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Spatial Variability of Soil Properties in Palm Groves of the Central Algerian Sahara (Case of Zelfana)

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Abstract. Monitoring soil quality in irrigated areas is essential for assessing the sustainability of production systems. In this respect, the spatial variability of the properties of irrigated soils is a mean to know the evolution of the latter. This study aims to determine the spatial variability of soil organic matter, salinity, pH and active limestone using a geostatistical approach. The present study was carried out in the region of Zelfana located in the Algerian central Sahara, the samples were collected from a depth of 0 to 30 cm and analysed for organic matter, salinity, pH and active limestone. The analytical results show that the soil is very poor in organic matter, very salty, alkaline to very alkaline and moderately calcareous. The geostatistical analysis revealed various patterns and levels of spatial distribution of the studied properties. The results showed a weak spatial dependence for organic matter, moderate for pH and salinity and strong for active limestone. The variographic analysis showed that the nugget effect is weak for organic matter and pH, moderate for salinity, while active limestone does not show a nugget effect. The range varies from 75 meters for salinity to 299 meters for organic matter, confirming the validity of the adopted sampling and allowing the optimization of future sampling plans. The Arcgis autoKriging function was used to select the best theoretical variogram model from those most commonly used in geostatistics (Gaussian, spherical, exponential and circular). This model was used to produce the spatial variability maps using ordinary kriging. Spatial variability of soil properties is influenced by agricultural intensification, something that must be taken into consideration for integrated and sustainable land management in similar regions.

Keywords. Geostatistics, Spatial variability, Organic matter, Salinity, pH, Active limestone.

I. INTRODUCTION

Soils in arid zones have been considered for a long time as an environment that does not represent any interest from a pedological perspective, because they are raw mineral soils, very little evolved, and very poor in organic matter [1]. Similarly, the soils of the Algerian Sahara are also characterized by a predominant evaporation and a scarcity of rain [2], which directly influences their physico-chemical properties, such as rapid oxidation, accumulation of salts on the surface of the soil and a poor production of organic matter [3].

The cultivation of these soils is only possible with irrigation [4], which consists in pouring water down to the soil profile, thus increasing the yield of certain crops and prolonging the vegetation period in dry seasons [5]. The irrigation technique can cause considerable modifications to the soil properties by the introduction of important quantities of soluble salts [4,6] and thus provokes phenomena of soil degradation by alkalinization, salinization and sodization [7].

Our work is a contribution to the study of the spatial variability of some physico-chemical properties of the irrigated soil in the palm grove, in the city of Zelfana (Central Algeria), a potentially date-producing area by an area of 1241,9149 ha and an annual production of 64658.48quintalsof dates [8]. This perspective takes into consideration the parameters: pH, organic matter (OM), electrical conductivity (EC) and active limestone (CaCo3) through geostatistical methods such as ordinary kriging and statistical analysis (descriptive analysis and PCA).

II. MATERIAL AND METHODS

- *Study Area*

The study has been carried out in the palm groves in the city of Zelfana (central Algeria) created in 1958 (fig.1). The experimental site covers a total area of 42 ha (latitude 32° 23′ north, 4° 13′ east and at an altitude of 355m).

