Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 2, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

AGRICULTURAL LANDS SPATIAL VARIABILITY EVALUATION BASED ON AGROCHEMICAL INDICES FOR DIFFERENTIATED FERTILIZATION MANAGEMENT

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Abstract

The study evaluated soil fertility based on specific agrochemical indices, in order to characterize the spatial variability of the agricultural land studied, and for differentiated fertilizers management. The agricultural land under study is located in the area of Tormac, Timis County, Romania. The soil is of the stagno-gleyc preluvosol type, medium loam-clay. Soil reaction (pH), humus content (H%), phosphorus content (P, ppm), and potassium content (K, ppm) were analysed. The values of the degree of saturation in bases (V%) and the nitrogen index (NI) were determined. The pH values varied between 5.40-6.84 ± 0.09, and the degree of saturation in the bases (V%), registered a variation in close correlation with the pH, in the range 51.81-89.02 ± 2.41%. Nitrogen index (NI) registered values between 1.21-2.63±0.08%. Phosphorus content (P) had values between 21.83-111.60 ± 4.88 ppm, and potassium content (K) recorded values between 115.00-341.0 ± 11.97 ppm. There were low values of the coefficient of variation in the case of soil reaction (CV_{pH} = 7.4868) and high values in the case of phosphorus content (CV_P = 44.186). The other agrochemical indices studied had intermediate values in terms of coefficient of variation (CV_V = 16.8066; CV_{NI} = 22.0252; CV_K = 27.3909). Principal Component Analysis facilitated the obtaining of the samples distribution diagram, in relation to the studied agrochemical indices, according to which PC1 explained 87.845% of the variance, and PC2 explained 10.218% of the variance.

Key words: *agricultural land, fertilizer management, soil fertility, spatial variability*

INTRODUCTION

Agricultural land is the main means of production in agriculture [5], and soil is the basic resource through which plants are grown [33], [32].

In conventional agriculture, the soil represents the nutritional media of plants and also through the soil way nutrients are provided for plant growth and development [9], [2].

Soil is characterized by physical, chemical and biological properties, which can be assessed on the basis of specific indices, and in relation to their value is defined and assessed fertility of soil and agricultural land productivity [19], [29].

Soil fertility is a natural trait, supplemented and sustained by man through a series of inputs with a role in the agricultural production process [36], [1].

The spatial distribution of soil properties is uneven, so there is some spatial variability in agricultural land fertility, relative to different influencing factors [35], [12], [3], [16].

Knowing the spatial variability of agricultural land is important for optimizing fertilization and soil improvement works, in order to obtain profitable production and efficiency of agricultural technologies [18], [34], [15], [30].

Different methods and models of analysis are used for the evaluation of agricultural lands, in order to sustainably manage soil resources and agricultural practices [7], [27], [21], [23].

Some methods of soil evaluation are based on chemical analyzes of soil samples, while others estimate the soil indirectly, by imaging analysis of the vegetation cover, as an expression of soil conditions but also of technological influences [10], [13], [17], [31].

Differentiated management of soil resources and agricultural crops, in relation to their spatial variability, is important in order to optimize agricultural technologies, especially crops fertilization [24], [26], [25], [18], [20], [30].

The purpose of these works, of differentiated fertilization, is to ensure nutrients for agricultural crops in relation to soil supply and production planning, in terms of their quantity and quality [4], [28], [14].

The present study evaluated the soil fertility within an agricultural area, in order to assess the spatial variability of agricultural land for its differentiated fertilization.

MATERIALS AND METHODS

The study aimed to evaluate an agricultural land with an area of approx. 120 ha, in the area of Tormac locality, Timiș County, Romania, regarding the spatial variability of soil fertility. The graphical representation of the reference area, in which the studied agricultural land is framed, is presented in Figure 1, based on the ArcGIS v.10.6 software [8].

Agrochemical indices defining soil fertility were analyzed, such as soil reaction (pH), humus content (H,%), phosphorus content (P, ppm) and potassium content (K, ppm) [6]. The degree of saturation in bases (V,%) was calculated, as a proportionality relationship with the pH. The nitrogen index (NI,%) was calculated in relation to V and H.

The analytical data set of agrochemical indices was analyzed in terms of statistical safety and the presence of variance, through the ANOVA test.

The degree of correlation between the studied agrochemical indices was evaluated and also the interdependence relations and the statistical safety conditions between certain indices were analyzed.

The degree of variability for each agrochemical index was assessed based on the coefficient of variation (CV) and by Diversity profile, as graphical analysis [11].

