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SOIL FERTILITY AS A NECESSARY MEASURE FOR SUSTAINABLE TOBACCO PRODUCTION IN THE AREA OF MUNCIPALITY OF DOLNENI

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Abstract

Republic of North Macedonia has a long history of tobacco production. Therefore, the precise determination of soil fertility parameters is of essential importance. The main purpose of this study was to determine the spatial distribution of tobacco soil properties as a useful strategy for guiding agricultural production and field management on specific sites. Furthermore, diagnosing soil fertility provides with proper and rational fertilization recommendations, which are integral parts of sustainable tobacco production. Following soil properties were monitored: pH, humus content, total nitrogen, available phosphorus and potassium, carbonates and physical clay in 153 of top soil samples (0-30 cm). The samples were collected from the area of municipality of Dolneni, which is part of Pelagonia region and accounts for almost 50% of the total area for tobacco production in the country.

The results show that soil properties exhibit spatial variation. Based on the performed classifications, 54 % of the soil samples have low humus and nitrogen content, 65 % of the samples have low available phosphorus content and only 6.5 % have low available potassium content. The soil reaction varies widely within the limits suitable for tobacco production, and most of the sampled soils are loamy. Thus, the application of mainly complex fertilizers, such as 10:30:20, 6:24:12 and 8:22:20, results with optimal fertility in the investigated area.

Key words: *soil properties, Pelagonia, spatial distribution*

INTRODUCTION

Soil is the basis of agricultural production, an extremely important medium for the cultivation and development of many crops. Soil is a heterogeneous, diverse and dynamic system and its properties change in time and space continuously (Brodsky et al.,2001; Denton et al., 2017). Soil properties vary spatially and they are affected by many factors that include nature of the pedogenic materials, evolution processes of the types of soil, soil management practices, fertility status, crop rotation (Bouma, 1999; Kumhalova & Matejkova, 2017; Jerzy & Boguslaw, 2018). Monitoring and quantifying variations in soil properties are necessary to understand the effects of land use and to provide sustainable agricultural management.

Analyses of spatial distribution and correlation of soil properties represents an important outset for precision agriculture (Boruvka et al., 2002). In the past years introduction of precision agriculture with the use of remote sensing, Geographic Information System (GIS) and Global Positioning Systems (GPS) has resulted in accurate and efficient mapping of fertility parameters (Bouma, 1997; Kuzyakova et al.,2001; Robinson & Metternicht, 2006). The concept of precision agriculture ensures an increase in productivity of agricultural goods while reducing production costs. By determining the most appropriate and localized management practices, precision agriculture helps to improve and align the soil conditions and quality for the effective use of nutrients (Bölenius et al., 2017; Usowicz & Lipiec, 2017). Almost all agricultural data has some form of spatial component that is used for predictive maps which have high levels of predictive accuracy on spatial variations (Robinson & Metternicht, 2006). Geographic information system technique provides various possibilities in prediction while wisely using the data obtained from agrochemical soil analyses.

Given the long history of tobacco production in Republic of North Macedonia, the precise determination of soil parameters is of essential importance. Controlling, managing and monitoring soil fertility is a long-term process, but it is a prerequisite for sustainable tobacco production. On the other side, diagnosing the soil fertility status using smart tools, leads toward effective management practices. This study was conducted as attempt to explore the fertility of agricultural soils of Municipality of Dolneni using the GIS tools. In this region, most of the arable area is part of the Pelagonia region, that occupies almost 50 % of the total area for tobacco production in Republic of North Macedonia. The main purpose was to map the spatial distributions of soil parameters as a useful strategy for guiding agricultural production and field management at specific sites.

MATERIAL AND METHODS

The study area is the Municipality of Dolneni, which is part of the largest tobacco production area in Pelagonia. The climate in this area is determined as continental with moderate precipitation (Lazarevski, 1993). The Pelagonian massif is a crystalline core with a continental type of Earth's crust, primarily composed of the oldest Precambrian formations (Durmudzanov et al., 2005; Jovanovski et al., 2012; Stafilov & Shajn, 2017). Alluvial and delluvial soil cover the municipality of Dolneni, mainly arable land. Soil samples were collected from 153 locations at fixed depth (0-30 cm) in each field with two replicates in the period from 2017-2021. Samples were collected in fall after crop harvesting. The sampling map (Figure 1) reveals distributional uniformity of samples and represents soil for tobacco cultivation only.

