Zagazig J. Agric. Res., Vol. 51 No. (5) 2024 991-1000

Soil Science and Agricultural Engineering

Available online at http://zjar.journals.ekb.eg
http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

SPATIO-TEMPORAL VARIATION OF SOIL FERTILITY STATUS UNDER POTATO CROP (*Solanum tuberosum*) CULTIVATION IN NEWLY RECLAIMED SOIL

Ibrahim F. Ibrahim*, A.M. Helmy, Sara E. Fouda, M.M. Khalil and S.M. Shaddad

Soil Sci. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 15/09/2024; Accepted: 22/09/2024

ABSTRACT: Soil properties vary greatly over space and time; therefore, the precise detection of spatio-temporal variation is essential to understand the dynamic soil conditions and consequently apply site-specific management. This paper aims at studying the spatial and temporal variation in some soil properties within a period of 4 years in a field cultivated by potato crop with a fixed annual compost application. Inverse distance weighting as a deterministic method was used to develop the spatial distribution maps of the studied soil properties (soil reaction, electrical conductivity, cation exchange capacity and soil organic matter). These maps were annually created for the soil properties under investigation, *i.e.* 2019, 2020, 2021 and 2022. Results revealed that there was variation over space and time for all soil parameters under study. Spatial maps of soil pH showed an annual change with a temporal increase comparing 2019 with 2022. Soil salinity maps revealed a decrease in both spatial and temporal scales. Spatial maps of CEC showed a fluctuation in the spatial distribution as well as from year to year with final improvement reaching a value of 20.4 cmol+/kg. Soil organic matter spatial maps showed an opposite pattern compared with the other soil parameters where a decrease in SOM was observed comparing the start and end of the whole period of study.

Key words: Spatio-temporal, soil fertility, potato crop, newly reclaimed soil.

INTRODUCTION

The Western Desert of Egypt is a key area for such agricultural expansion, which represents about two thirds of the Egyptian territory. It includes different areas (five Oases in the Western Desert including Siwa, Bahariya, Farafra, Dakhla, and Kharga and three depressions including Fayoum, Wadi El-Natrun, and Qattara) that could be used for agricultural purposes on the basis of their land suitability and availability of water resources **Ramady *et al.* (2019).** Surface irrigation is the common irrigation system used in Egypt, which is not efficient and loses a considerable amount of water. Additionally, it might not be suitable for certain crops of low water requirements. Therefore, precise irrigation is a key factor for optimizing potato production in these regions through an effective irrigation management and scheduling (right amount at a right time) as it is one of the water sensitive crops. Scheduling of irrigation at the critical stages would increase crop productivity and water use efficiency of potato, **Yin *et al.* (2023)**. There are numerous approaches that can be used to schedule irrigation, which differ in precision, time and cost **(FAO, 2000; Jones 2004 and Assouline, 2019)**.

Soil is a dynamic and complex ecosystem that plays a pivotal role in agricultural productivity, influencing not only crop yield but also plant health and soil sustainability. Among various soil types, sandy soils are characterized by their coarse texture, rapid drainage, and lower nutrient-holding capacity, presenting unique challenges and opportunities for agricultural practices. In regions where sandy soils dominate, cultivation of potato (*Solanum tuberosum*), a crop that demands specific moisture and nutrient conditions, becomes increasingly intricate.

* **Corresponding author: Tel. :**+ 201141210105
E-mail address: ibrahemfatoh483@gmail.com

Understanding the spatio-temporal variations of sandy soils under potato cultivation is crucial for optimizing crop management strategies and enhancing agricultural sustainability.

Soil is a dynamic and heterogeneous natural resource that displays significant spatial and temporal variations due to a multitude of influencing factors, including climate, topography, vegetation, and anthropogenic activities. Understanding such variations is crucial for effective land management, agricultural sustainability, and environmental protection. Spatial variation pertains to the differences in soil properties observed across different locations, which can result from historical geological processes, contemporary land-use practices, and localized climatic conditions **(Baker *et al.*, 2005).** Temporal variation, on the other hand, refers to changes in soil characteristics over time, often influenced by seasonal shifts, climatic changes, and soil management practices **(Zhao *et al.*, 2018).** The complexity of these variations necessitates a multifaceted approach in soil research, requiring integration of field studies, remote sensing technologies, and advanced statistical models to capture the intricate patterns of soil dynamics. By delving into the spatial and temporal aspects of soil variability, researchers and practitioners can better predict soil behavior, enhance agricultural productivity, and inform conservation strategies **(Liu *et al.*, 2021).**

The spatio-temporal variations in soil characteristics such as texture, moisture content, nutrient availability, and microbial activity significantly affect potato growth and tuber quality. These variations can occur due to factors like weather patterns, irrigation practices, soil amendments, and land use changes, necessitating a comprehensive understanding of their interplay. By analysing soil attributes across different spatial scales and over time, farmers and agronomists can formulate more effective agronomic interventions tailored to the specific needs of potato crops.