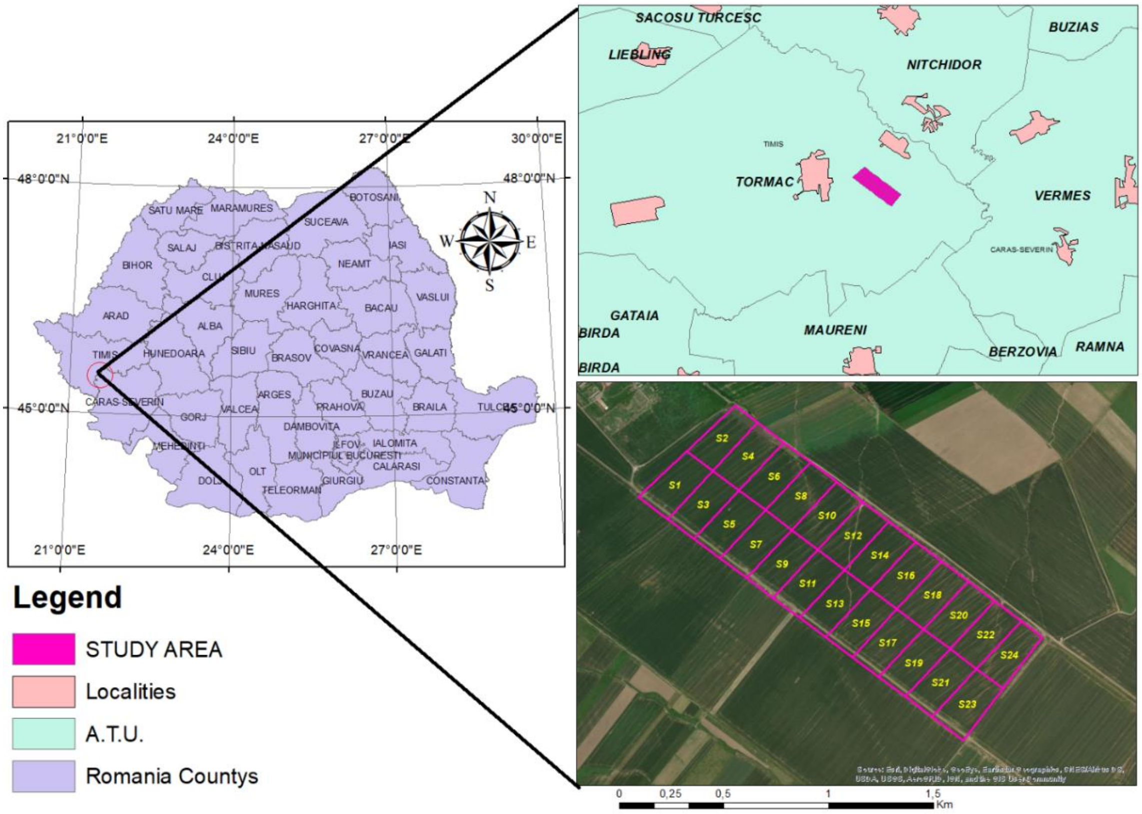

Fig. 1. The location area of the agricultural land under study, Tormac locality, Timis County, Romania
Source: Original figure, created with ArcGIS software.

The analysis and expression of the analyzed surface by quality classes, in relation to each agrochemical index analyzed, was done by percentage reporting (%), with representative graphical distribution.

PCA analysis was used to obtain the distribution diagram of the soil samples in relation to the agrochemical indices (as biplot). Also, in the PCA analysis, the presence of the variance in the analytical data set was explained as a percentage, by PC1 and PC2.

Cluster analysis was used to evaluate the grouping of samples based on Euclidean distances, in relation to the degree of similarity for to the values of the agrochemical indices studied.

RESULTS AND DISCUSSIONS

From the analysis of the soil samples, for the characterization of the studied agricultural land, and by calculations, resulted the values of agrochemical indices with reference to soil reaction (pH), degree of saturation in bases (V,%), nitrogen index (NI,%), phosphorus content (P, ppm) and potassium (K, ppm), (Table 1).

The pH values varied between 5.40-6.84 ± 0.09, and the degree of saturation in the bases (V,%), registered a variation in close correlation with the pH, in the range 51.81-89.02 ± 2.41%.

The nitrogen index (NI) registered values between 1.21-2.63%. The phosphorus content had values between P = 21.83-111.60 ± 4.88 ppm, and the potassium content recorded values between K = 115.00-341.0 ± 11.97 ppm.

The ANOVA - Single factor test confirmed the presence of variance in the data set, as well as the data safety (for Alpha = 0.001; F> Fcrit, p <0.001).