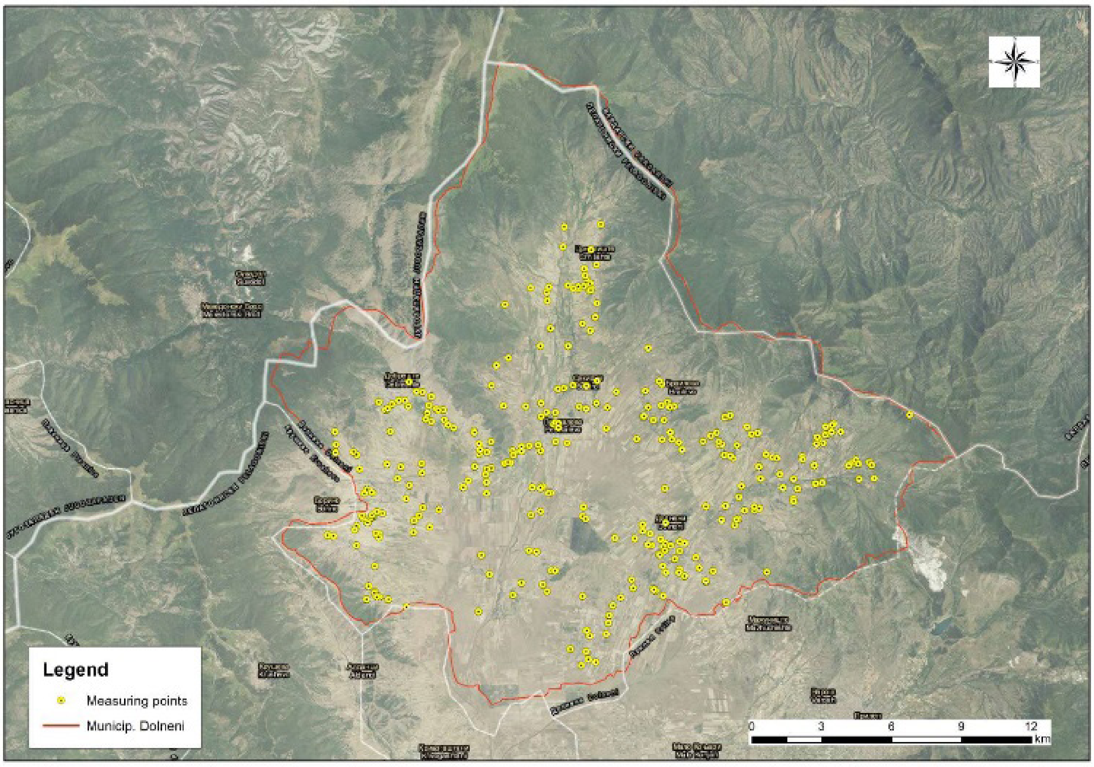

Figure 1. Sampling locations (municipality of Dolneni, n=153)

The variables as soil texture, pH, total nitrogen, organic matter, carbonates, available phosphorus and potassium were determined (Pelivanoska, 2012). The geographical coordinates of the sampling points are plotted on a map using the tools of the Source Geographic Information System - QGIS, software version 3.18.2. Interpolations and analysis of all sampling points were made according to Inverse distance weighting (IDW) parameters. This technique predicts attribute values at unsampled area based on the spatial distance of known observations from these unsampled locations (Wu & Hung, 2016).

RESULTS AND DISCUSSION

The examination of soil fertility through the analysis of average soil samples taken from a unit of production area is the fundamental measure for diagnosing the current state of the soil. Summary statistics of the analysed soil parameters are provided in Table 1. As shown, the coefficient of variation for most of the tested parameters is higher than 25%, indicating the heterogeneity of agricultural soil in the study area. The coefficient of variation for available phosphorus is 131 %, suggesting that this parameter exhibits greater variability compared to the other parameters in the study area. The highest coefficient of variation can be attributed to the carbonate content of the tested samples, as only 4 out of all tested samples contained carbonate (Table 1).

