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SPATIAL VARIABILITY OF DESERT SOIL IN NAJAF GOVERNORATE, IRAQ USING GEOSTATISTICS

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ABSTRACT

The study area was chosen within the administrative boundaries of Najaf governorate , in the western part (the western plateau), and between two longitude 44°2'32.99" -44° 13'31.41" East and two showrooms 31° 59'15.94" - 31° 53'1.65" North, for the purposes of studying variations of soil, As the area of the study area 19776 ha, After Identifying 57 locations and two depths 0-25 cm and 25-50 cm by (Al Augar), Its coordinates are determined by means of a device GPS. Spatial variability were studied horizontally for morphological and physical and chemical characteristics of the study area soils and applied to the methods of advanced statistics, which included of geostatistics. The results of the Geostatistics indicated that the most variability morphological Properties are texture, followed by the property of structure, then consistency, and finally the Properties of color. Morphological Properties were less variations than the rest of the Properties. The results of Kriging indicated that the range for the spatial variability of morphological Properties ranged between 3011 - 4257 meters as it was the lowest value for texture and the highest value for the color Property of surface horizons. As for the subsurface horizons the range between 3065 - 4306 meters the lowest value for texture and the highest value for the color Property. As for the range of the spatial variability of the physical Properties ranged between 813- 4083meters, The lowest value was for the ratio of gravel and the highest value for the bulk density of surface horizons. The subsurface horizons were with a range of 896-4111 meters. The range of the spatial variability of the chemical properties ranged between 850-4560 meters the lowest value for EC and the highest value for PH for surface horizons as for subsurface horizons it ranged between 854-5138 meters the lowest value for ESP and the highest value for pH. As for the values of the coefficient of variation for the properties of the soil ranged from 2.6-124.70% and 1.20-143.10% for the surface and subsurface horizons respectively, And it was the lowest value of pH and the highest value of the percentage of gravel, It is noted that the smaller the coefficient of variation the greater the values of the range. The most appropriate statistical models when using Geostatistics were the model Spherical followed by Circular in the rate of 56.25and 43.75 % respectively they were most appropriate to most of the soil Properties, An Exponential model in the rate of 3.13% of describing variability of silt separation applied to subsurface horizons as it gave a good representation of the Semivariogram. The number of samples in the Geostatistics of morphological, physical and chemical properties ranged from 3-19 samples, while in the random case 1-387 samples.

***Keywords*:** Spatial Variability, Geostatistics, Desert Soil, Kriging.

Introduction

Soil is a heterogeneous substance found as a result of various natural factors, and that the Variability and variation in its properties is not perceived at one classification level but at different classification levels the most acceptable of which are the lowest classification levels, namely the series, and the Variability in their properties is not only horizontal but also vertical with depth, The study of spatial Variability of soil properties is important for knowing the existing types of soils and documenting their properties, This leads to the safety of representing samples in preparation for studying them by scientific research available to other sciences (Al-Akidi, 1990). In recent years, the spotlight has been made on the use of Geostatistics in studying and understanding Variability in soil properties, Which provides us with a set of statistical tools to enter time and spatial Variability in the data processing process to allow the description and modeling of spatial patterns and Forecasting of the values of different properties at sites from which samples are not taken and to confirm those Forecasting (Krasilinkov, *et al.*2008). Geostatistics was used to describe the spatial Variability of soil properties, and the Kriging technique was adopted to efficiently estimate values in unspecified sites. And it developed and presented successful results in describing spatial Variability. Mann *et al.* (2010), when studying soils in Florida, showed that the mean range of soil particles were 1665, 1010, and 2,486 meters for sand, silt, and clay respectively.

Akbas (2014) when studying some soil properties in Turkey, for two surface depths 0-20 cm and subsurface 20-40 cm found that the soil color had a low Coefficient of Variation for the surface soils in the dry and wet state ranging between 6.9-6.4%, and for subsurface soils ranged between 6.1-7.8. %. Al-Salmi (2017) found that Gypsum was the most Variability, then the electrical conductivity EC, then the ratio of the exchange of sodium (ESP), organic matter, calcium carbonate, and finally the soil interaction pH For the subsurface horizons, the Coefficient of Variation values ranged between 4.37-148.43% for the surface horizons and 3.68-123.25% for the subsurface horizons. Naaman (2018), found when studying the Variability of the soil of the Al-Haffar project, that the highest value was for soil structure, as the value of the range 4750.33 meters, and that the appropriate model for the Variability in soil structure is the Spherical model. Panday *et al.* (2019) indicated in their study when comparing three uses of soils in Nepal that the bulk density is of high Variability, the value of the coefficient of variation is 20, 17 and 12% for agricultural soils, forests and weeds respectively, meaning that the bulk density is of high heterogeneity. In agricultural soils more than weeds and forest soils, the coefficient of variation for the proportion of silt was 32, 28 and 23% for agricultural soils, weeds and forests respectively.

Materials and Methods

1. The study area was chosen within the administrative boundaries of Najaf governorate, in the western part (the western plateau), As the area of the study area 19776 ha, After Identifying 57 locations and two depths surface and subsurface its coordinates are determined by means of a device GPS (Figure 1). Morphological properties (color, texture, structure and consistence) were transformed into quantitative according to Landon, J. R. (2014).
2. Calculate the coefficient of variation C.V using an equation(1)

$$C.V= \sigma / \bar{x} * 100 \qquad .... (1)$$

Where C.V= coefficient of variation. σ=standard deviation . $\bar{x}$= mean.

3. Using Geostatistics to calculate the Semivaraince Function using Arc GIS 9.3. a Visible satellite from the 8 Land sat satellite, captured on 19/04/2018, was used the coordinates of the locations taken by the GPS device are projected so that we can take distance readings from the program Geographical correction of the studied sample sites for use in the mentioned program.