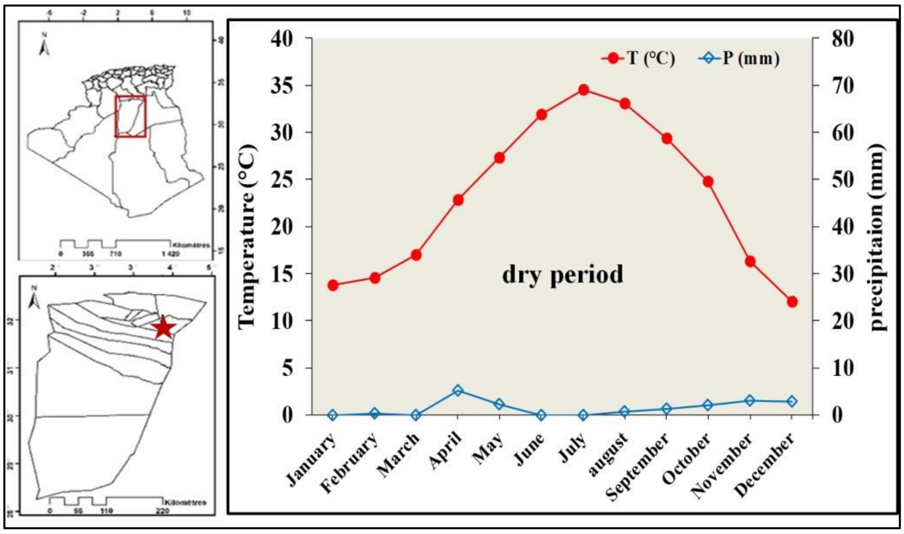

FIGURE 1. Location of the study area of Zelfana (Algeria).

The climate of the study area is typically Saharan, characterized by two seasons: a hot and dry season (from April to September) and a moderate season (from October to March) with a large difference between summer and winter temperatures and an extreme temperature that can reach to 50°C in July. Annual rainfall is low ranging from 100 to 200 mm/year [9].

The soil structure in Zelfana belongs to the domain of the Saharan platform, mostly covered by recent age formations, represented mainly by calcareous gypsum crusts and alluvial deposits [10].

It should be noted that these palm groves are irrigated by water of Albian origin, characterized by a salinity that varies from 1.65 to 2.35 dS/m at 25°C with an average of 1.96±0.25 dS/m at 25°C [11].

- *Soil Sampling and Analysis*

Soil sampling was carried out randomly to a depth of 0-30 cm using an auger. The distribution of the sampled points is shown in Figure 2.

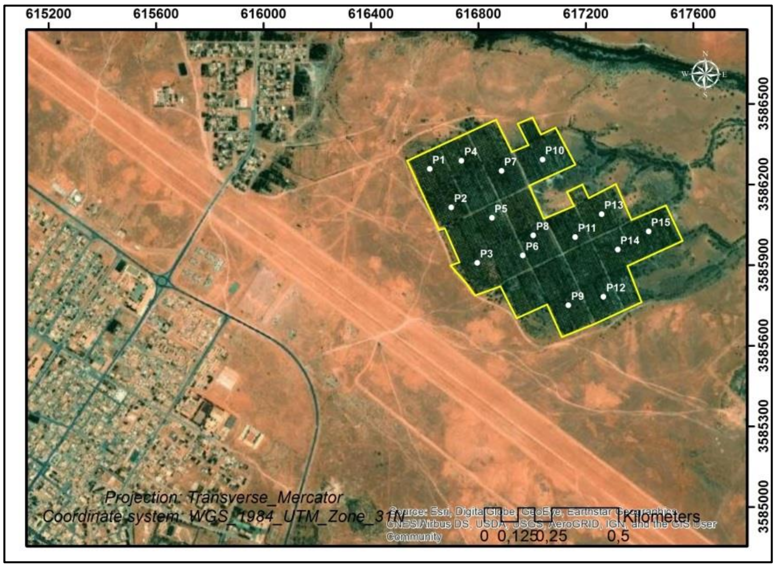

FIGURE 2. Spatial distribution of sampled points.

The samples were air-dried, then sieved with a 2mm square mesh sieve then transferred to the laboratory for the determination of organic matter content, according to the method of WALKLEY and BLACK. The electrical conductivity

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and the pH were measured at a temperature of 25°C on a soil to water ratio of 1/5. The determination of active limestone is carried out according to the method of Drouineau-Galet.

- *C. Statistical Analysis*

The results were subjected to a descriptive analysis in which, the various descriptive parameters were calculated. The Principal Component Analysis (PCA) was also established for the quantitative variables using R software (v3.5.3).

The spatial data was interpolated according to the kriging method using the "AUTOKRIGE" function of the "AUTOMAP" package under R v3.5.3. In fact, the "AUTOKRIGE" function aims to choose the best theoretical model of a variogram among those most used in geostatistics (Gaussian, spherical, exponential and circular) [12,13]. The geostatistical models generated were subsequently run on ArcGIS v10.3 to obtain thematic variability maps for each parameter studied. The coefficient of variation (intensity of variability) is interpreted according to the scale of Nolin et al. (1997): CV (%) = 100.σ/m, including: CV<15% low, 15%<CV<35% moderate, 35%<CV<50% high, 50%<CV<100 very high.