Nitrogen is a very important component of proteins, chlorophyll and nicotine in the tobacco plant. Optimal content of soil nitrogen is required for high yield, good quality and proper development of the tobacco plants. All tested soils have low to medium total nitrogen that varies from 0.01 to 0.20 %. Based on the performed classifications, 58 % of the collected samples have low humus and nitrogen content, 65 % of the samples have low available phosphorus content and only 6.5 % have low available potassium content. The soil reaction shows wide variation, with most of the sampled soils being loamy. According to agrochemical parameters, soils suitable for the production of oriental tobacco should have an average content of humus, low content of available phosphorus, optimal content of available potassium, and a neutral to slightly acid pH reaction (Mitreski, 2012; Pelivanoska et al.2017, 2018). According to these authors, most of the tested samples fall within the suitable limits for producing high-quality tobacco raw materials.

Table 1. Statistical parameters that characterize the frequency distribution of soil properties (n=153).

Soil parameter	X_g	Md	S_a	Skewness	Kurtosis	Minimum	Maximum	CV, %
Humus, %	1.47	1.4	0.5	0.65	0.70	0.5	3.2	33
Total nitrogen, %	0.07	0.1	0.02	0.61	0.59	0.0	0.2	33
pH (H_20)	5.95	5.9	0.6	1.06	2.78	4.6	8.4	11
pH (KCl)	4.94	4.9	0.6	1.57	4.62	3.8	7.7	13
$CaCO_3$	0.63	0.0	4.5	8.63	81.58	0.0	47.7	718
P_2O_5 mg/100 g	11.30	6.6	14.8	4.27	22.72	1.3	115.9	131
K_2O mg/100 g	18.56	16.9	7.2	1.27	2.20	5.6	50.2	39
Clay, %	32.47	31.4	9.3	0.89	0.98	15.7	68.0	29

*Xg – geometrical mean, Md - median, Sa– standard deviation, CV- coefficient of variation

The Pearson correlation coefficients pertaining to the associations between soil properties and the element content of all analysed soil samples are presented in Table 2. Correlations were observed to identify positive or negative influence of the selected variables. The correlation coefficients considered significant were only those with probability level lower than 1% and 5% ($P<0.01$ and $P<0.05$). A strong and positive correlation is observed between humus content and total soil nitrogen (r=0.999). For the rest of the analysed variables, moderate correlations were obtained.

Table 2. Pearson's correlation coefficients between selected soil properties.

	Humus	Total nitrogen	pH (H_20)	pH (KCl)	$CaCO_3$	P_2O_5	K_2O
Total nitrogen	0.999**	1					
pH (H_20)	0.298**	0.288**	1				
pH (KCl)	0.380**	0.376**	0.912**	1			
$CaCO_3$	0.206*	0.205*	0.487**	0.550**	1		
P_2O_5	0.154	0.154	0.156	0.261**	0.111	1	
K_2O	0.478**	0.480**	0.272**	0.360**	0.076	0.282**	1
Clay	0.525**	0.524**	0.223**	0.232**	0.007	-0.037	0.135

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed)

Based on the normality tests, most of the observed variables exhibit normal distribution, except available phosphorus and carbonate content. The spatial distributions of the selected soil parameters are presented in Figure 2-8. The maps are interpolated using the inverse distance weighting process, which is a deterministic estimation method. It determines values at unmeasured points by using a linear combination of values at nearby measured points (Wu & Hung, 2016). Various approaches exist for selecting the appropriate interpolation method (Goovaers, 1992, 1999; Robinson & Metternicht, 2006; Zhang et al., 2011; Zhang et al., 2013; AbdelRahman et al., 2018; AbdelRahman et al., 2021). According to the most of the mentioned authors, ordinary kriging and inverse distance weighting are the most frequently used geostatistical techniques for predicting soil parameters. In this research, inverse distance weighting was considered the most reliable interpolation method (Hengl et al., 2007; Sun et al., 2012; Ibrahim et al., 2015).