From the analysis of the values of the studied agrochemical indices, in relation to the intervals and limits of significance and classification [22], different distributions levels were found, which shows a spatial variation of the studied agricultural land.

Table 1. The values of the agrochemical indices for the characterization of agricultural land soil fertility in the area of Tormac locality, Timis County, Romania

Nr	pH	V	IN	P	K
S1	6.81	88.24	2.47	63.43	239.66
S2	6.53	81.01	2.27	21.83	215.00
S3	6.25	73.77	2.07	53.96	163.00
S4	6.36	76.61	2.15	68.40	341.00
S5	6.77	87.21	2.44	65.00	227.67
S6	5.40	51.81	1.45	44.48	182
S7	5.91	64.98	1.92	49.78	269
S8	5.67	58.78	1.74	41.36	232
S9	6.84	89.02	2.63	111.60	267
S10	6.22	72.99	2.16	98.58	161
S11	6.15	71.19	2.11	53.74	160
S12	6.73	86.17	2.55	84.65	292.67
S13	5.85	63.43	1.64	68.88	250
S14	6.56	81.78	2.11	79.15	314
S15	6.64	83.85	2.16	77.77	267
S16	5.87	63.95	1.65	40.78	191
S17	5.99	67.05	1.73	29.96	196
S18	5.65	58.27	1.50	52.50	169
S19	5.93	65.50	1.53	31.97	149
S20	5.40	51.81	1.21	24.74	169
S21	5.85	63.43	1.48	25.88	155
S22	6.29	74.80	1.75	34.96	115
S23	5.81	62.40	1.46	34.64	164
S24	5.46	53.36	1.25	41.46	255
SE	±0.09	±2.41	±0.08	±4.88	±11.97

SE – Standard Error
Source: Own data resulting from the analysis of soil samples.

In terms of soil reaction, 8.34% of the agricultural analyzed surface has a neutral pH, 20.83% of the land surface has a weakly acid reaction, and 70.83% of the land surface has a moderately acid reaction (Figure 2).

In relation to the degree of saturation in bases (V), 20.83% of the studied agricultural land area has V <60%, 50.00% of the land area falls within the range of V = 60-80%, and 29.17% of the land has values V> 80% (Figure 3).

The nitrogen index (NI) indicates a part of 41.67% of the surface with low nitrogen supply and 58.33% of the surface with moderate nitrogen supply (Figure 4).

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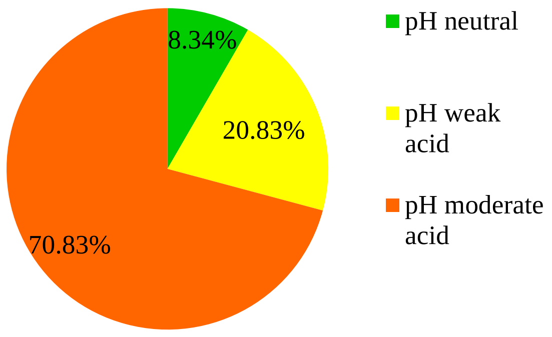

Fig. 2. Percentage distribution of the studied agricultural land, in relation to the soil pH
Source: Figure generated based on analytical data.

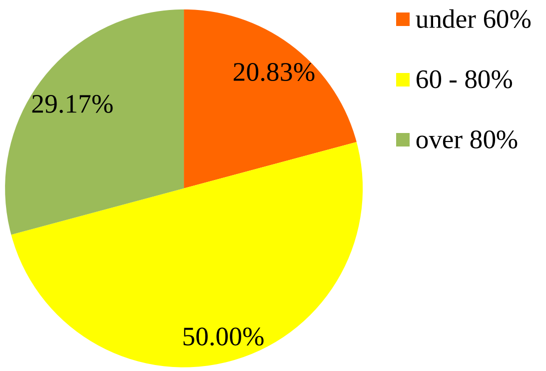

Fig. 3. Percentage distribution of the studied agricultural land, in relation to the degree of saturation in bases (V%)
Source: Figure generated based on analytical data.

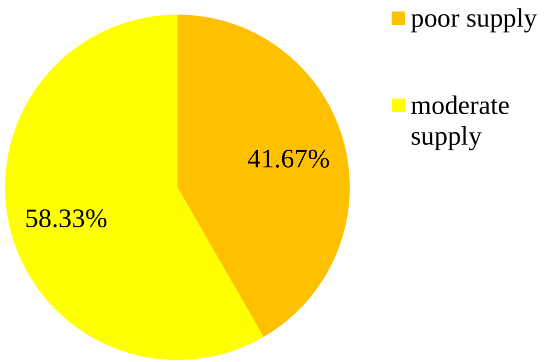

Fig. 4. Percentage distribution of the studied agricultural land, in relation to nitrogen index (NI)
Source: Figure generated based on analytical data.