This study aims at investigating the spatio-temporal variability in soil under potato crop cultivation during the period between 2019 and 2022.

MATERIALS AND METHODS

Experiment Location and Climatic Conditions

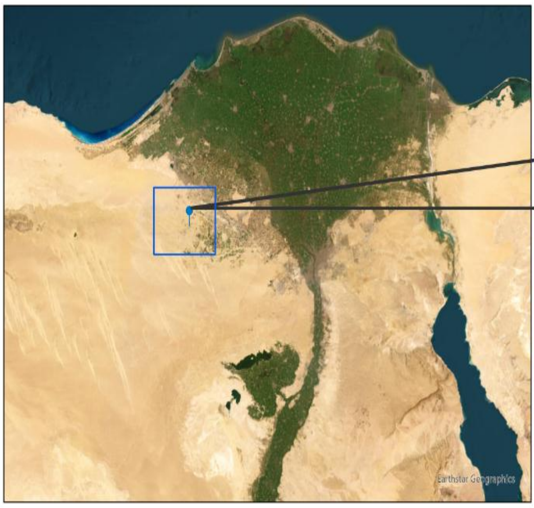
The experiment was conducted in the Wadi El-Natroun region of Egypt (30°17'59.8"N 30°01'39.9"E), Figure 1. Wadi El-Natroun is a narrow depression situated to the West of the Nile Delta, encompassing an area of 281.7 km² (equivalent to 28,170 ha). The area in question presents a potential opportunity for reclamation and utilisation, given its strategic location in close proximity to Cairo and the availability of groundwater of suitable quality for irrigation purposes.

The source of irrigation water is groundwater, which is used in through a centre pivot irrigation system. The subterranean water in Wadi El-Natroun has its source in seepage from the Nile stream, due to its proximity and low level **(Gabr, 2023).** The EC of the irrigation water is 1.55 dSm^{-1}, which is suitable for the growth of potatoes. The Wadi El Natroun area is classified as an extremely arid region, characterised by a mean annual rainfall of 41.4 mm, evaporation of 114.3 mm and temperature of 21°C (**EMA, 1996**). Physical and chemical properties of soil are listed in Table 1. Also, more details about the climatic conditions over the crop growth season are shown in Table 2.

Soil Sampling and Laboratory Analysis

Eight soil samples representing the whole pivot were collected after harvest time each year during the years of 2019, 2020, 2021 and 2022. Soil samples were air-dried and sieved through a 2 mm sieve and subjected to the following analysis: pH, electrical conductivity (EC) of paste extract, cation exchange capacity (CEC), organic matter (OM).

Soil reaction (pH) was measured using a glass electrode in soil suspension (1:2.5 w:v) and electrical conductivity (EC) was measured in soil paste extract using EC meter according to (**USDA, 1954**). CEC was measured according to **Jackson (1958)**. Organic matter (OM) was determined according to **Black *et al.* (1965)**. Soil texture was determined according to the international pipette method, **Wirth (1946)** and the soil moisture properties were measured according to **Baruah and Barthakur (2001).**



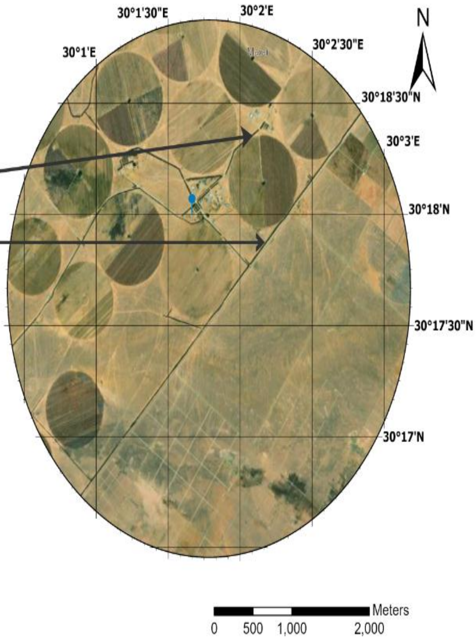


Fig. 1. geographical settings of the study area

Table 1. Soil physical and chemical analysis of both sites

Property			**Soluble Ions (mmole$_c$ L^{-1})**		
Physical Property				**CO_3**	nil
%	**Clay**	1.38	**Anion**	**HCO_3**	0.86
	Silt	1.61		**Cl**	21.50
	Sand	97.01		**SO_4**	5.51
Soil Texture Class		Sand	**Cation**	**Ca**	7.31
Soil moisture property (%)				**Mg**	4.32
Saturation		30.25		**Na**	15.2
Field Capacity		15.79		**K**	1.03
Wilting Point		7.43			
pH (Water: Soil, 1:2.5 suspension)		7.90	**Available Nutrient (mg kg^{-1})**	**N**	186
EC, Soil Paste (dS m^{-1})		2.86		**P**	21.8
$CaCO_3$ (g kg^{-1})		29.7		**K**	188
OM (g kg^{-1})		3.91		**Mn**	3.25
				Zn	1.06
				Fe	4.07
				Cu	0.96