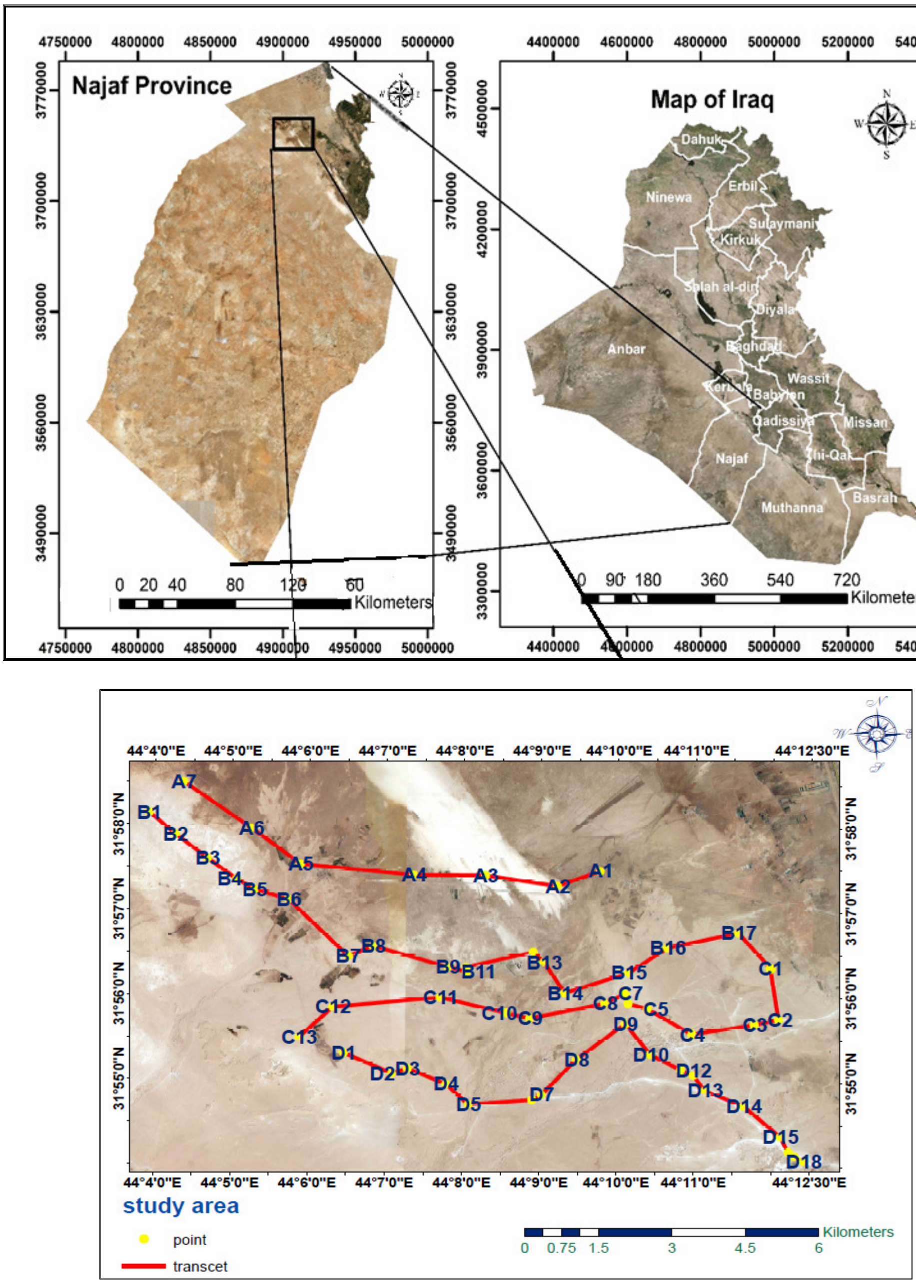

Fig. 1 : a map showing the location of the transect of the study area.

4. Calculation of the Semi Variance function as in the equation (2)

   $(h) = 1/2n\sum[Z(Xi + h) - Z(Xi)]$ …. (2)

   where $\gamma(h)$= Mean square of differences between all observations separated by distance (h).

   h= the distance between each pair of observations (Lag distance). n= the number of pairs observations distance of (h). Xi= the value of the studied soil property. Z= the studied series.
5. Variogram drawing, which represents the relationship between the Semi Variance with the distance h, in order to find the range and spatial dependencies, as shown in the figure (2).

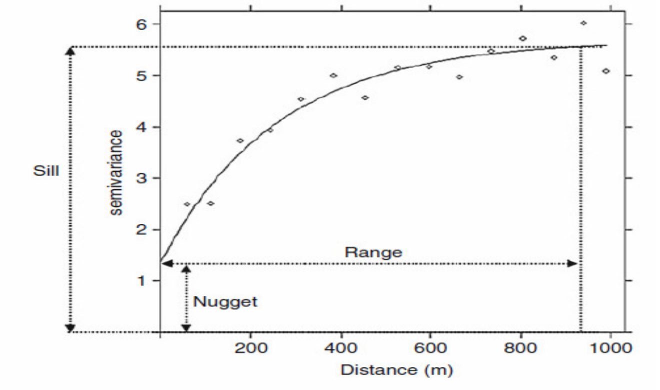

Fig. 2 : Semi Variance Function perfect planner.

6. Calculate the range.
7. Calculate randomness ratio by equation (3).

   randomness ratio= $\frac{S}{Sill} * 100$ …. (3).

   Where: S= standard deviation. Sill= the highest value of the Semi Variance.
8. Calculate the number of samples required to represent the property by methods:
   a. Spatiality dependent method: where the longest transect of the study area is divided by the range.
   b. The use of one of the laws of randomness, according to(Al-Nasir and Al-Marzouk, 1989).

   $N=t^2\alpha\sigma^2/(\alpha x)2$ …. (4).

   Where: N = Number of samples required. tα = the t value is based on degrees of freedom. σ² = variance. α = level of significance (0.05). x = mean.
9. Calculate Spatiality dependent as the equation (5):

   Spatiality Dependent =nugget/(nugget+sill)*100 ….(5).