The values of phosphorus content (P, ppm) indicate that 29.17% of the surface has a poor supply of phosphorus, 50.00% of the surface has a phosphorus good supply and respectively 20.83% of the surface has a very good phosphorus supply (Figure 5). Regarding the supply with potassium, 4.17% of the studied land area has a moderate supply with potassium, 45.83% has a good supply, and 50.00% of the surface has a very good supply of potassium (Figure 6).

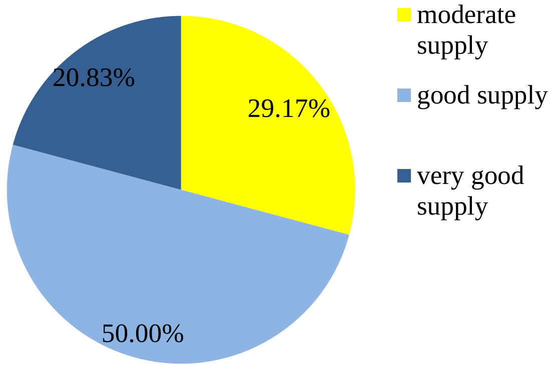

Fig. 5. Percentage distribution of the studied agricultural land, in relation to soil phosphorus content (P, ppm)
Source: Figure generated based on analytical data.

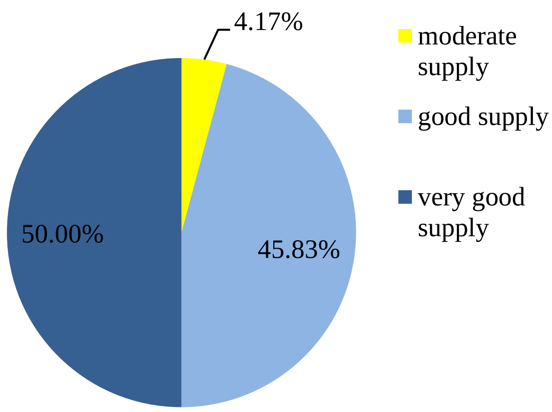

Fig. 6. Percentage distribution of the studied agricultural land, in relation to soil potassium content (K, ppm)
Source: Figure generated based on analytical data.

In the conditions of agricultural use of the studied land, certain balances have been established between agrochemical indices, and from the correlation analysis were identified very strong positive correlations between pH and V (r = 0.999), between pH and NI (r = 0.934) , and between V and NI (r = 0.937). Low correlations were identified between P and pH (r = 0.601), between P and V (r = 0.608) and between P and NI (r = 0.689). Lower levels of correlation were identified between K and studied agrochemical indices (Table 2).

Table 2. Correlation table between the studied agrochemical indices

	pH	V	NI	P	K
pH					
V	0.999				
NI	0.934	0.937			
P	0.601	0.608	0.689		
K	0.412	0.418	0.470	0.526	

Source: Original values determined based on analytical data.

The interdependence relationship between the Nitrogen Index (NI) and V was described by equation (1), a polynomial equation of degree 2, in statistical safety conditions (R^2 = 0.878, p <0.001). The graphical distribution of NI values in relation to V are shown in Figure 7.

$$\text{IN} = 0.0001372x^2 + 0.0135x + 0.2413 \quad (1)$$

where: IN – Nitrogen Index; x – degree of saturation in bases (V%)

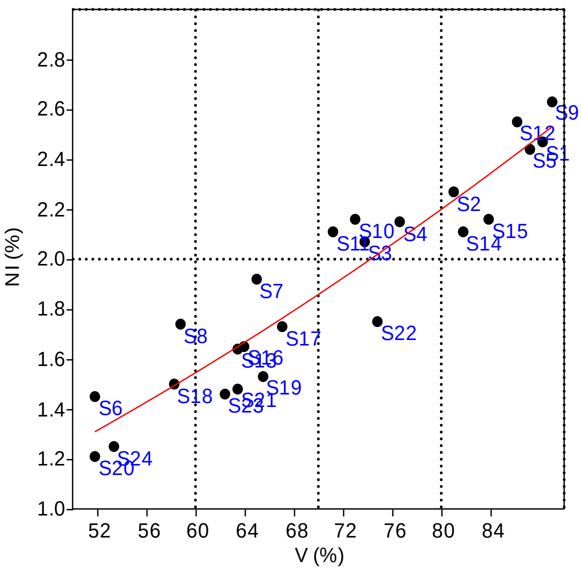

Fig. 7. Distribution of NI values in relation to V, in the conditions of the studied agricultural land
Source: Original graph based on analytical data.