Based on the soil properties fertilizer application rates were calculated and mainly complex fertilizers were found suitable for tobacco production. For the majority of the tested soils (71%) from the municipality of Dolneni, the recommended fertilizer is mainly complex NPK 10:30:20. For the remaining samples, NPK 6:24:12 and 8:22:20 are suggested. To maintain fertility and prevent soil depletion, it is necessary to apply fertilizer in quantities derived from yields. On very poor and acidic soils, nutrient availability decreases, requiring an increase in the dose of mineral fertilizers. To increase the amount of available phosphorus by 1 mg in 100 grams of soil, 30 kg of pure P_2O_5 is required. It is advised to only apply nitrogen to soils with very high and extremely high levels of phosphorus and potassium.

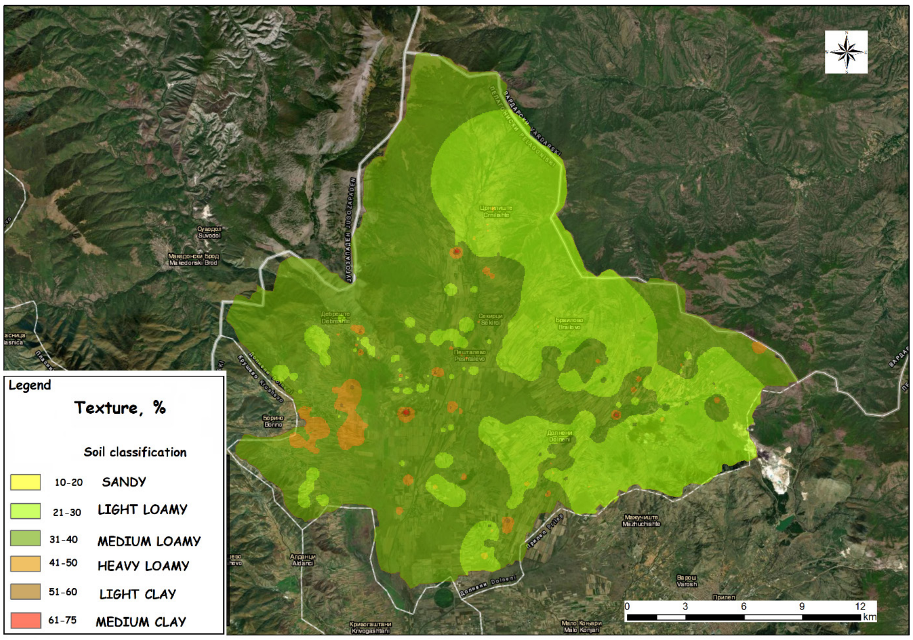

Figure 2. Spatial distribution of physical clay content