Soluble ions were determined in the extract of the soil paste

Table 2. Meteorological data of the experimental site during the growth season 2019-2020.

Climatic factor	Precipitation (mm)	T max. (°C)	T min. (°C)	Relative humidity (%) (Max)	Evapotranspiration (ET) (mm day^{-1})	Solar Radiation, (W m^{-2})	Wind Speed (m s^{-1}) (Max)
September	0.0	37.5	17.1	53	4.8	205.184	3.0
October	0	38.6	13.2	56	3.6	138.568	2.8
November	0.4	25.8	6.7	70	2.6	11.959	2.6
December	0	24.6	5.2	87	2.2	100.408	4
January	0	20.5	3.7	79	2.4	113.43	5.4

Note: The weather station is located inside the center pivot, at a height of one meter and half over the plants. T max. and T min. are the maximum and minimum temperatures during the month, respectively.

Soluble ions were measured as described by **Miller and Curtin (2007)**. Available macro and micronutrients as well as available nitrogen (NH_4-N and NO_3-N) were extracted with KCl (2N). The available phosphorus content (P) was extracted and measured calorimetrically using the ascorbic acid method with UV–vis-NIR spectrophotometer **Olsen *et al.* (1954)**. The available potassium (K) (mg kg^{-1}) was extracted using 1.0 N ammonium acetate at pH 7.0 and determined using flame photometer method **(Jackson, 1958)**.

Spatial Distribution of Soil Properties

Inverse distance weighting (IDW) was used to develop continuous surface mapping to illustrate the spatial distribution of the studied soil parameters over 4 years (2019–2022). IDW explicitly makes the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW uses the measured values surrounding the prediction location.

The study area during the period between 2019 and 2022 was cultivated by potato crop **(***Solanum tuberosum* L**.** var. Santana**)**, with an annual rate of compost equal to 71.5 Mg ha^{-1} added to soil during its preparation. Brief description of agricultural practices for potato are reported in (Table 3). Fertilization program of potato crop was applied according to the FAO guidelines as follows: 80-120 kg N ha^{-1}, 50-80 kg P ha^{-1} and 125-160 kg K ha^{-1}, **(Ali *et al.*, 2021)**.

RESULTS AND DISCUSION

Soil pH

Fig. 2 (a-d) shows the spatio-temporal variation during the 4 years. The pH maps show (Figure 2a) a slight difference in their values within the time span from 2019 to 2022. All spatial maps over the whole period indicate an alkaline soil reaction but it is worth to mention that the pH spatial maps of 2022 showed and increased values as compared with the map of 2019.

Electrical Conductivity

The soil salinity level at the first year (2019) was higher than the other three years indicating that the agricultural practices had a great impact in reducing soil salinity. The EC spatial map (Fig. 2b) of 2019 show three different classes reaching a maximum value in each class of 3.53, 5.47 and 7.40 dS m^{-1} ordered from the lowest class to the highest class. Looking at the spatial maps of 2020, 2021 and 2022 these was a clear decrease in soil salinity over the whole area under study. Such decrease in soil salinity may positively enhance the soil conditions for better plant growth.

Cation Exchange Capacity (CEC)

Cation exchange capacity, (CEC) is one of the most important soil fertility indicator. Therefore, any improvement in, it would positively affect soil nutrient retention and consequently plant uptake. The spatial map of CEC (Fig. 2c) shows some artefacts over the field where there was no

Table 3. Brief description of potato agricultural practices performed in both sites.