   Where: nugget= Semi Variance Function when h = 0. the qualitative description of Spatiality Dependent was based on equation (5) Iqbal, *et al.* (2005) as the Spatiality Dependent is described as Strong if the ratio is less than 25%, and Moderate if the ratio is between 25-50% and Weak, if the ratio is between50- 75% and very Weak, if the ratio is more than 75% .

Results and Discussion

Horizontal Variability of the morphological properties using Geostatistics

Table 1 showed the values of the range reached to 3011 and 3065 meters for the soil texture, 4256 and 4306 meters for soil color, 3570 and 3157 meters for Soil structure, 3498 and 3232 meters for soil consistency for the surface and subsurface horizons, respectively. The randomness ratio was 107.14 and 103.70% for soil texture, 69.57 and 72.22% for soil color, 50.43 and 24.22% for Soil structure for both horizons, respectively. The appropriate model was the Circular and Spherical for the soil texture, Spherical and Circular for soil color for the surface and subsurface horizons, respectively. and model was the Spherical for Soil structure and soil consistency, for both, and the surface and subsurface horizons. It is noted that there is a slight variability for soil texture between the surface and subsurface horizons because these soils are desert soils with similar sedimentation conditions, in addition to the influence of direct environmental conditions, meaning that the surface horizons were more variability than the subsurface horizons, and this is consistent with (Bouma *et al.,* 2006 and Qurayshi, 2012). It is noted from the range values for soil color that there is a slight variation of the surface and subsurface horizons and the reason is attributed to the fact that sedimentary soils are often brown to yellowish brown due to the lack of organic matter and the lack of rain, meaning that the factors affecting the color of the soil are few and this is consistent with (Al-Salmi, 2017). The structure variability is one of the few heterogeneous properties specifically in desert soils. It is noted that the range values are close to the surface and subsurface horizons because they are desert soils and most of soil are not exploited in agriculture. It is noticed from the range values to describe spatially variability for soil consistency that the variability is small for the surface and subsurface horizons and this is due to the low soil content of clay as well as the lack of rainfall. It is noticed that the subsurface horizons varied more than the surface horizons. This is attributed to the fact that most of the surface horizons have a similar A high content of salts and thus affects the consistency and is almost identical for all surface horizons, thus the variability decreases and the range increases. As for the subsurface horizons, the cause of the variability is the difference in the soil content of gypsum from one site to another, and thus a variability in the consistency values, which leads to an increase in the variance. Figure 3 shows a map of the spatial variability of soil texture, color, structure and consistency for the surface and subsurface horizons to soil the study area.

Table 1 : Statistical analysis of the numerical values of some morphological properties using Geostatistics.

Model type	Randomness ratio%	Range (m)	Nugget	Partial Sill	C.V %	properties
Circular	107.14	3011	0.03	0.81	38.60	**Texture-0**
Spherical	103.70	3065	0.02	0.79	38.30	**Texture-1**
Spherical	69.57	4257	0.02	1.59	10.00	**Color-0**
Circular	72.22	4306	0.13	1.31	9.90	**Color-1**
Spherical	50.43	3570	0.41	3.06	20.50	**Structure-0**
Spherical	24.22	3157	0.02	13.52	41.70	**Structure-1**
Spherical	40.00	3498	0.64	5.11	24.50	**Consistency-0**
Spherical	30.38	3232	2.08	7.86	31.80	**Consistency-1**

0: Surface horizons. 1: Subsurface horizons.

Horizontal variability of the physical properties using Geostatistics.

Table 2 showed the range values for describing the variability of soil particle size distribution, the values of the range reached to 3592 and 3909 meters for the sand particle, 3585 and 2995 meters for silt particle, 3585 and 2995 meters for clay particle for the surface and subsurface horizons, respectively.