The analysis of the degree of variation of the agrochemical indices values, for the studied agricultural land, was made based on the coefficient of variation (CV). Based on the obtained results, from the analysis of the analytical data set, low values of the coefficient of variation were found in the case of soil reaction (CV_{pH} = 7.4868) and high values in case of phosphorus content (CV_P = 44.186). The other agrochemical indices studied had intermediate values in terms of coefficient of variation (CV_V=16.8066; CV_{NI}=22.0252; CV_K=27.3909).

The analysis of the degree of variation of the agrochemical indices, for the studied agricultural land, was also evaluated on the basis of Diversity profiles, as a graphical analysis (Figure 8). According to the Diversity profiles, there was a small variation in the case of pH values and a high variation in the case of P values. This shows a high spatial variability in terms of phosphorus content (P), followed, in descending order, by potassium (K), nitrogen index (NI), degree of saturation in bases (V) and soil reaction (pH).

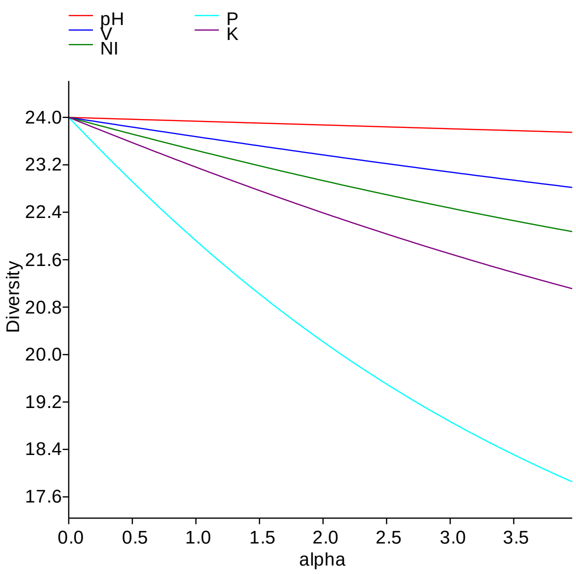

Fig. 8. Diversity profiles of the soil agrochemical indices, in the case of agricultural land studied
Source: Original graph based on analytical data.

Principal Component Analysis facilitated the obtaining of the sample distribution diagram, in relation to the studied agrochemical indices (Figure 9). PC1 explained 87.845% of the variance, and PC2 explained 10.218% of the variance. At the same time, it was found the distribution of variants in relation to certain agrochemical indices, depending on the analytical values, which express the state of the agricultural land.

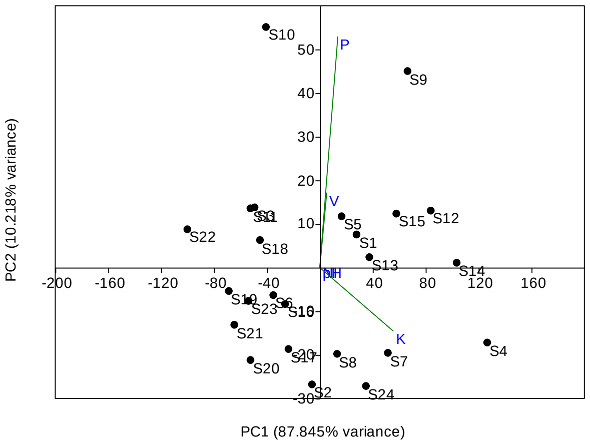

Fig. 9. PCA diagram regarding the distribution of samples in relation to the values of the studied agrochemical indices
Source: Original diagram based on analytical data.

Cluster analysis facilitated the grouping of samples, based on Euclidean distances (Coph.corr. = 0.750), depending on the degree of similarity in relation to the studied agrochemical indices (Figure 10).

The high degree of ramifications within the dendrogram, expresses a high degree of variability of the land, in relation to the studied fertility indices.

Two clusters were outlined, with a large number of subclusters each. From the analysis of Similarity and Distance Indices (SDI) values, the highest degree of similarity between the samples (S3-S11) was found, SDI = 3.9644.

High levels of similarity were recorded
between samples (S5-S1), SDI = 12.146,
between samples (S16-S17), SDI = 12.317,
between samples (S19-S23), SDI = 15.549,
between samples (S6-S16), SDI = 15.567,
between samples (S6-S18), SDI = 16.587,
between samples (S3-S18), SDI = 16.705, and
between samples (S19-S21), SDI = 18.237.