Agricultural practice	Description
Soil preparation	Ploughing with Packer on 15/09/2019
	Rotary harrowing on 28/09/2019
	Ridge (The soil was ridged to 25cm above the tubers and the distance from top of the ridge to the bottom of the furrow was around 34 cm) on 12/10/2019.
	Dammer diker on 15/10/2019
Crop planting	Planting date on 28-29/09/2019
	planting distances (18.5 cm)
	The number of potato tubers used for planting (6 tubers/ m^2)
	Seed rate (3480 kg ha^{-1})
	First possible harvest (Jan. 14, 2019)
	Previous crop (Spring barley)

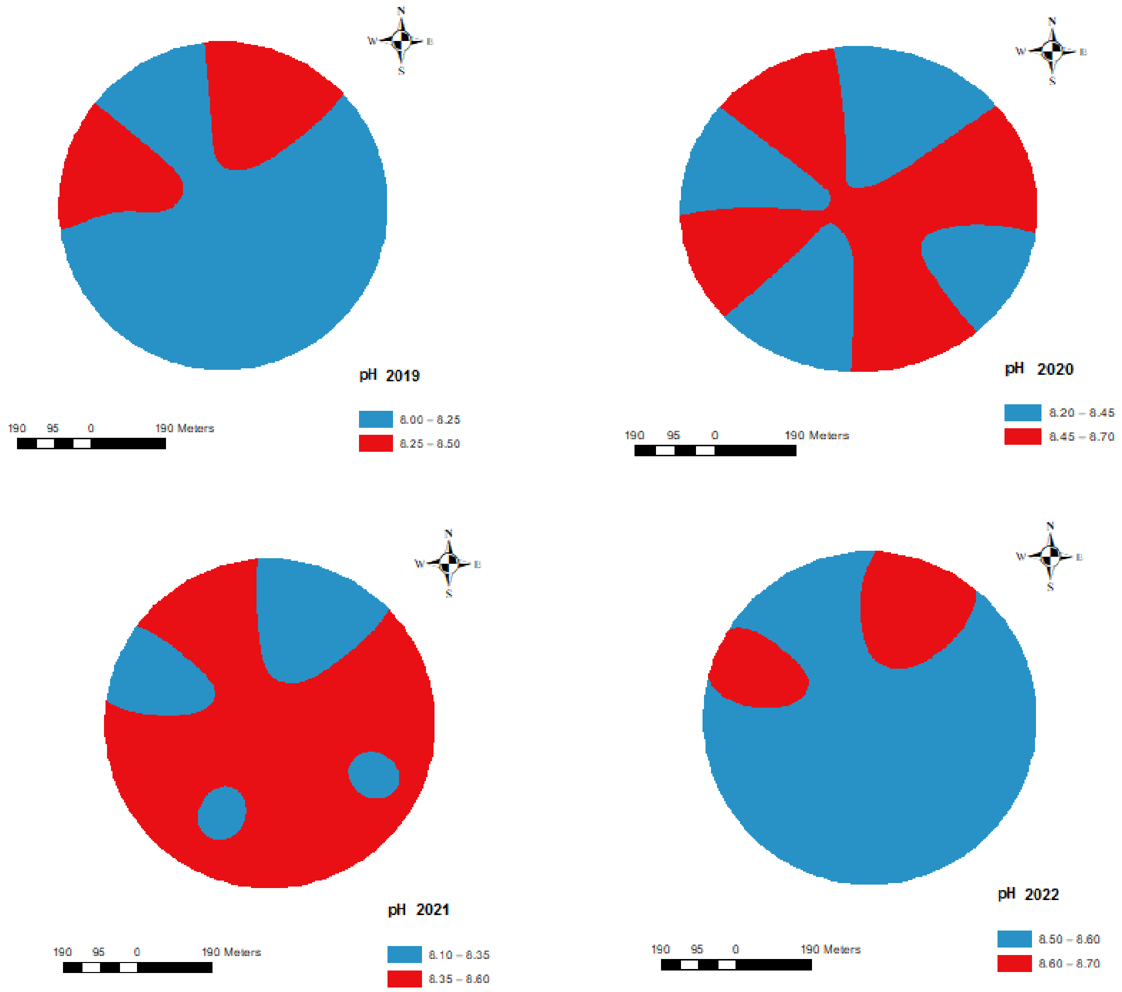


Fig. 2a. The spatio-temporal variation during the 4 years (pH)