III. RESULTS AND DISCUSSIONS

The results related to the study of soil parameters in the palm grove of Zelfana are summarized in the following table.

TABLE 1. The values of the physico-chemical properties of the soil of the palm grove of Zelfana (Algerian center).

Parameters	Maximum	Minimum	mean	standard deviation	CV %
OM (%)	0.45	0.13	0.23	0.09	43.54
pH	8.62	8.07	8.27	0.15	1.88
EC (dS/m)	2.61	0.92	2.02	0.42	20.66
active ($CaCO_3$)	9.71	3.5	6.59	1.8	27.66

Table 1, shows that the studied soil has an organic matter content between 0.13 and 0.45 % with an average of 0.23±0.09 %, which reflects a poverty of this soil in organic matter. The pH value is high in the order of 8.27±0.15, indicating a very alkaline reaction of the studied soil. While, electrical conductivity (EC) presents a maximum of 2.61 dS/m which classifies the studied soil as salty to very salty. The average value of active limestone is 6.59 ± 1.8 % indicates that the *Zelfana* palm grove has a moderately calcareous soil.

The coefficient of variation for the parameters studied shows little spatial variation in organic matter (43.54%), electrical conductivity (20.66%) and active limestone (27.37%). However, the pH values seem homogeneous (1.88%).

In order to analyze the spatial dependence of these parameters, we used the Variogram tool with the "AUTOKRIGE" function for a better choice of the theoretical model. The obtained results are detailed in the table 2 and graphically represented by figure 3.

TABLE 2. Best-fit variogram models.

	Best-Fit Model	Nugget (C0)	Sill (C0+C)	Range (m)	Ratio %
OM	Gaussian	0.01	0.01	299	> 75 % (Low)
pH	spherical	0.02	0.03	98	25-75 % (Moderate)
EC	Gaussian	0.11	0.25	75	25-75 % (Moderate)
Active $CaCO_3$	Exponential	0	4.1	102	< 25 % (High)

The autoKrige function showed that the most reliable model to represent the organic matter and electrical conductivity data is the Gaussian model. The spherical model is the most reliable model for pH and the exponential model for active limestone.

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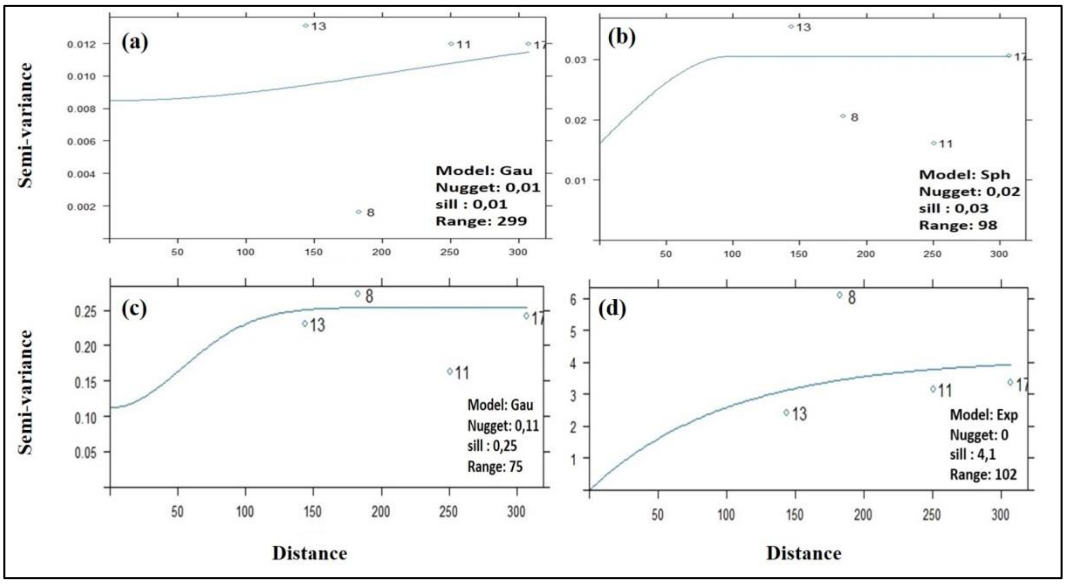

FIGURE 3. Experimental variograms of the studied parameters, (a) Organic matter, (b) pH (spherical), (c) electrical conductivity (Gaussian), (d) active limestone (exponential).