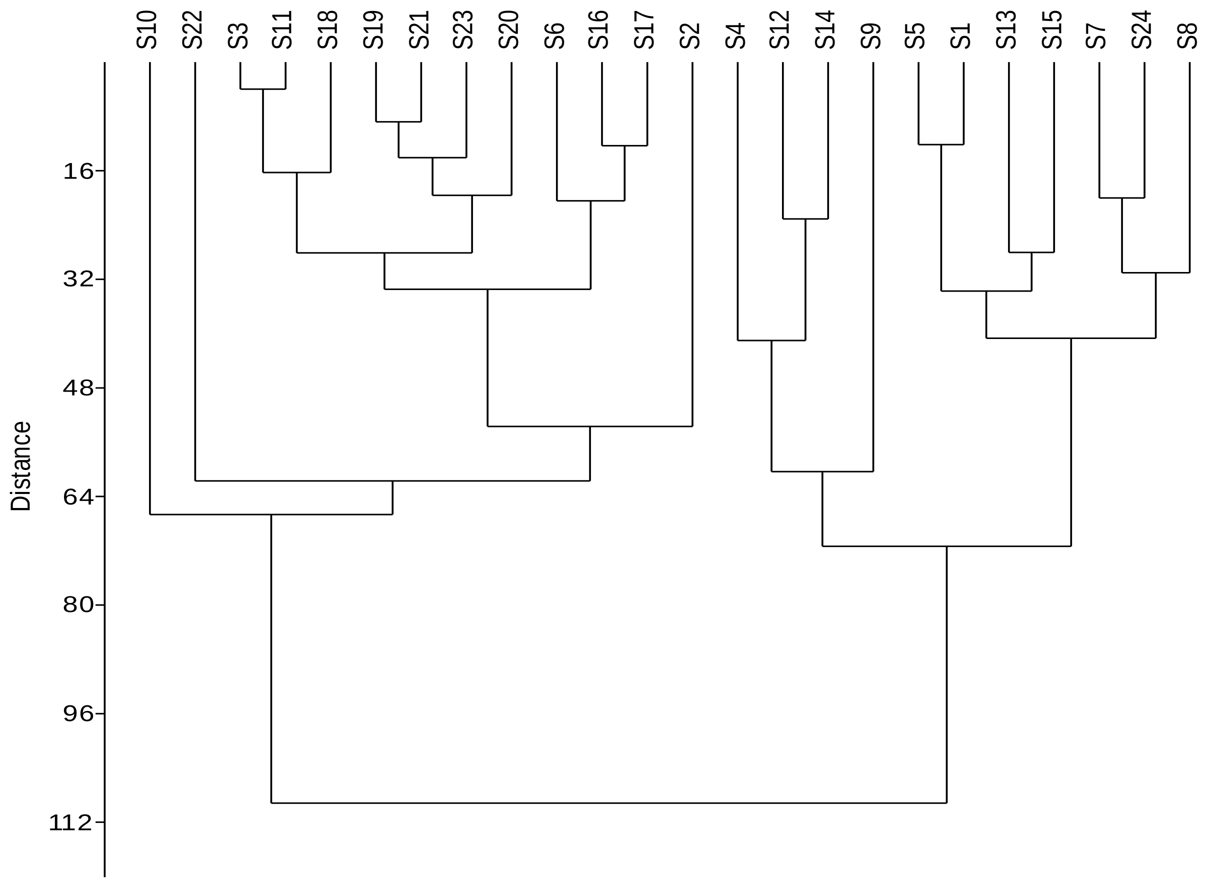

Fig. 10. Clusters diagram regarding the grouping of samples related to the studied agricultural land
Source: Original diagram based on analytical data.

The high degree of spatial variation of the studied agricultural land indicates the need for a differentiated approach, regarding calcarous and fertilizers resources application, in order to ensure optimal plant cultivation conditions.

Thus, in relation to pH, 70.83% of the studied surface has a moderate acid pH, and requires attention for correction with calcareous products. In terms of degree of saturation in bases (V%), an indicator for assessing the need to correct acidity, 20.83% of the studied land area requires an immediate correction of soil reaction by aapplication os calcareous resources.

In terms of the degree of nitrogen supply, assessed on the basis of the nitrogen index (NI), it can be estimated that 41.67% of the surface has a low supply and 58.33% a moderate supply of nitrogen. Therefore, in sizing the assortment of nitrogen fertilizers and doses, the level of the supply soil and the agricultural crops will be taken into account, so as to ensure an adequate nutrition of the cultivated plants.

The level of phosphorus supply of the land can be appreciated as moderate for 29.17% of the surface, good supply for 50.00% of the surface and very good supply for 20.83% of the surface. It is recommended to establish the differentiated doses of phosphorus fertilizers, in relation to the state of land supply and the consumption needs of agricultural crops.