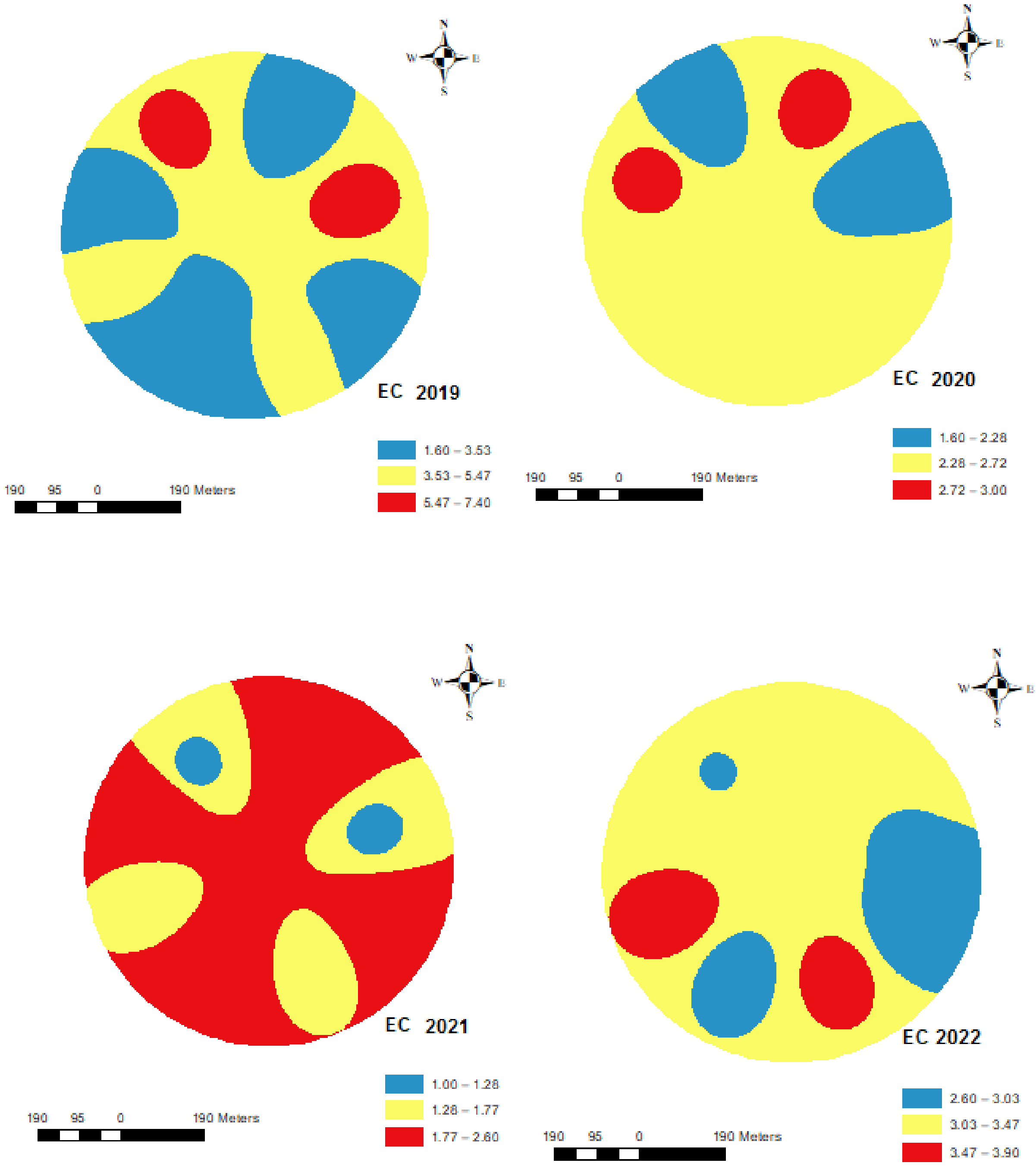


Fig. 2b. The spatio-temporal variation during the 4 years (EC)