According to Figure 3, the variogram representing organic matter has a step of 0.01 and a range of 299 m, of which, the nugget effect is in the order of 0.01. That of EC (step of 0.25, a range of 75 m) has a nugget effect equal to 0.11. The representation of pH revealed a step of 0.03 and a range of 98 m with a nugget effect of 0.02. Whereas, the active limestone variogram has a step of 4.1, a range of 102 m and does not show a nugget effect.

Based on the best variogram models obtained, the spatial variation maps of different studied parameters are presented in Figure 4.

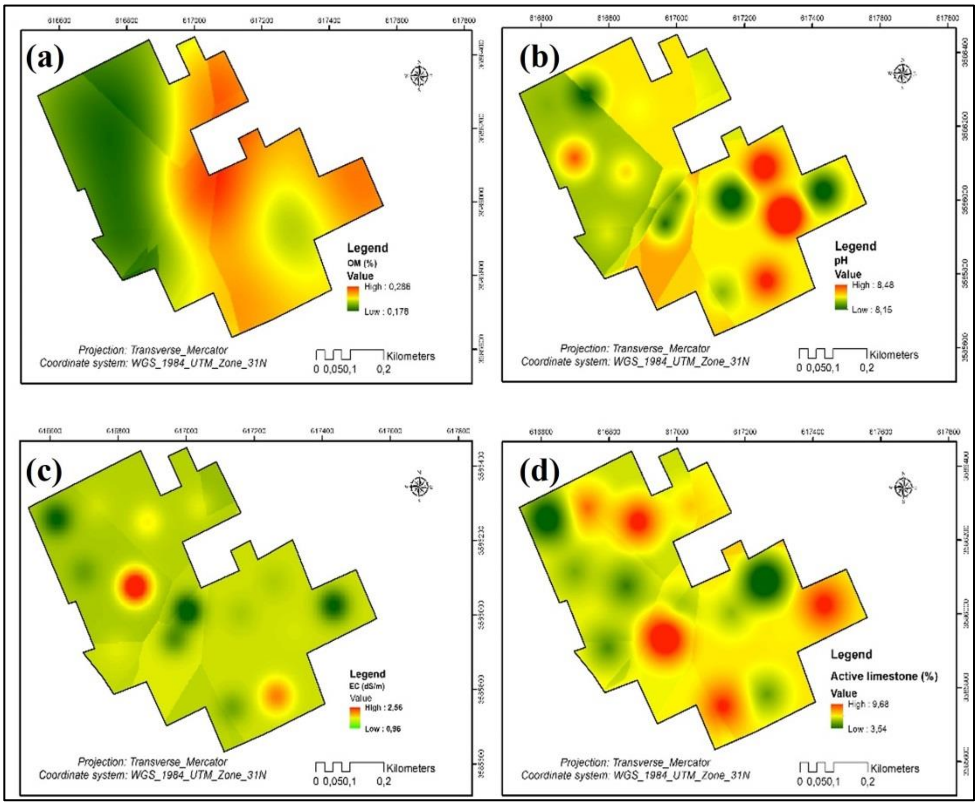

FIGURE 4. Map of spatial variability of the studied parameters, (a) organic matter, (b) pH, (c) electrical conductivity, (d) active limestone.

Figure 4, shows a high variation of organic matter in the studied plot with a coefficient of variation of 43.54%. A moderate variation is observed for electrical conductivity and active limestone with a coefficient of 20.66% and 27.37%

respectively. For pH, the coefficient of variation of about 1.88% shows a low variation.

Principal component analysis (PCA) is applied to check for possible correlations between the studied soil parameters. The results obtained are summarized in Figure 5.