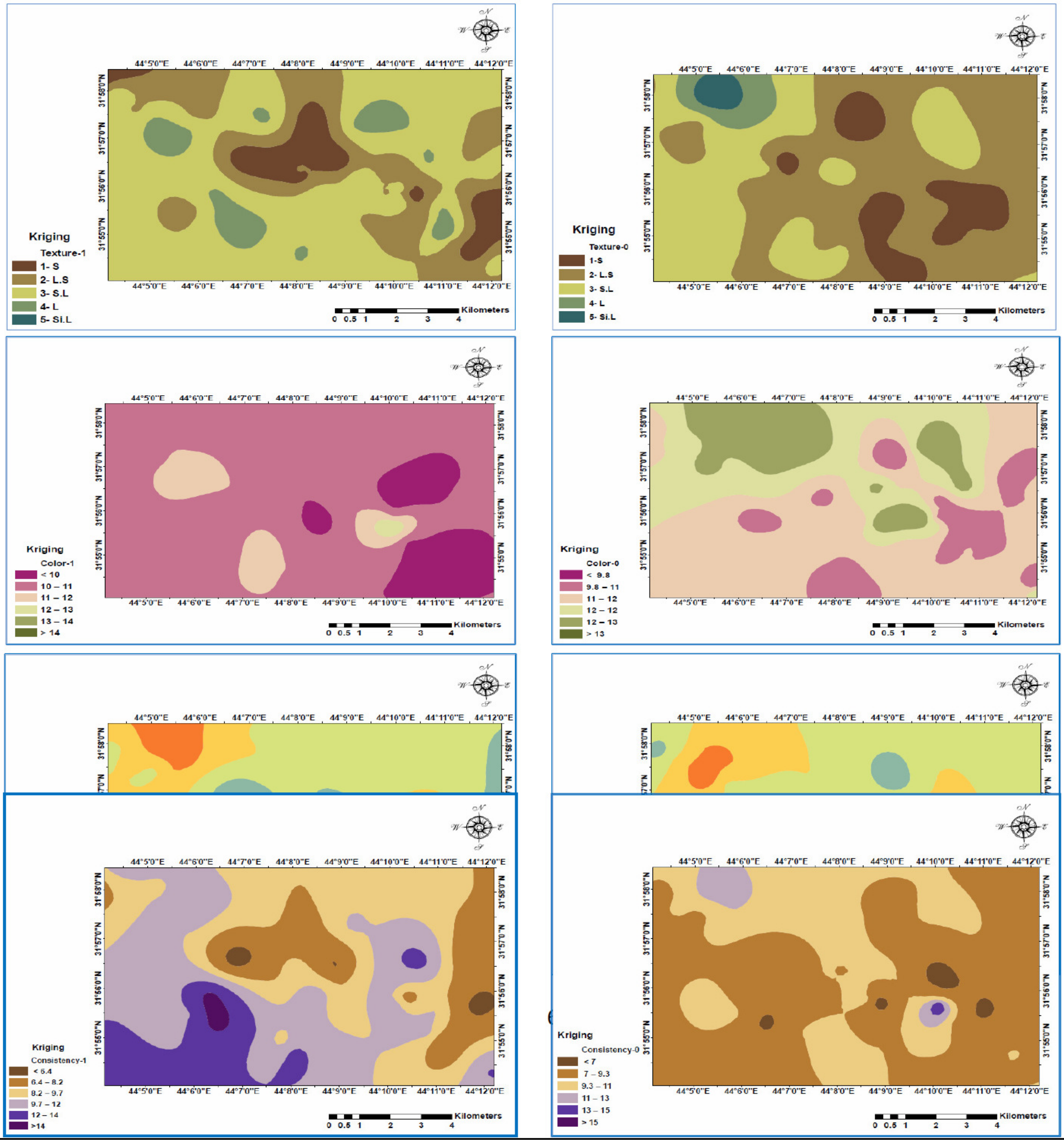

Fig. 3 : a map of the spatial variability of soil texture, color, structure and consistency for the surface(0) and subsurface(1) horizons to soil the study area.

The appropriate model was the Spherical model for both horizons, for sand Particle, the circular and exponential model for silt Particle, the Spherical and Circular model for clay particle, for the surface and subsurface horizons respectively. It is observed that the spatial variability of soil particle size distribution generally has similar range values due to the homogeneous distribution of these particles in desert soils and the nature of sedimentation in the study area. Table 2 showed the values of the range reached to 4083 and 4111 meters for soil bulk density, 813 and 896 meters for the gravel ratio for the surface and subsurface horizons respectively. The appropriate model was the Spherical model and the circular model for bulk density and gravel ratio, respectively and for the surface and subsurface horizons, and this is consistent with what he found (Janik, 2008 and Nauman, 2018). The results show that the variability of the gravel ratio is high because the soil of the study area contains large quantities of gravel in separate areas. It is noted from the range values to describe the variability of the gravel ratio spatially that the variability in the surface horizons is higher than the subsurface, this is attributed to that the study area contains large areas covered with gravel, especially in the surface horizons, and this is the characteristic of desert soils, as it is called the Desert Pavement. Figure 4 shows a map the spatial variability of sand particle, silt particle, clay particle, bulk density and gravel ratio for the surface and subsurface horizons to soil the study area.

Table 2 : Statistical analysis of spatial variability data for physical properties using Geostatistics of surface and subsurface horizons.

Model type	Randomness ratio%	Range (m)	Nugget	Partial Sill	C.V %	properties
Spherical	6.19	3592	2.57	237.92	20.00	**%Sand-0**
Spherical	7.51	3909	4.62	140.04	13.90	**%Sand-1**
Circular	50.00	3695	3.41	24.89	19.61	**%Silt-0**
Exponential	9.17	1793	3.49	110.56	62.10	**%Silt-1**
Spherical	24.20	3585	0.19	14.89	20.00	**%Clay-0**
Circular	46.59	2995	0.37	3.73	38.80	**%Clay-1**
Spherical	500.00	4083	0.002	0.03	11.50	**Bulk Density-0**
Spherical	681.82	4111	0.002	0.02	10.00	**Bulk Density-1**
Circular	19.00	813	0.00	27.27	124.7	**%Gravel-0**
Circular	18.28	896	0.00	27.25	143.1	**%Gravel-1**

0: Surface horizons. 1: Subsurface horizons.