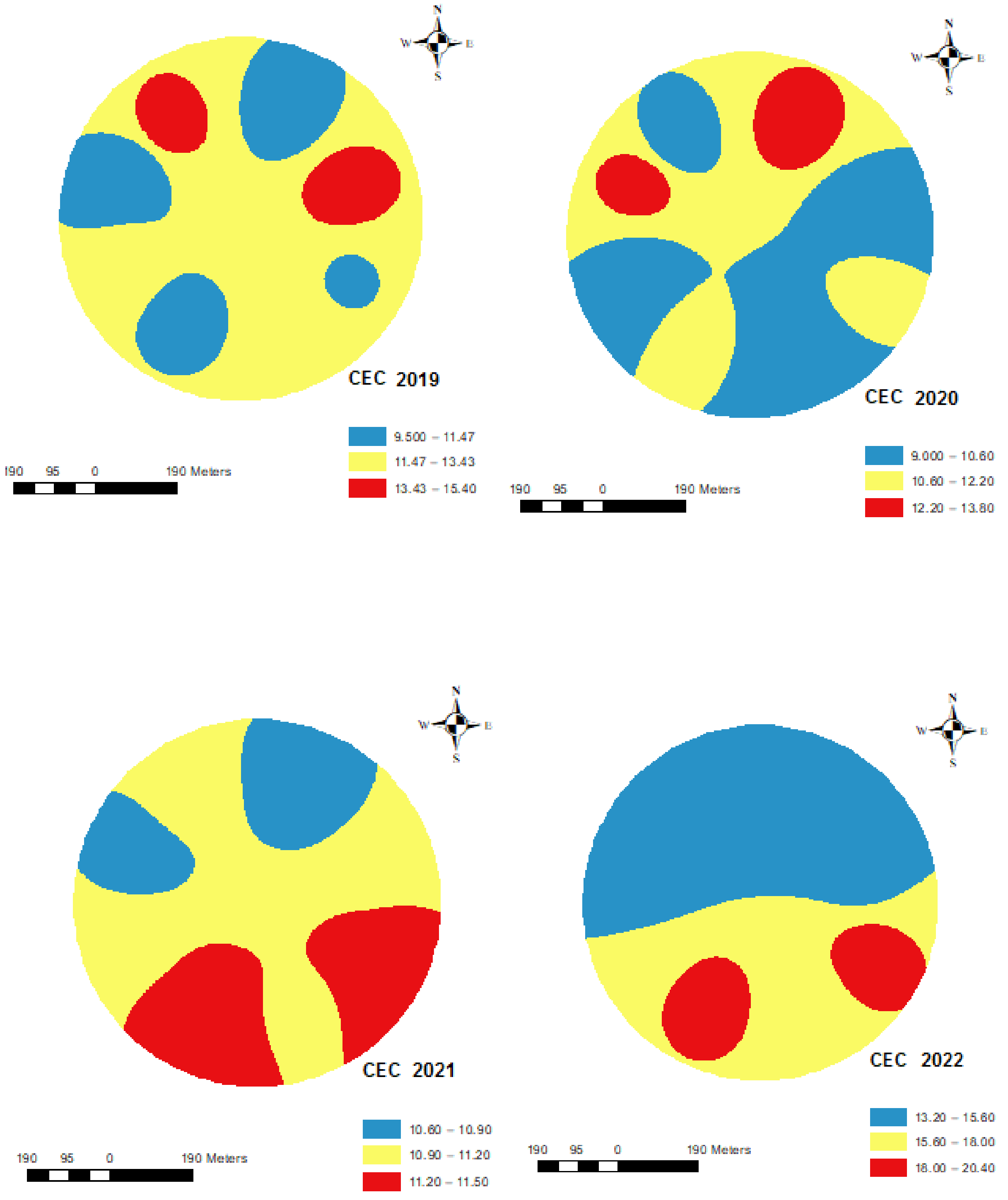


Fig. 2c. The spatio-temporal variation during the 4 years (CEC)

considerable change in years 2019, 2020 and 2021. However there was an increase in **CEC comparing the first year with the last year (2022)**. This effect might be attributed to application of compost during the 4 years of application. There was a fluctuation in CEC values over the filed during the first three years of application, however when comparing the last year with the previous years there was an increase in all map classes reaching a maximum value of 20.4 $cmol^+/kg$.

Soil organic Matter (SOM)

Soil organic matter is an important indicator of soil health as it affects greatly soil physical, chemical and biological properties. However, accumulation of soil organic matter is usually rapid initially. It declines slowly, and reaches an equilibrium level varying from thousands of years in sandy materials to hundreds of years in fine-textured soils (**Sparks, 2003**). This fact was evident when looking at the first-year soil organic matter content. It reached values between 0.44 and 0.53% in the first year and started to decrease during the years 2020 and 2021, then a more decrease was observed in 2022 SOM spatial map with values ranged between 0.24 and 0.34% (Fig. 2d). This may be attributed to the hot and dry conditions characterizing the region where the study area is located.