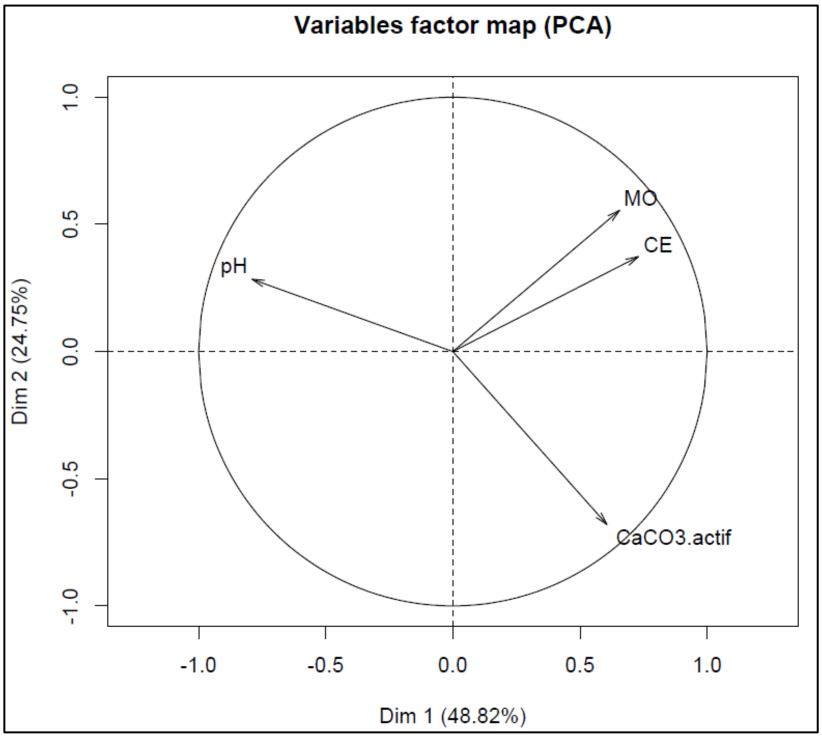

FIGURE 5. Principal component analysis (PCA) between the soil parameters studied.

According to figure 5, the contribution rate of axis 1 is 48.82%, that of axis 2 is 24,75, reflecting a good representation of the variables studied on the factorial plan with 73.57% of total inertia.

Axis 1 represents a positive correlation between the parameters MO, EC and negative with pH. Axis 2 shows a negative correlation of the pH factor with the active limestone factor. In general, we found that the two parameters MO and EC are negatively correlated with the other two parameters (pH and active $CaCO_3$).

IV. DISCUSSION

Soil analyses of the palm grove of Zelfana (Central Algeria) revealed that the soil is very poor in organic matter with an average content of 0.23±0.09%. Several authors have reported that the Algerian Sahara soils are known to be, as a whole, poor in organic matter which is often less than 0.1% [14,15,6,16].

This poverty in OM can be justified, on one hand, by the extreme climatic conditions of the Saharan regions, in particular temperature and rainfall [17,18]. On the other hand, agricultural intensification including irrigation can be considered as an incubator of optimal conditions (humidity and temperature) for the degradation of soil organic matter in Mediterranean regions [19,20].

The results of soil pH analysis in the study area show that the soil is alkaline to very alkaline with an average pH value of about 8.27±0.15. The values recorded are within the range for soils in arid regions, from a pH slightly below 7 to a pH of around 9 [21-24,6, 25,4,26]. Inside the soil, when roots take up mineral elements in the state of anions, such as nitrate NO^{-3} they releases OH^- which induces an alkalinization of the soil [27].

The soil of the palm grove in Zelfana is salty to very salty with an average electrical conductivity of 2.02±0.42 dS/m. The salts accumulated in the soil come mainly from irrigation water, knowing that the salinity of the latter varies from 1.65 to 2.35 dS/m at 25°C in the region of Zelfana [11]. These waters belong to class C3, characterized by a high salinity. They are unusable even with good drainage [21]. These results are similar to those obtained by [28]. The accumulation of salts in the Saharan areas is due to the scarcity of rainfall that does not penetrate deeply into the soil to cause appreciable infiltration [16]. The rise of salts to the surface and soil desiccation are due to high evaporation rates [29].