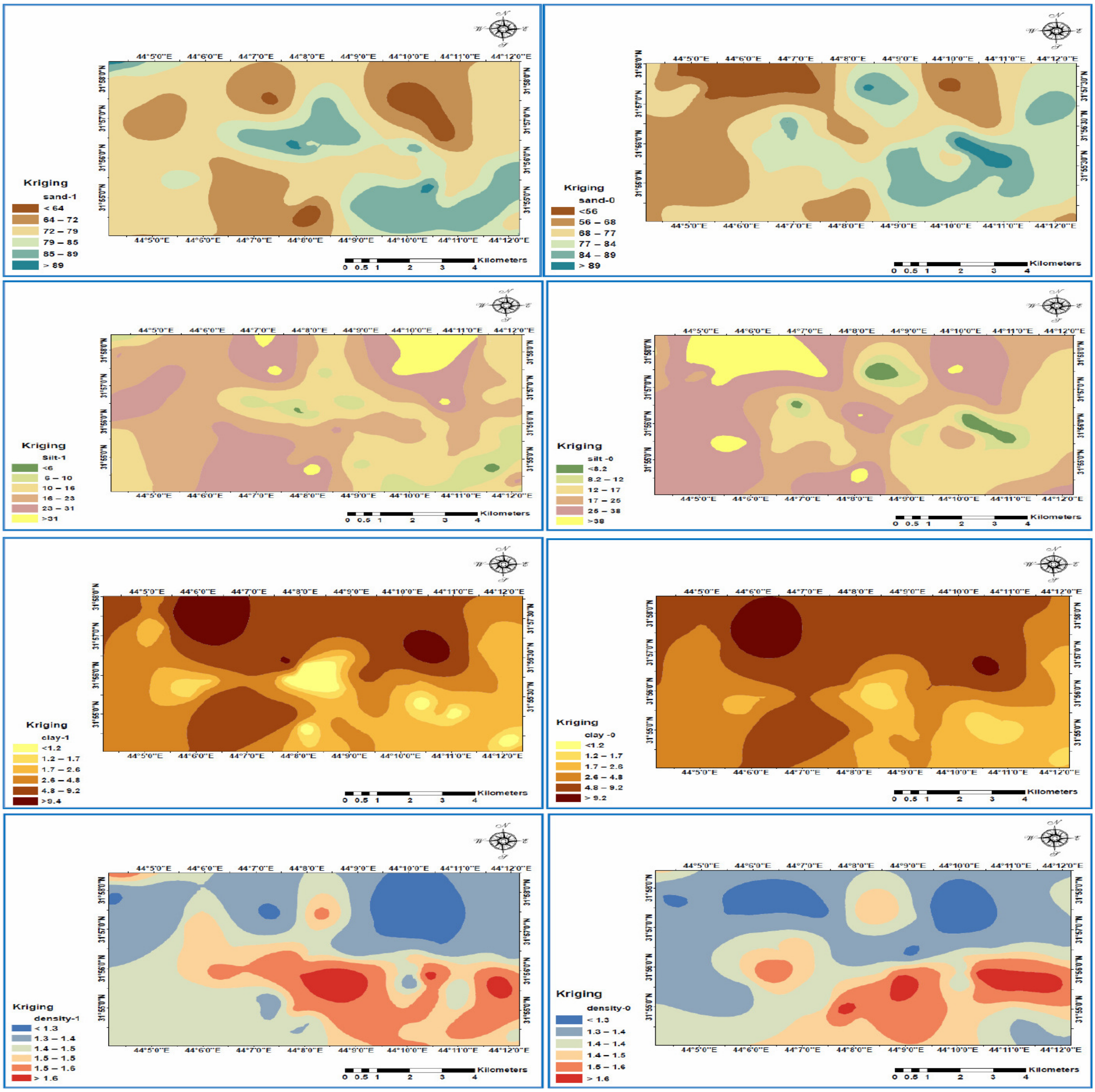

Fig. 4 : a map the spatial variability of sand particle, silt particle, clay particle, bulk density and gravel ratio for the surface(0) and subsurface(1) horizons to soil the study area.

Horizontal variability of chemical properties using Geostatistics

Table 3 showed the values of the range reached to 4560 and 5138 meters for soil pH, 850 and 1245 meters for Electrical Conductivity, 854 and 1358 meters for Exchanged Sodium Percentage for the surface and subsurface horizons, respectively.

The appropriate model was the Circular and Spherical for soil pH and the surface and subsurface horizons, respectively. and the Circular model for Electrical Conductivity, and the Spherical model for Exchanged Sodium Percentage, for the surface and subsurface horizons. and this is consistent with what he found (Aishah, *et al.* 2010; Behera, *et al.* 2016; Al Salmi, 2017), from where of the appropriate model for each properties. It is noted from the range values to describe the variability of soil interaction spatially that the variability is small and this is attributed to the nature of the soil of the study area, which contains high amounts of calcium carbonate that affect the soil interaction, and lead to the similarity soil interaction values in the surface and subsurface horizons. It is noted from the range values to describe the spatially variability of electrical conductivity, that the variability is very high and this variability is attributed to the difference in geographical location, as well as the variability of the ground water level, the lack of vegetation cover and the proximity of the salty ground water to the surface in some locations, It leads to higher salinity in the surface horizons compared to the subsurface horizons. It is noticed that there is relationship, Between the range values of the Exchange Sodium Percentage with the values of the range of the Electrical Conductivity, That is, we note the high values of the range both properties in the subsurface horizons, and this is consistent with (Rahl, 2012). Figure 5 shows a map the spatial variability of soil pH, Electrical Conductivity, Exchanged Sodium Percentage for the surface and subsurface horizons to soil the study area.

Table 3 showed the values of the range reached to 3063 and 1912 meters for carbonate minerals, 982 and 2121 meters for Gypsum, 832 and 3050 meters for Cation Exchange Capacitance, 1557 and 1697 meters for Organic Matter for the surface and subsurface horizons, respectively.

The appropriate model was the Circular for carbonate minerals, Spherical for Gypsum and Organic Matter, for the surface and subsurface horizons. spherical and circular model for Cation Exchange Capacitance for the surface and subsurface horizons, respectively. And this is consistent with what he found (Shahandeh *et al.,* 2005; Ayoubi *et al.,* 2007; Yong dong *et al*., 2008; Al Salmi, 2017), from where of the appropriate model for each properties. The soil of the study area is sedimentary soils containing calcium carbonate in varying quantities, and it is noted from the range values to describe the spatially variability of carbonate minerals, that The variability is high, especially in the subsurface horizons, and this is attributed to the high temperatures and the lack of rain, which leads to the stability of the lime content, especially in the surface horizons. As for the subsurface horizons, we notice high variability due to the presence of gypsum mixed with lime, so we find sites where lime increases and gypsum decreases, and thus high contrast appears. It is noted from the range values to describe the spatially variability of the Cation Exchange Capacity that the variability is very high, especially in the surface horizons because it is affected by a number of soil properties, including clay content, organic matter content and soil interaction. It is noted from the range values to describe the spatially variability for organic matter, that the variability is small for both the surface and subsurface horizons and because the percentage of organic matter is low in soils of the study area due to the hot and dry climate. Figure 6 shows a map the spatial variability of carbonate minerals, gypsum, Cation Exchange Capacity, organic matter for the surface and subsurface horizons to soil the study area.