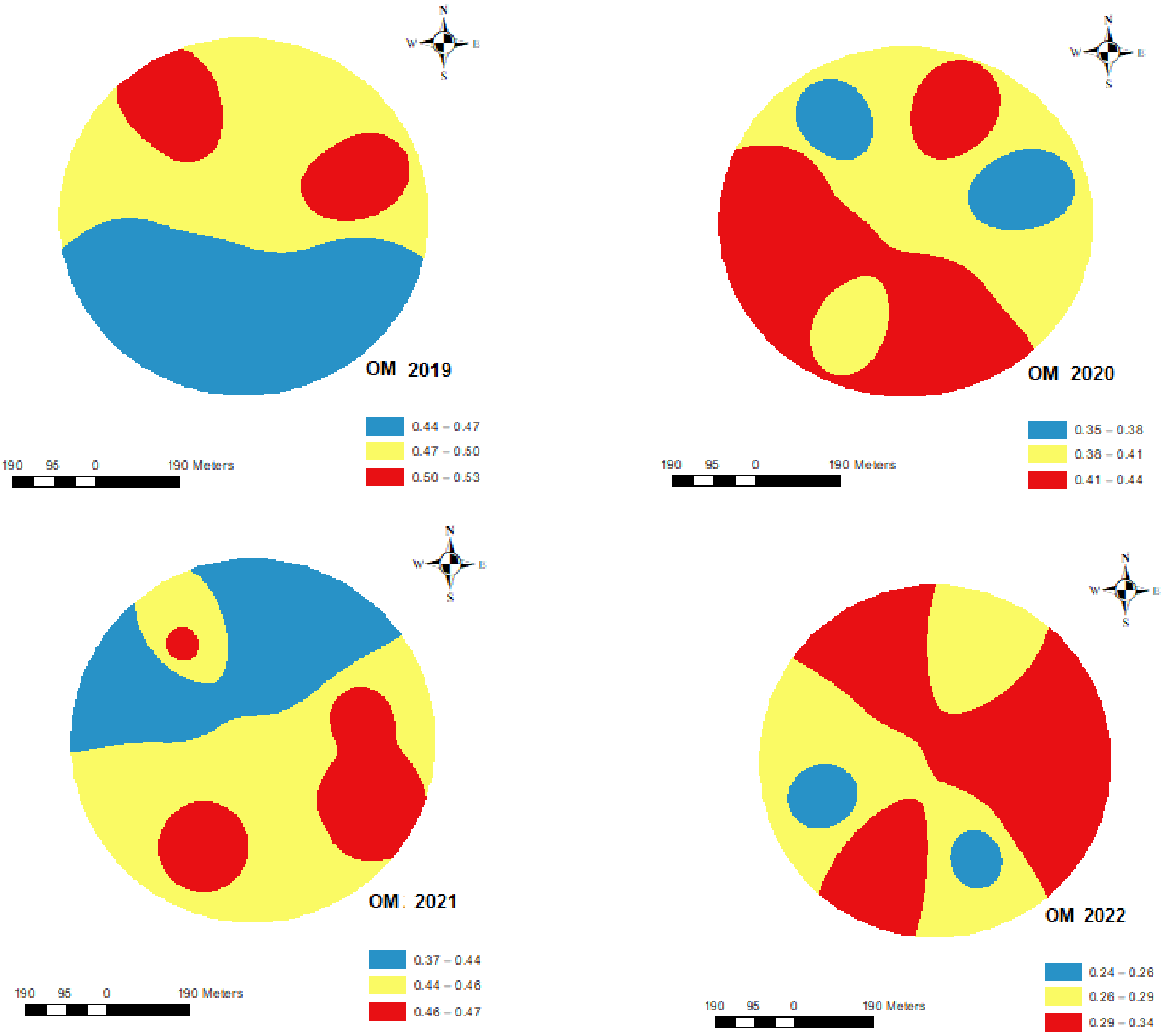


Fig. 2d. The spatio-temporal variation during the 4 years (SOM)

Conclusion

Spatial and temporal variation of some soil properties was affected by the consecutive cultivation of potato crop and compost application within the 4-year period. The spatial maps of the studied soil parameters were created using the deterministic method of interpolation named as inverse distance weighting. The spatial maps of soil pH over the 4 years showed slight differences. Maps of EC and CEC show an clear improvement over spatial and temporal scales. The temporal SOM variation show a decrease pattern considering the start and end years of application. A delineation of management zones could be helpful to precisely apply all agricultural inputs.

REFERENCES

Ali, M.M.E., S.A. Petropoulos, D.A.F.H. Selim, M. Elbagory, M.M. Othman, A.E.D. Omara and M.H. Mohamed (2021). Plant Growth, Yield and Quality of Potato Crop in Relation to Potassium Fertilization. Agron., 11: 675.

Assouline, S. (2019). A simple method to design irrigation rate and duration and improve water use efficiency. Water Res. Res., 55 6295 –6301:doi:10.1029/2019WR025221.

Baker, J.M., A.E. Suyker and K.J. Davis (2005). Crop management and environmental impact. Agric. Systems, 86 (1): 432-452.

Baruah, T.C. and H.P. Barthakur (2001). A Textbook of Soil Analysis. Publisher, Sangam Books Limited, India.

Black, C.A., D.D. Evans, L.E. Ensminger, J.L. White and F.E. Clarck (1965). Methods of Soil Analysis. Ame. Soc. Agron, Madison, Wisconsin, U.S.A.

EMA (1996). Numerical Models in EMA (Egyptian Meteorological Authority, 1996).

FAO (2000). Global Forest Resources Assessment 2000: Main Report; Food and Agriculture Organization (FAO) of the United Nations.

Gabr, M. (2023). Land reclamation projects in the Egyptian Western Desert: management of 1.5 million acres of groundwater irrigation., doi:10.1080/02508060.2023.2185745.