In the case of potassium, according to the analytical values 4.17% of the surface is included in average supply, 45.83% in good supply and 50.00% in very good supply. The sizing of potassium fertilizers is recommended to be done in terms of doses in relation to the condition of the land and the needs of crops.

CONCLUSIONS

From the analysis of agrochemical indices, the agricultural land studied has a high spatial variability in terms of phosphorus content (P), followed in decreasing order, by potassium (K), nitrogen index (NI), degree of saturation in bases (V) and soil reaction (pH).

Due to the fact that the differentiated degree of spatial variability of the studied land, in relation to the analyzed agrochemical indices, it is recommended the differentiated approach of fertilization for each nutrient, respectively the application of calcarous resources, in relation to the concrete situation in the field, given by the analyzed samples.

ACKNOWLEDGEMENTS

The authors thanks to the GEOMATICS Research Laboratory, BUASMV "King Michael I of Romania" from Timisoara, for the facility of the software use for this study.

REFERENCES

[1]Agegnehu, G., van Beek, C., Bird, M.I., 2014, Influence of integrated soil fertility management in wheat and tef productivity and soil chemical properties in the highland tropical environment, J. Soil Sci. Plant Nutr., 14(3):532-545.

[2]Arriaga, F.J., Guzman, J., Lowery, B., 2017, Chapter 5 - Conventional agricultural production systems and soil functions, Soil Health and Intensification of Agroecosystems, 109-125.

[3]Awal, R., Safeeq, M., Abbas, F., Fares, S., Deb, S.K., Ahmad, A., Fares, A., 2019, Soil physical properties spatial variability under long-term no-tillage corn, Agronomy, 9(11):750.

[4]Dobrei, A., Sala, F., Mălăescu, M., Ghiță, A., 2009, Researches concerning the influence of different fertilization systems on the quantity and quality of the production at some table grapes cultivars, Journal of Horticulture, Forestry and Biotechnology, 13:454-457.

[5]Duffy, M., 2009, Economies of size in production agriculture, J. Hunger Environ. Nutr., 4(3-4):375-392.

[6]Dumitru, M. (coord.), Manea, A. (coord), Lăcătușu, R., Rizea, N., Ștefănescu, D., Tănase, V., Vrânceanu, N., Preda, M., Lăcătușu, A., Matei, M., Matei, S., 2011, Metode de analiză chimică și microbiologică (Methods of chemical and microbiological analysis), Sitech Pub;ishing House, Craiova, 298 pp.

[7]Elsheikh, R., Shariff, A.R.B.M., Amiri, F., Ahmad, N.B., Balasundram, S.K., Soom, M.A.M., 2013, Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops, Comput. Electron. Agric., 93:98-110.

[8]ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

[9]Fageria, N.K., 2005, Soil fertility and plant nutrition research under controlled conditions: basic principles and methodology, J. Plant Nutr., 28(11):1975-1999.

[10]Govedarica, M., Ristic, A., Herbei M.V., Sala, F., 2015, Object oriented image analysis in remote sensing of forest and vineyard areas, Bulletin UASVM Horticulture, 72(2):362-370.

[11]Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001, PAST: Paleontological statistics software package for education and data analysis, Palaeontol. Electron.,