Table 3 : Statistical analysis of spatial variability data for chemical properties using Geostatistics of surface and subsurface horizons.

Model type	Randomness ratio%	Range (m)	Nugget	Partial Sill	% C.V	properties
circular	350.00	4560.03	0.00	0.06	2.6	**pH-0**
spherical	833.33	5138.24	0.00	0.012	1.20	**pH-1**
circular	3.04	850.09	4.91	1153.66	124.40	**EC-0**
circular	6.02	1245.13	2.73	285.63	85.10	**EC-1**
circular	4.71	85**4.17**	3.97	428.67	97.30	**ESP-0**
circular	9.95	1358.39	3.37	113.86	74.20	**ESP-1**
circular	**11.63**	3062.47	0.48	66.93	**28.4**	**%CaCO$_3$-0**
circular	10.06	1912.37	4.74	105.15	45.50	**%CaCO$_3$-1**
spherical	11.**23**	981.58	3.67	74.75	95.36	**%Gypsum-0**
spherical	13.51	2121.36	4.79	47. 56	45.00	**%Gypsum-1**
spherical	**33.01**	**832.31**	**0.29**	**13.04**	**37.40**	**CEC-0**
circular	34.56	3050.09	0.82	6.53	28.50	**CEC-1**
spherical	466.67	1556.79	0.003	0.042	67.00	**%O.M-0**
spherical	795.92	1697.02	0.00	0.049	62.80	**%O.M-1**

0: Surface horizons. 1: Subsurface horizons.

Spatial depended and take sampling

Use the Variogram and after calculating the semi Variogram function and depending on equation (2), the relationship with distance was drawn to find the spatial depended or range by using GIS software and using Geostatics and kriging technology, as the appropriate model is chosen depending on several factors: the lowest standard error (variance error), and the highest value for (Sill) and lowest Nugget value so as to achieve the highest spatial depended. Also, one of the laws of randomness used equation (4) to calculate the number of samples in the random way.

Tables (4, 5 and 6) show the distance with the highest autocorrelation (more than 0.5). As for the qualitative description of spatial dependability, we have relied on equation (5) adopted by Iqbal *et al.* (2005).

Tables (4, 5 and 6) strong spatial dependability for all the properties and the surface and subsurface horizons, as it ranged between 0.15-17.30 for the morphological properties as the lowest value was for the structure and the highest value for the consistency of the subsurface horizons, and ranged between 0.00-10.75 for the physical properties if the lowest value for the gravel ratio for the surface and subsurface horizons and the highest value for the silt ratio, and it ranged between 0.00-10.04 for the chemical properties as it was the lowest value for soil interaction (pH) for the surface and subsurface horizons and for the organic matter for the subsurface horizons. The highest value was the cation exchange capacity of the positive ions for the subsurface horizons.

