility evaluation using ASLE, nutrient index models and GIS techniques: A case study on some soils of Dakahlia Governorate, Egypt, Egypt. J. Soil Sci., vol. 59, no. 4, pp. 403–415.

El-Seedy, M.E and M.A. Saeed. 2019. Tracking changes in soil fertility at North Nile Delta, Egypt using GIS techniques, J. Soil Sci. Agric. Eng., vol. 10, no. 10, pp. 627–635.

FAO. 2019. The international Code of Conduct for the Sustainable Use and Management of Fertilizers, Rome, Italy, FAO. 56 pp. https://doi.org/10.4060/ CA5253EN.

FAO. 1970. Physical and Chemical Methods of Soil and Water Analysis, Soils Bull. No. 10, Food and Agriculture Organization, Rome, Italy.

Gao, R., N. Ai, G. Liu, C. Liu and Z. Zhang. 2022. Soil C: N: P stoichiometric characteristics and soil quality evaluation under different restoration modes in the loess region of northern Shaanxi Province, Forests, vol. 13, no. 6, p. 913.

IFAD. 2021. Investing in rural people in Egypt. Int. Fund Agric. Dev., vol. Via Paolo.

Irawan, S., E. Antriyandarti, D.N. Suprihatin and A.W. Pangesti. 2022. Study the Relationship of Soil Fertility with Land Suitability For Arabica Coffee (Coffea arabica L.) Development in Bandar Sub-district, Pacitan District, in IOP Conference Series: Earth and Environmental Science, IOP Publishing, , p. 12029.

Kassim, Y., M. Mahmoud, S. Kurdi and C. Breisinger. 2018 . An agricultural policy review of Egypt: First steps towards a new strategy.

Kerry, R., M.A. Oliver and Z.L. Frogbrook. 2010. Sampling in precision agriculture,Geostatistical Appl. Precis. Agric., pp. 35–63.

Liakos, K.G., P. Busato, D. Moshou, S. Pearson and D. Bochtis. 2018. Machine Learning in Agriculture: A Review. Sensors, 18, 2674. https://doi.org/10.3390/s18082674.

Liang, X., T. Yang, J. Niu, L. Zhang, D. Wang, J. Huang, Z. Yang and R. Berndtsson. 2022. Quality assessment and rehabilitation of mountain forest in the Chongli Winter Olympic Games Area, China, Forests, vol. 13, no. 5, p. 783.

Liu, G., Y. Li and A. Gazula. 2019. Conversions of Parts per Million on Soil Test Reports to Pounds per Acre ,-HS1229 , pp: 1-3 , UFIFAS Extension , Florida University , https://edis.ifas.ufl.edu/pdf/HS/HS122900.pdf

McBratney, A., B. Whelan, T. Ancev and J. Bouma. 2005. Future directions of precision agriculture, Precis. Agric., vol. 6, pp. 7–23.

Mohamed, M.A, G.A. Elgharably, M.H. Rabie, H.M. Mohamed and M.A. Eissa. 2019. Evaluation of Soil Fertility Status in Toshka, Egypt: Available

Micronutrients, World J. Agric. Sci, vol. 15, pp. 1–6.

Mokaya, V. 2019. Future of precision agriculture in India using machine learning and artificial intelligence, Int. J. Comput. Sci. Eng, vol. 7, no. 2, pp. 1020–1023.

Munnaf, M.A. and A.M. Mouazen. 2021. Development of a soil fertility index using on-line Vis-NIR spectroscopy, Comput. Electron. Agric., vol. 188, p. 106341.

Nafiu, A.K., M.O. Abiodun, I.M. Okpara and V.O. Chude. 2012. Soil fertility evaluation: a potential tool for predicting fertilizer requirement for crops in Nigeria, African J. Agric. Res., vol. 7, no. 47, pp. 6204–6214.

Nariyanti, S., A. Herawati, G. Herdiansyah, H. Irianto, E.W. Riptanti and A.Qonita. 2022. Soil fertility index based on altitude: A comprehensive assessment for the cassava development area in Indonesia, Ann. Agric. Sci., vol. 67, no. 2, pp. 158–165,.

Page, A.L., R.H. Miller and D.R. Keeney. 1982. Methods of soil analysis, part II, Am. Soc. Agron. Madison, WI,.

Pang, D., J. Cao, X. Dan, Y. Guan and J. Zhou. 2018. Recovery approach affects soil quality in fragile karst ecosystems of southwest China: Implications for vegetation restoration,Ecol. Eng., vol. 123, pp. 151–160.

Pini, M., G. Marucco, G. Falco, M. Nicola and W.D. Wilde. 2020. Experimental testbed and methodology for the assessment of RTK GNSS receivers used in precision agriculture, IEEE Access, vol. 8, pp. 14690–14703.

Ravikumar, P. 2014. Spatial distribution of macronutrients in soils of Markandeya river basin, Belgaum (d), Karnataka (s), India, Proc. Int. Acad. Ecol. Environ. Sci., vol. 4, no. 2, p. 81,.