The results show that the soil is moderately calcareous. The active limestone content of the study area varies from 3.5 to 9.71%. This moderate fraction may be the result of leaching of limestone from the surface horizon to the horizon down below following irrigation, which highlights a decarbonation gradient [30-33,21,34,35]. Since active limestone dissolves rapidly in soil solutions [36], the accumulation of limestone in the soil (limestone profile) becomes higher in depth [37,38].

The results of the multiple correlation study showed no significant correlation between the different parameters studied (P> 0.05). Nevertheless, the most important positive correlation was noted between organic matter (OM) and electrical conductivity (EC) (R=0.43). The electrical conductivity increases with the contribution of organic matter, the organic matter increased the salinity of the soil through the mineralization of these organic compounds [39].

Other negative correlations were similarly recorded between pH and active limestone (R=-0.45), on one hand, and between pH and electrical conductivity on the other (R=-0.3751). The pH increases when the calcium concentration in the solution decreases [40]. The decrease in pH is related to the presence of limestone in the soil [41]. For the electrical conductivity, this result is close to the work of [42], the study of the relationship between pH and EC shows a negative correlation.

The variographic analysis revealed a low nugget effect, which means that the variation of organic matter, pH and salinity at distances less than the sampling step (150 m), the nugget effect of active limestone is (0) which signified the reliability of sampling step. Indeed, the nugget effect can be defined as an indicator of continuity at close distances [43]. A significant nugget effect requires additional sampling of properties at smaller distances in order to detect spatial dependence [44].

Spatial dependence is determined by the ratio between the nugget and the bearing and is expressed as a percentage [45]. The spatial dependence of organic matter is low with a value of 100%, salinity and pH are moderately spatially dependent, the nugget to step ratio values are 44% and 66.67% respectively. Active limestone is in the class (<25%), which is consistent with strong spatial dependence (Table 2).

After selecting the best performing variogram models, spatial variability maps were made by ordinary kriging. These maps show that the highest values are recorded as follows: organic matter in the east of the study area, pH in the southeast, salinity in the west and active limestone in the northeast.

CONCLUSION

The study of spatial variability of soil properties in the Zelfana palm grove (central Algerian Sahara) was carried out by random sampling of fifteen (15) profiles. The results obtained revealed that the studied soil is very poor in organic matter and alkaline to very alkaline. We also recorded that the soil is very salty and moderately calcareous.
The study of multiple correlations showed no significant correlation between the different parameters studied (P> 0.05). Nevertheless, the most important positive correlation was noted between OM and EC and other negative correlations were similarly recorded between pH and active $CaCO_3$. The spatial variation of organic matter is high with a CV of 43.54%, moderate for electrical conductivity and active limestone with a CV of 20.66% and 27.37% respectively. While that of pH is low with a CV of 1.88%. The most reliable variogramm models of the studied parameters are the Gaussian model for organic matter and electrical conductivity, the spherical model for pH and the exponential model for active limestone. Organic matter is weakly space dependent, salinity and pH are moderately space dependent, and active limestone has strong space dependence. The study on spatial variability is interesting for a good understanding of the current situation of agricultural soils in order to better manage, maintain and improve their productivity.