Jackson, M.L. (1958). Soil Chemical Analysis. Prentice Hall, Inc., Englewood Cliffs, New Jersey, USA.

Jones, H.G. (2004). Irrigation scheduling: advantages and pitfalls of plant-based methods. J. Exp. Bot., 55: 2427-2436.

Liu, D., X. Zhang and Y. He (2021). Effects of land use change on soil properties in agricultural systems: A meta-analysis. Soil Use and Manag., 37 (1): 35-45.

Miller, J.J. and D. Curtin (2007). Electrical Conductivity and Soluble Ions. 161-171, doi: 10.1201/9781420005271.ch15.

Olsen, S.R., C.V. Cole, S.W. Frank and L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United states Dept. Agric., Colorado, USA.

Ramady, H.T., A.N. Bakr, T. Elbana, E. Mohamed and A.A. Belal (2019). The Soils of Egypt. Soil Science (65). Cham: Springer, International Publishing.

Sparks, D.L. (2003) Environmental soil chemistry. Academic Press, Elsevier Sci., Camb., MA, USA.

USDA (1954). Diagnosis and improvement of saline and alkali soils. Agriculture Hand Book No. 60 US Gov. Printing Office, Washington, D.C., USA.

Wirth, E.H. (1946). Soil and plant analysis, by C.S. PIPER. Interscience Publishers, Inc., New York. J. Ame. Pharm. Assoc., 35:192-192, doi:https://doi.org/10.1002/jps.3030350611.

Yin, J., Y. Yang, R. Eeswaran, Z. Yang, Z. Ma, and F. Sun (2023). Irrigation scheduling for potatoes (*Solanum tuberosum* L.) under drip irrigation in an arid region using AquaCrop model. Frontiers in Plant Sci., 14: doi:10. 3389/fpls.2023.1242074.

Zhao, J., Z. Li and Q. Li (2018). Temporal variations in soil moisture and their influences on soil enzyme activities in different land uses. Geoderma, 318: 196-203.

التبـــايـــن المكـــانـــي والـــزمـــانـــي لحـــالـــة خصـــوبـــة التـــربـة تحت زراعـــة محصـــول البطـــاطس (*Solanum tuberosum*) في التـــربـــة المستصلحـــة حديثـــًا

إبراهيم فتوح إبراهيم - أيمن محمود حلمي - ساره السيد السيد فوده - محمد محمود نبيل- سامح محمد شداد

قسم علوم الأراضي - كلية الزراعة - جامعة الزقازيق - مصر

تختلف خصائص التربة بشكل كبير عبر المكان والزمان؛ لذلك، فإن الكشف الدقيق عن التباين المكاني والزماني أمر ضروري لفهم ظروف التربة الديناميكية وبالتالي تطبيق الإدارة الخاصة بالموقع. تهدف هذه الورقة البحثية إلى دراسة التباين المكاني والزماني في بعض خصائص التربة خلال فترة 4 سنوات في حقل مزروع بمحصول البطاطس مع تطبيق سماد سنوي ثابت. تم استخدام ترجيح المسافة العكسية كطريقة حتمية لتطوير خرائط التوزيع المكاني لخصائص التربة المدروسة (تفاعل التربة، والتوصيل الكهربائي، والسعة التبادلية الكاتيونية، والمادة العضوية في التربة). تم إنشاء هذه الخرائط سنويًا لخصائص التربة قيد التحقيق، لسنوات 2012 و2013 و2014 و2015. كشفت النتائج عن وجود تباين عبر المكان والزمان لجميع قياسات التربة قيد الدراسة. أظهرت الخرائط المكانية لدرجة حموضة التربة تغيرًا سنويًا مع زيادة زمنية مقارنة بعام 2012 مع عام 2015. كشفت خرائط ملوحة التربة عن انخفاض في كل من المقاييس المكانية والزمانية. أظهرت الخرائط المكانية للمادة العضوية في التربة تقلبًا في التوزيع المكاني وكذلك من عام إلى آخر مع تحسن نهائي بلغ قيمة 20.4 سنتيمول $^{+}$ / كجم. أظهرت الخرائط المكانية للمادة العضوية في التربة نمطًا معاكسًا مقارنة بمعلمات التربة الأخرى حيث لوحظ انخفاض في المادة العضوية في التربة عند مقارنة بداية ونهاية فترة الدراسة بأكملها.

المحكمـــون :

1- أ.د. علـــي أحمـــد عبد الســـلام أستاذ الأراضي متفرغ – كلية الزراعة بمشتهر – جامعة بنها.

2- أ.د. محمد سعيد دسوقي ابو هاشم أستاذ الأراضي – كلية الزراعة – جامعة الزقازيق.