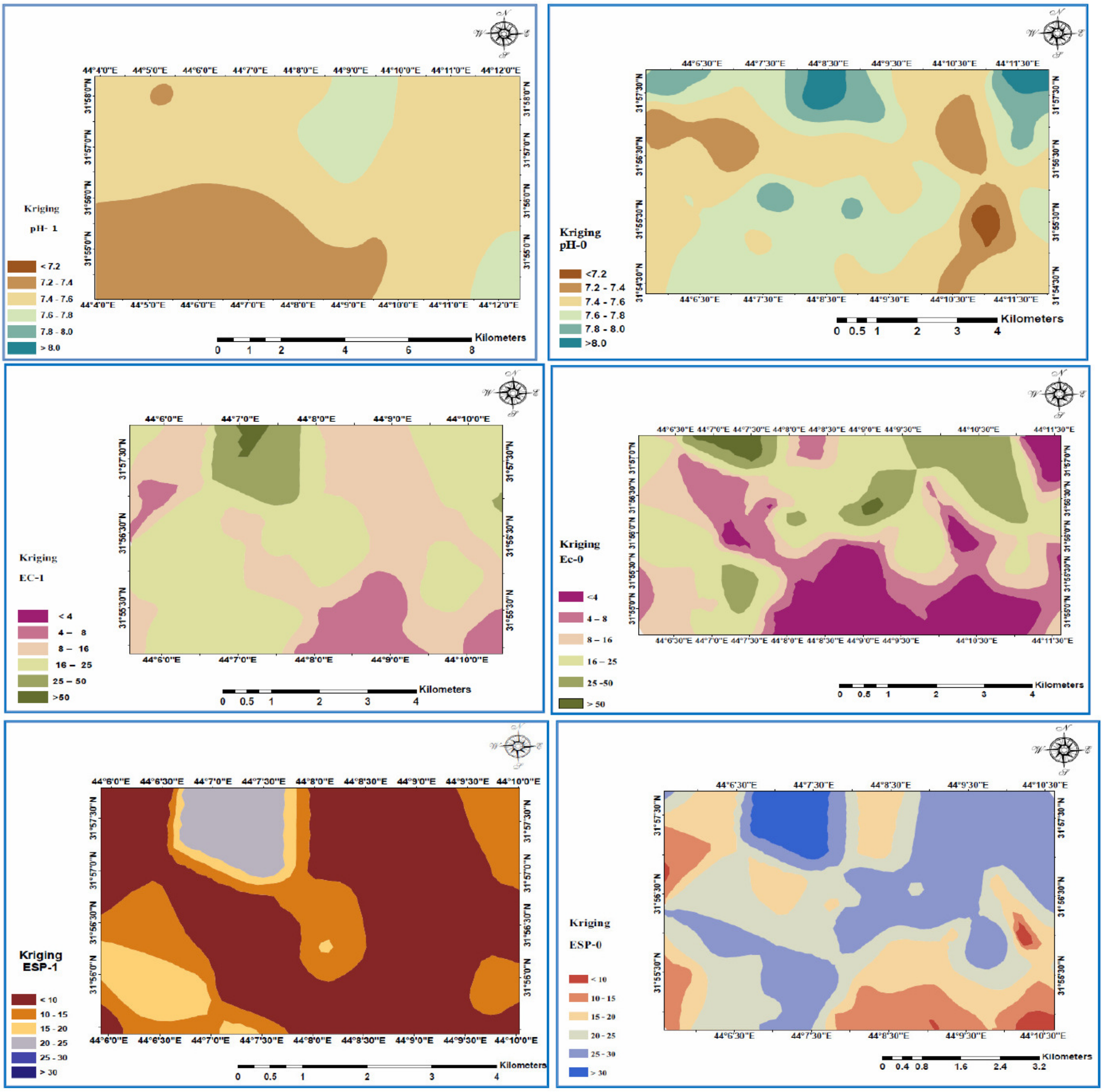

Fig. 5 : a map the spatial variability of soil pH, Electrical Conductivity, Exchanged Sodium Percentage for the surface(0) and subsurface(1) horizons to soil the study area.

Spatial dependability of morphological properties

Table 4 showed the range values for the morphological properties 3011-4306 meters, the lowest value for soil texture for the surface horizons, and the highest value for the color properties for the subsurface horizons and structure and consistency for subsurface horizons, but in the case of relying on the random law, it required a number of samples from 2 to 28 samples and the lowest number of samples was for the color properties of the subsurface horizons. As for the highest number of samples of the structure properties of the subsurface horizons, this is a large number compared to the case of Geostatistics.

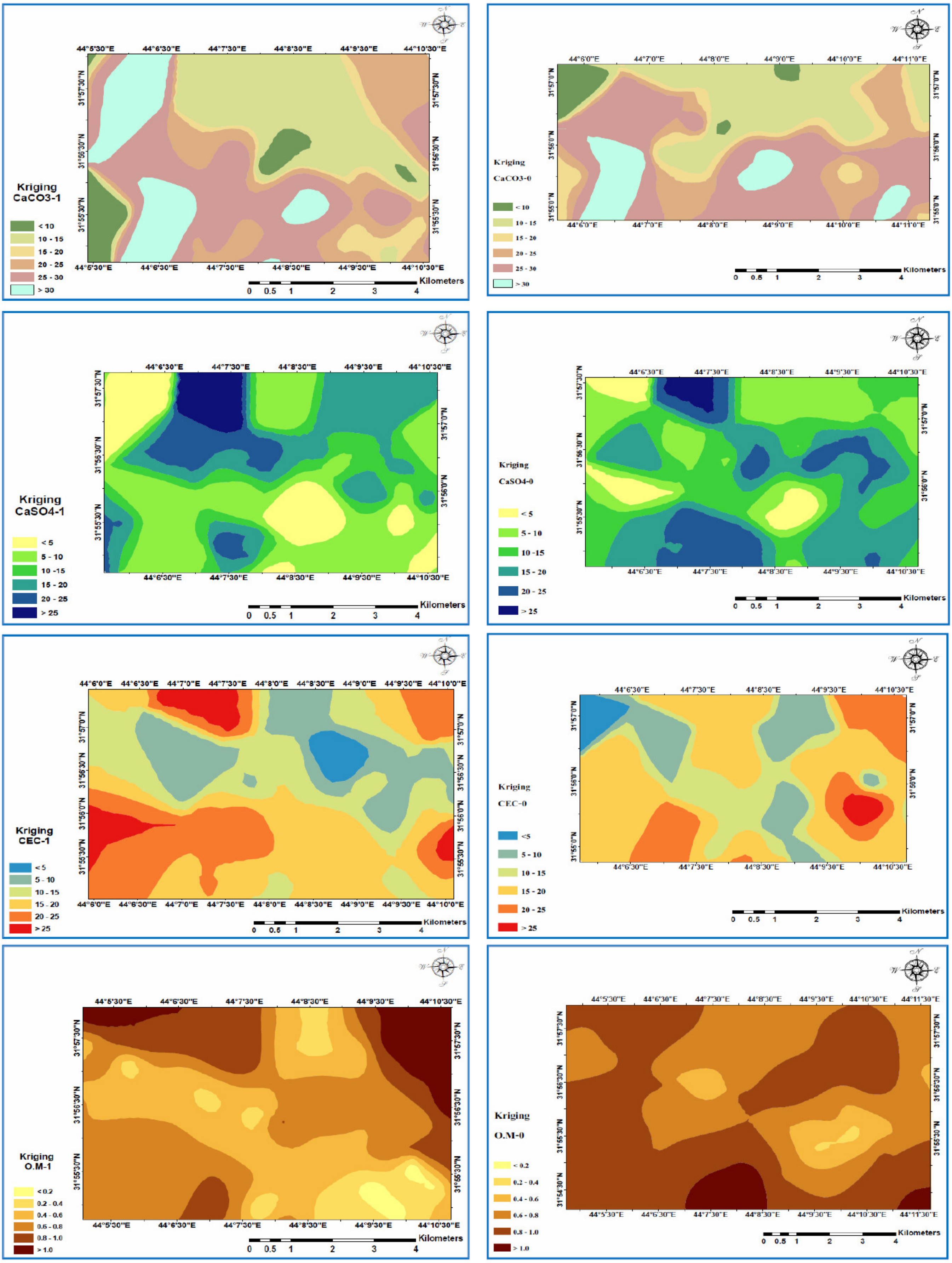

Fig. 6 : a map the spatial variability of carbonate minerals, gypsum, Cation Exchange Capacity, organic matter for the surface(0) and subsurface(1) horizons to soil the study area.