REFERENCES

[1] Aubert, G.1960. Les sols de la zone aride. Colloque général sur les problèmes de la zone aride. Paris, p.4.
[2] Hamdi, A.B. 2001. Le fonctionnement actuel et passé de sol du sud Sahara (cuvette d'Ouargla) approche micro morphologique, géochimique, minéralogique et organisation spatiale. Thèse doctorat. I.N.A Paris Grignon. 281 p.
[3] OMM. 2005. Le climat et la dégradation des sols. Organisation météorologique mondiale, pp. 10-20.
[4] Benbrahim, F. 2001. Etude de l'effet saisonnier de la nappe phréatique sur la dynamique des sels solubles dans un sol cultivé et non cultivé dans la cuvette de Ouargla (Cas de l'exploitation de l'I.A.S.). Mémoire d'ingénieur d'Etat, I.A.S., Ouargla, 111p.
[5] Frenken K. 1997. Irrigation potential in Africa : A basin approach (Vol. 4). Food & Agriculture Org.
[6] Daoud, Y., Halitim, A. 1994. Irrigation et salinisation au Sahara Algérien. Sécheresse 5(3), pp. 151-160.
[7] Cheverry, C.L., Robert, M. 1998. La dégradation des sols irrigués et ressource en eau : une menace pour l'avenir de l'agriculture et pour l'environnement des pays au sud de la méditerranée. Etude et gestion des sols 5(4), pp. 217-226.
[8] DSA. 2021. Direction des services agricoles. Rapport des cultures en wilaya.
[9] O.N.M. 2020. Données climatiques de la région de Ghardaïa. Ed. Office National de la Météorologie, Ghardaïa.
[10] D.P.A.T. 2005. Atlas de la Wilaya de Ghardaïa. Ed. El Alamia - 142 P.
[11] Ouali, S., Mehmah, B., Malek, A. 2007. Etude de faisabilité d'utilisation des eaux thermales de Zelfana Dans la Production d'Hydrogène. Centre de Développement des Energies Renouvelables. Algérie.
[12] Nolin, M.C., Caillier, M.J., Wang, C. 1991. Variabilité des sols et stratégie d'échantillonnage dans les études pédologiques détaillées de la plaine de Montréal. Canadian journal of soil science. 71, pp.439-451.