4(1):1-9.
[12]Haruna, S.I., Nkongolo, N.V., 2013, Variability of soil physical properties in a clay-loam soil and its implication on soil management practices, International Scholarly Research Notices 2013: ID 418586.
[13]Herbei, M., Sala, F., 2016, Biomass prediction model in maize based on satellite images, AIP Conf. Proc., 1738:350009-1 – 350009-4.
[14]Honfoga, B.G., Parrales, I.G., 2018, Diagnosing soil degradation and fertilizer use relationship for sustainable cotton production in Benin, Cogent Environmental Science, 4(1):1422366.
[15]Ichami, S.M., Shepherd, K.D., Hoffland, E., Karuku, G.N., Stoorvogel, J.J., 2020, Soil spatial variation to guide the development of fertilizer use recommendations for smallholder farms in western Kenya, Geoderma Regional, 22:e00300.
[16]Jiao, S., Li, J., Li, Y., Xu, Z., Kong, B., Li, Y., Shen, Y., 2020, Variation of soil organic carbon and physical properties in relation to land uses in the Yellow River Delta, China, Sci. Rep., 10:20317.
[17]Khaki, B.D., Honarjoo, N., Davatgar, N., Jalalian, A., Golsefidi, H.T., 2017, Assessment of two soil fertility indexes to evaluate paddy fields for rice cultivation, Sustainability, 9:1299.
[18]Metwally, M.S., Shaddad, S.M., Liu, M., Yao, R.-J., Abdo, A.I., Li, P., Jiao, J., Chen, X., 2019, Soil properties spatial variability and delineation of site-specific management zones based on soil fertility using fuzzy clustering in a Hilly Field in Jianyang, Sichuan, China, Sustainability, 11:7084.
[19]Mukherjee, A., Lal, R., 2014, Comparison of soil quality index using three methods, PLoS ONE, 9(8):e105981.
[20]Pandey, D., Ojha, R.B., Chalise, D., Das, S., Twanabasu, B., 2019, Spatial variability of soil properties under different land use in the Dang district of Nepal, Cogent Food Agric., 5(1):1600460.
[21]Rahman, Md.M., Howladar, M.F., Faruque, M.O., 2017, Assessment of soil quality for agricultural purposes around the Barapukuria coal mining industrial area, Bangladesh: insights from chemical and multivariate statistical analysis, Environmental Systems Research, 6:24.
[22]Rusu, M., Mărghitaș, M., Constantin, T, Mihai, M., 2010, Cartarea agrochimică – Studiul agrochimic al solurilor (Agrochemical mapping - The agrochemical study of the soils), AcademicPress, Cluj Napoca, pp. 236.
[23]Said, M.E.S., Ali, A.M., Borin, M., Abd-Elmabod, S.K., Aldosari, A.A., Khalil, M.M.N., Abdel-Fattah, M.K., 2020, On the use of multivariate analysis and land evaluation for potential agricultural development of the northwestern coast of Egypt, Agronomy, 10:1318.
[24]Sala, F., Boldea, M., 2011, On the optimization of the doses of chemical fertilizers for crops, AIP Conf. Proc., 1389:1297.
[25]Sala, F., Rujescu, C., Constantinescu, C., 2016, Causes and solutions for the remediation of the poor allocation of P and K to wheat crops in Romania. AgroLife Scientific Journal, 5(1):184-193.
[26]Sánchez, J.D., Ligarreto, G.A., Leiva, F.R., 2011, Spatial variability of soil chemical properties and its effect on crop yields: a case study in maize (*Zea mays* L.) on the Bogota Plateau, Agron. Colomb., 29(2):456-466.
[27]Sarkar, A., Ghosh, A., Banik, P., 2014, Multi-criteria land evaluation for suitability analysis of wheat: a case study of a watershed in eastern plateau region, India, Geo-spatial Information Science, 17(2):119-128.
[28]Serrano, J., da Silva, J.M., Shahidian, S., Silva, L.L., Sousa, A., Baptista, F., 2017, Differential vineyard fertilizer management based on nutrient's spatio-temporal variability, J. Soil Sci. Plant Nutr., 17(1):46-61.
[29]Sillero-Medina, J.A., Hueso-González, P., Ruiz-Sinoga, D., 2020, Differences in the soil quality index for two contrasting Mediterranean landscapes in Southern Spain, Land, 9:405.
[30]Song, F.-f., Xu, M.-g., Duan, Y.-h., Cai, Z.-j., Wen, S.-l., Chen, X.-n., Shi, W.-q., Colinet, G., 2020, Spatial variability of soil properties in red soil and its implications for site-specific fertilizer management, J. Integr. Agric., 19(9):2313-2325.
[31]Taghizadeh-Mehrjardi, R., Nabiollahi, K., Rasoli, L., Kerry, R., Scholten, T., 2020, Land suitability assessment and agricultural production sustainability using machine learning models, Agronomy, 10(4):573.
[32]Tahat, M.M., Alananbeh, K.M., Othman, Y.A., Leskovar, D.I., 2020, Soil health and sustainable agriculture, Sustainability, 12:4859.
[33]White, P.J., Crawford, J.W., Álvarez, M.C.D., Moreno, R.G., 2012, Soil management for sustainable agriculture, Applied in Environmental Soil Science, Special Issue Soil Management for sustainable Agriculture, 2012: ID 850739.
[34]Xu, X., He, P., Pampolino, M.F., Qiu, S., Zhao, S., Zhou, W., 2019, Spatial variation of yield response and fertilizer requirements on regional scale for irrigated rice in China, Sci. Rep., 9:3589.
[35]Zelong, M., Yuanbo, G., Tingxing, H., 2006, Characteristic of soil hydro-physical properties and water dynamics under different vegetation restoration types, Wuhan Univ. J. Nat. Sci., 11:1009-1014.
[36]Zhen, L., Zoebisch, M.A., Chen, G., Feng, Z., 2006, Sustainability of farmers' soil fertility management practices: a case study in the North China Plain, J. Environ. Manage., 79(4):409-419.