Table 4 : Spatial reliability of morphological properties and number of samples by various statistical methods.

n	N	Model type	Class of Spatiality dependent	Spatiality dependent	Range (m)	Nugget	Partial Sill	property
2	24	Circular	Strong	3.45	3011	0.03	0.81	Texture-0
5	24	Spherical	Strong	2.41	3065	0.02	0.79	Texture-1
4	2	Spherical	Strong	1.23	4257	0.02	1.59	Color-0
4	2	Circular	Strong	8.28	4306	0.13	1.31	Color-1
4	7	Spherical	Strong	10.57	3570	0.41	3.06	Structure-0
5	28	Spherical	Strong	0.15	3160	0.02	13.52	Structure-1
4	10	Spherical	Strong	10.02	3498	0.64	5.11	Consistency-0
5	16	Spherical	Strong	17.30	3232	2.08	7.86	Consistency-1

N: number of samples in the random state. n: number of samples in the case of a Geostatistics.
0: Surface horizons. 1: Subsurface horizons.

Spatial dependent physical properties.

Table 5 showed the values of the range of the physical properties, ranging between 813 - 4111 meters, the lowest value was for the ratio of gravel to the surface horizons and the highest value for the bulk density properties of the surface horizons. The number of samples ranged between 4-19 samples and the lowest number of samples was for sand partial and bulk density of the surface and subsurface horizons and silt and clay particles for the surface horizons, and the highest number of samples for the ratio of gravel to the surface horizons, but in the case of relying on the random law, as it required a number of samples between 2-382 samples and the lowest number of samples was for the bulk density of the subsurface horizons. The highest number of samples was for the gravel ratio for the surface horizons and this is a large number Comparison with the number of samples in the case of Geostatistics.

Table 5 : Spatial reliability of physical properties and number of samples by various statistical methods.

n	N	Model type	Class of Spatiality dependent	Spatiality dependent	Range (m)	Nugget	Partial Sill	Property
4	7	Spherical	Strong	1.06	3592	2.57	237.92	%Sand-0
4	3	Spherical	Strong	3.09	3909	4.62	140.04	%Sand-1
4	68	Circular	Strong	10.75	3695	3.41	24.89	%Silt-0
8	7	Exponential	Strong	2.97	1793	3.49	110.56	%Silt-1
4	31	Spherical	Strong	1.24	3585	0.19	14.89	%Clay-0
5	22	Circular	Strong	8.28	2995	0.37	3.73	%Clay-1
4	3	Spherical	Strong	5.88	4083	0.002	0.03	Bulk Density -0
4	2	Spherical	Strong	8.33	4111	0.002	0.02	Bulk Density-1
19	382	Circular	Strong	0.00	813	0.00	27.27	Gravel-0
17	328	Circular	Strong	0.00	896	0.00	27.25	Gravel-1

N: number of samples in the random state. n: number of samples in the case of a Geostatistics.
0: Surface horizons. 1: Subsurface horizons.

Spatial dependent of chemical properties.

The results of Table 6 showed the values of the range of the chemical properties, ranging between 832 - 5138 meters, and the lowest CEC value was for the surface horizon and the highest value for the pH of the subsurface horizon. The number of samples ranged between 3-18 samples and the lowest number of samples was for the PH properties for both the surface and subsurface horizons, and higher number of samples was for the EC, ESP and CEC properties of the surface horizons, but in the case of relying on the random law, as it required a number of samples between 1-387 samples and the lowest number of samples was for the pH and for both horizons, and the highest number of samples was for the OM properties of the subsurface horizons. In the case of the case of Geostatistics.

Table 6 : Spatial reliability of chemical properties and number of samples by various statistical methods.

n	N	Model type	Class of Spatiality dependent	Spatiality dependent	Range (m)	Nugget	Partial Sill	Property
3	1	circular	Strong	0.00	4560	0.00	0.06	pH-0
3	1	spherical	Strong	0.00	5138	0.00	0.012	pH-1
18	326	circular	Strong	0.42	850	4.91	1153.66	EC-0 dS.m^{-1}
12	116	circular	Strong	0.94	1245	2.73	285.63	EC-1 dS.m^{-1}
18	152	circular	Strong	0.91	854	3.97	428.67	ESP-0
11	88	circular	Strong	2.79	1358	3.37	113.86	ESP-1
5	23	circular	Strong	0.71	3063	0.48	66.93	%$CaCo_3$-0
8	33	circular	Strong	4.14	1912	4.74	105.15	%$CaCo_3$-1
15	60	spherical	Strong	4.47	982	3.67	74.75	%Gypsum-0
7	33	spherical	Strong	8.38	2121	4.79	47. 56	%Gypsum-1
18	43	spherical	Strong	3.00	832	0.29	13.04	CEC -0 cm.Kg^{-1}
5	13	circular	Strong	10.04	3050	0.82	6.53	CEC -1 cm.Kg^{-1}
10	67	spherical	Strong	6.25	1557	0.003	0.042	%O.M-0
9	387	spherical	Strong	0.00	1697	0.00	0.049	%O.M-1

N: number of samples in the random state. n: number of samples in the case of a Geostatistics.
0: Surface horizons. 1: Subsurface horizons.

Conclusions

The presence of horizontal spatial variability in the properties of the studied soil, which are important in the work of surveying and classifying soils, especially in determining the boundaries between the soil units. The Spherical and Circular models are the appropriate models for most soil properties when using Geostatistics, with a ratio of 56.25 and 43.75%, respectively, while the Exponential model applied to the ratio of clay partial for the subsurface horizons at a rate of 3.13% as it gave a good representation of the semi variogram function. The number of samples decreased for properties that have spatial dependability when relying on Geostatistics, while a large number of samples were required in the case of relying on the law of randomness. There is a positive relationship between the coefficient of variation C.V and variability, as the higher the values of the coefficient of variation, the greater the variability. There is an inverse relationship between the coefficient of variation and the range, as the greater the values of the coefficient of variation, the lower the values of the range when relying on the Geostatistics. The results show that the highest coefficient variation was for the chemical properties, then the physical properties, then the morphological properties. The most appropriate statistical method for describing variability of soil properties is the method of Geostatistics. The degree of spatial dependent was high for all morphological, physical and chemical properties of the soil, indicating a high correlation between these properties with each other over the distance.

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