[13] Dauphine, A., Voiron-canicio, C. 1988. Variogrammes et structures spatiales. Collection Reclus Modes d'Emploi n°12. Edition Montpellier: Gip Reclus, 56p.
[14] Durant, J. H. 1954. Les sols d'Algérie. S.E.S. Alger, 244 p.
[15] Dutil, P. 1971. Contribution à l'étude des sols et des paléosols du Sahara. Thèse. Doctorat. Univ, Strasbourg. 346 p.
[16] Halilat, M. T. 1998. Etude expérimentale de sable additionné d'argile. Comportement physique et organisation en conditions salines et sodiques (Doctoral dissertation, Institut National Agronomique Paris Grignon).
[17] Citeau, L., Bispo, A., King, D. 2008. Gestion durable des sols. Ed Quae, France, 320 p.
[18] Soco. 2009. Réduction du taux de matière organique, l'agriculture durable et la conservation des sols : Processus de dégradation des sols, N°: 3, 4 p.
[19] Laurence, W. 1998. Dynamique et biomasse des fragments de la forêt amazonienne. Actualités des Forêts tropicales, Bulletin de l'OIBT, 6 : pp 12-13.
[20] Badraoui, M., Agbani, M., Soudi, B. 2000. Evolution de la qualité des sols sous mise en valeur intensive au Maroc. Séminaire 'Intensification agricole et qualité des sols et des eaux', Rabat, Maroc, 6-7.
[21] Durand, J.H. 1958. Les sols irrigables : Etude pédologique. Edition Imbert. Alger, 190 p.
[22] Buckman, H.O., Brady, N.C. 1965. The nature and properties of soils. The Macmillan Company. New York, U.S.A, 653 p.
[23] Halitim, A. 1988. Sols des régions arides d'Algérie. Edition O.P.U. Alger, 384 p.
[24] Bouzid, H. 1993. Contribution à l'étude de la dynamique de la salinité dans un sol sableux sous irrigation par pivot (Gassi Touil). Mémoire d'ingénieur d'Etat. I.N.F.S.A.S. Ouargla, 46 p.
[25] Djili, K., Daoud, Y., Gaouar, A., Beldjoudi, Z. 2003. La salinisation secondaire des sols au Sahara. Conséquences sur la durabilité de l'agriculture dans les nouveaux périmètres de mise en valeur. Sécheresse 14(4), pp. 241-246.
[26] Benbrahim, F., Benslama, M., Kemassi, A., Darem, S., Hamel, I., Chikhi, F., Halilat, M. T. 2016. Evaluation de la durabilité de la céréaliculture sous pivot par l'étude de la salinisation du sol dans la région d'Ouargla. Ciência e Técnica Vitivinicola, 31(5), pp.107-123.
[27] Perry, R. S., Adams, J. B. 1978. Desert varnish: evidence for cyclic deposition of manganese. Nature, 276(5687), 489-491.
[28] Dekhinat, S., Bensaid, R., Bensid, Z., Koreib, F., Mouna, Y. 2010. Analyse de la variabilité spatiale de la salinité des sols dans une palmeraie Algérienne (Biskra, Algérie). Sciences & Technologie. D, Sciences de la terre, 9-14.
[29] Meddich, A., Hafidi, M., El Mokhtar, M. A., Boumezzough, A. 2015. Characterization of physicochemical parameters and mycorrhizal potential of salt soils of North-east date palm grove of Marrakesh [Caractérisation des parametres physicochimiques et des potentialités mycorhizogenes des sols salés de la palmeraie Nord-est de Marrakech]. Journal of Materials and Environmental Science, 6(9), 2469-75.
[30] Baize, D. 2000. Guide des analyses courantes en pédologie, 2ème édition revue et augmentée. I.N.R.A. Paris, 257p.
[31] Djili, K., Daoud, Y. Ayache, N. 1999. Analyse de la distribution verticale et spatiale du calcaire dans les sols de l'Algérie septentrionale. Etude et gestion des sols, 6(3), 201-213.
[32] Djili, K., Daoud, Y. 1999. Distribution latérale et verticale de l'ESP des sols du Nord de l'Algérie compte rendu du séminaire national sur la salinisation des terres agricoles. CRSTRA. Chélif. Le 01 02 juin, n° 99, pp : 25- 44.
[33] Duchaufour, P. 1977. Pédologie. Pédogénèse et classification. Tome I, Ed. Masson. Paris, 477p.
[34] Durand, J.H. 1983. Les sols irrigables. Etude pédologique. Ed. Imprimerie Boudin. Paris, 339 p.
[35] Pouget, M. 1980. Les sols à croûtes calcaires dans les steppes algériennes. Quelques aspects morphologiques et esquisse d'une évolution actuelle. Cah. ; ORSTOM Sec. Pedol. 18,3.4, 235-236 p.
[36] INRA. 2012. Rapport sur l'étude du sol de la région d'Aigrefeuille-sur-Maine (Loire-Atlantique) à partir de la base de données des analyses de terre. INRA. France, 5 p.
[37] El Idrissi Raghni, M. 1992. Differenciations des sols du plateau de meknes. Relations avec le modele et le substrat calcaire (Doctoral dissertation, Paris 6).
[38] Ruellan, A. 1973. Morphologie et répartition des sols calcaires dans des régions méditerranéennes et désertiques. soils bulletin n°21, rapport of the FAO UNDP régional science ou réclamation and ravagèrent of calcareuse soils. Cairo. Egypte, pp 272-300.
[39] Koull, N., Halilat, M. T. 2016. Effets de la matière organique sur les propriétés physiques et chimiques des sols sableux de la région d'Ouargla (Algérie). Etude et Gestion des sols, 23, 9-23.
[40] Brady, N. C., Weil, R. R. 1990. The Nature and Properties of Soils, Macmillan Publishing Company. New york.
[41] Benbrahim, F. 2018. Variabilité spatiale de la qualité du sol dans les agrosystèmes du sahara algérien. Thèse de doctorat. Université badji mokhtar-annaba,140p.
[42] Koull, N. 2007. Effets de la matière organique sur les propriétés physiques et chimiques des sols sableux de la region de Ouargla (Doctoral dissertation, Ouargla, Université de Kasdi Merbah. Faculté des Sciences et Sciences de l'Ingenieur), 100 p.
[43] Al-omran, A.M., Al-wabel, M.I., El-maghraby, S.E., Nadeem, M.E., Alsharani, S. 2013. Spatial variability for some properties of the wastewater irrigated soils. Journal of the Saudi society of agricultural sciences, 12(1), pp.167–175.
[44] Arslan, H., Güler, M., Cemek, B. 2013. Spatial estimation of the risky areas for drainage and salinity in suluova plain, turkey using geostatistical methods. Fresenius Environ Bull, 22(10), 2916-2924.
[45] Cambardella, C.A., Moorman, T.B., Parkin, T.B., Karlen, D.L., Novak, J.M., Turco, R.F., Konopka, A.E. 1994. Field-scale variability of soil properties in central Iowa soils. Soil science society of America journal. 58(5), pp.1501-1511.