Sarkar, A.K. 2015. Soil acidity and liming, Soil Sci. An Introd. (Eds. RK Ratt. JC Katyal, BS Dwivedi, AK Sarkar, T. Bhattacharyya, JC Tarafdar SS Kukal). Indian Soc. Soil Sci. New Delhi, pp. 329–352,.

Teagasc. 2022. soil index System, Head Off. Teagasc, Oak Park. Carlow, R93 XE12, , [Online]. Available: https://www.teagasc.ie/crops/soil--soil-fertility/soil-analysis/soil-index-system/.

Tunçay, T., Ş. Kılıç, M. Dedeoğlu, O. Dengiz, O. Başkan and I. Bayramin. 2021. Assessing soil fertility index based on remote sensing and gis techniques with field validation in a semiarid agricultural ecosystem, J. Arid Environ., vol. 190, p. 104525,.

USAID. 2022. United States Agency for International Development, [Online]. Available: https://www.usaid.gov/egypt/agri- culture-and-food-security.

Wang, Y., Z. Zhang, Y. Liang, Y. Han, Y. Han and J. Tan. 2020. High potassium application rate increased grain yield of shading-stressed winter wheat by improving photosynthesis and photosynthate translocation, Front. Plant Sci., vol. 11, p. 134.

Yang, M., A. Mouazen, X. Zhao and X. Guo. 2020. Assessment of a soil fertility index using visible and near-infrared spectroscopy in the rice paddy region of southern China, Eur. J. Soil Sci., vol. 71, no. 4, pp. 615–626.

Zhang, M.K and J.M. Xu. 2005. Restoration of surface soil fertility of an eroded red soil in southern China, Soil Tillage Res., vol. 80, no. 1–2, pp. 13–21.

Zhang, N., M.Wang and N. Wang. 2002. Precision agriculture—a worldwide overview, Comput. Electron. Agric., vol. 36, no. 2–3, pp. 113–132.

Zhao, W., X. Cao, J. Li, Z. Xie, Y. Sun and Y. Peng. 2023. Novel Weighting Method for Evaluating Forest Soil Fertility Index: A Structural Equation Model, Plants, vol. 12, no. 2, p. 410.

الملخص العربي

تقييم خصوبة التربة والاحتياجات السمادية من النيتروجين والفوسفور والبوتاسيوم لمحصول القمح (شرق العوينات – جنوب غرب مصر)

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الوادي الجديد من المناطق الواعدة للمشروعات الزراعية القومية في مصر. واستخدام مؤشر خصوبة التربة والزراعة الدقيقة يسعى إلى تعظيم الإنتاجية وتقليل الأضرار البيئية. لذلك فإن الهدف من هذه الدراسة هو تقييم خصوبة التربة من العناصر الكبرى (النيتروجين – الفوسفور – البوتاسيوم). من أجل ذلك تم جمع ٢٥ عينة تربة (عمق ٠-٥٠ سم). وقد أظهرت النتائج أن معظم عينات التربة كانت متوسطة (Mf) وعالية الخصوبة (Hf) بالنسبة للنيتروجين بنسبة (٤٤٪). بخلاف ذلك، كانت ٦٤٪ من عينات التربة ذات خصوبة منخفضة بالنسبة للفوسفور، والتي لديها قدرة إنتاج قمح منخفضة (أقل من ٥٠٠ كجم/هكتار).

صنفت خريطة GIS لفئات خصوبة التربة (FN) عينات التربة إلى أربع مجموعات. تميزت خريطة خصوبة التربة بالنسبة للفوسفور بغياب فئة الخصوبة العالية جدًا، ووجود فئة الخصوبة العالية بنسبة قليلة جدا (٩٢,٠٠ هكتار، ٠,٠٩٪)، وهيمنة فئة الخصوبة المنخفضة (٧٣٥٢,٠٠ هكتار، ٧٢,٩٤٪). أما بالنسبة لفئات الخصوبة الخاصة بالبوتاسيوم فقد احتلت فئة الخصوبة العالية جدا كامل المساحة المدروسة (١٠٠٨٠ هكتار، ١٠٠٪). بالنسبة للنيتروجين فقد أوضحت الخرائط أن معظم المنطقة المدروسة لم تكن بحاجة لاستخدام النيتروجين في الحصول على الإنتاج المنخفض من القمح (<٥٠٠ كجم / هكتار)، ونحتاج لإضافة ٥ كجم للهكتار من النيتروجين على (٥٥,٥٪) من المنطقة المدروسة للحصول على الإنتاجية المتوسطة من القمح (٥٠٠- ٧٥٠ كجم / هكتار).

لتحقيق الإنتاجية المرتفعة من القمح (٧٥٠-١٠٠٠ كجم / هكتار) تم تصنيف المنطقة إلى تسعة مستويات مختلفة من الاحتياجات النيتروجينية وثمانية مستويات مختلفة من الاحتياجات الفوسفاتية. وأخيرًا أشار البحث إلى عدم وجود حاجة لسماد البوتاسيوم حتى في حالة الحصول على الإنتاجية العالية من القمح.

الكلمات الدالة:فئات الخصوبة، الزراعة الدقيقة، الوادي الجديد.