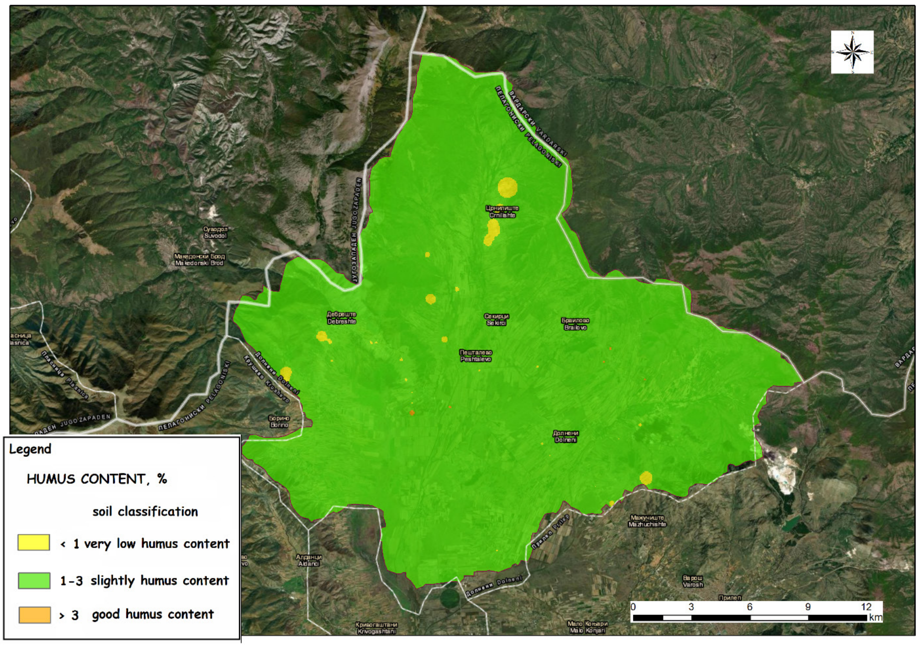

Figure 3. Spatial distribution of humus content

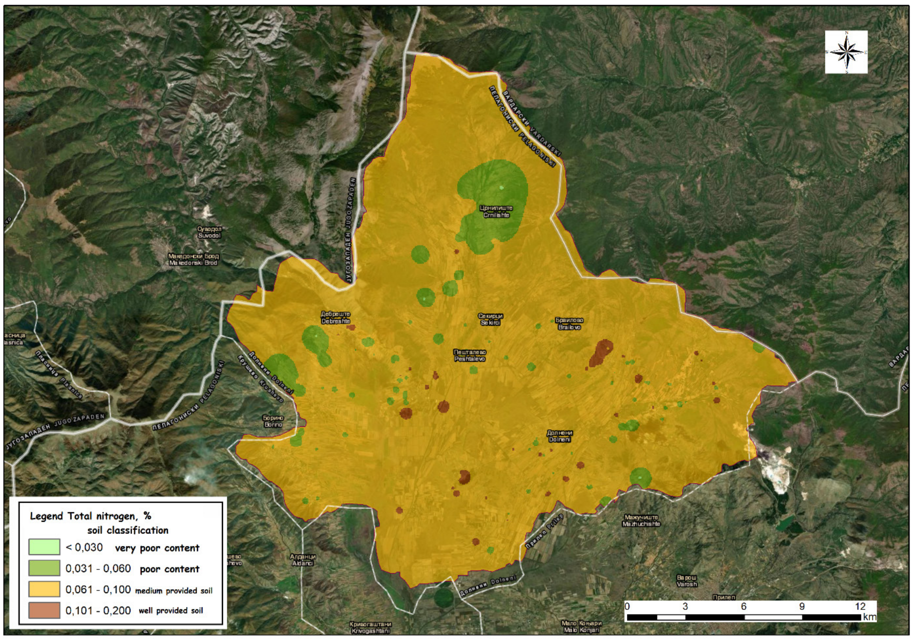

Figure 4. Spatial distribution of total nitrogen content

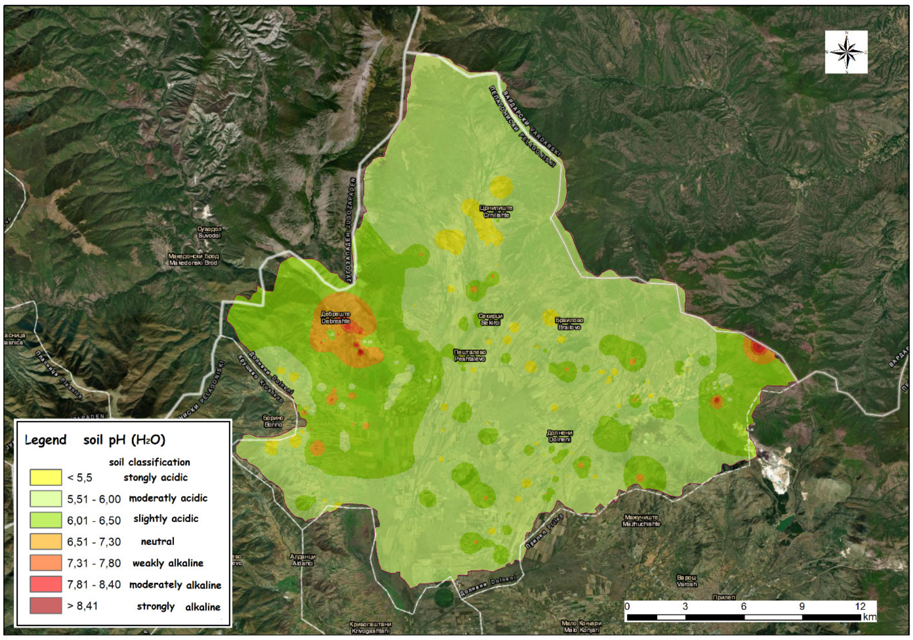

Figure 5. Spatial distribution of soil pH in water

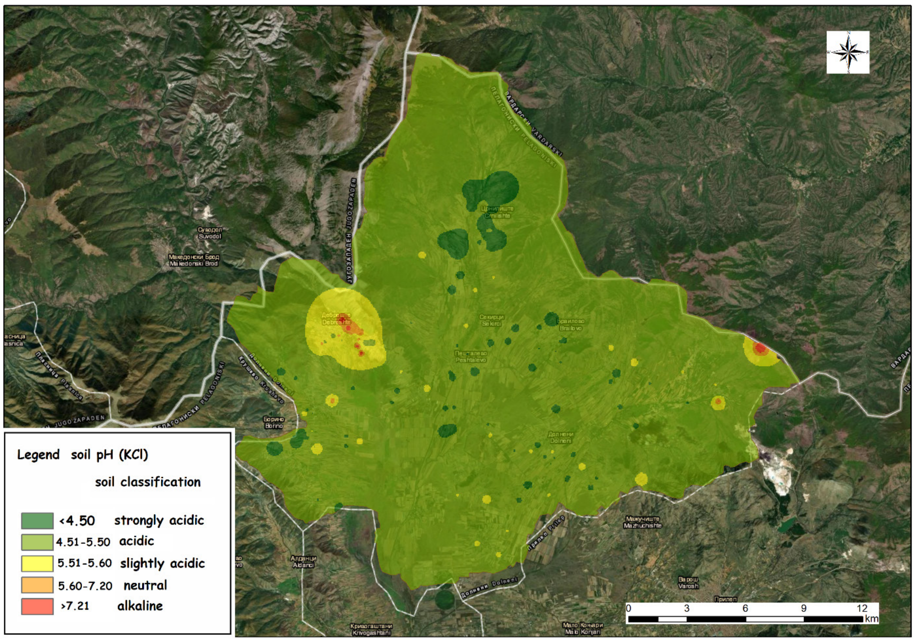

Figure 6. Spatial distribution of soil pH (KCl)

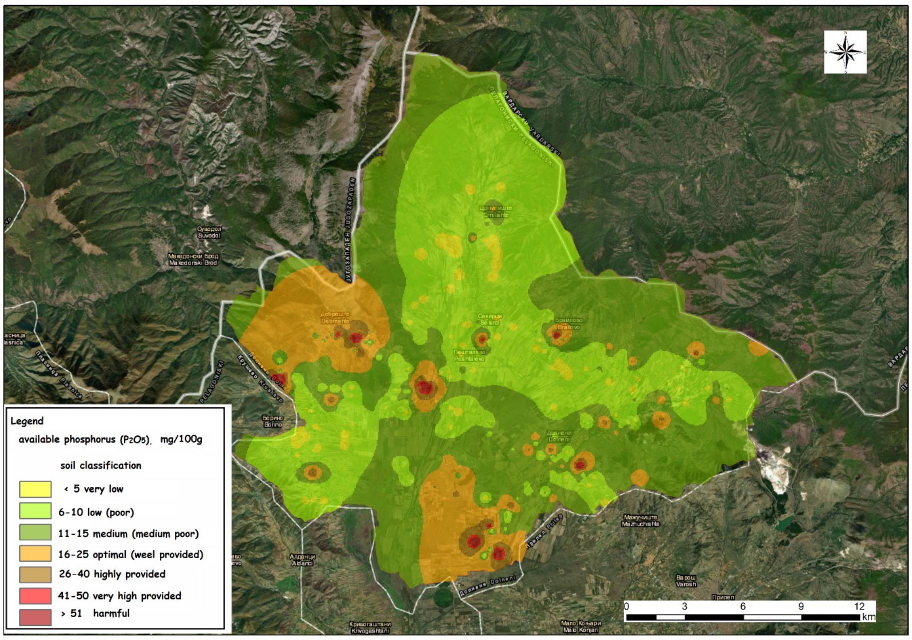

Figure 7. Spatial distribution of available phosphorus content (P_2O_5)

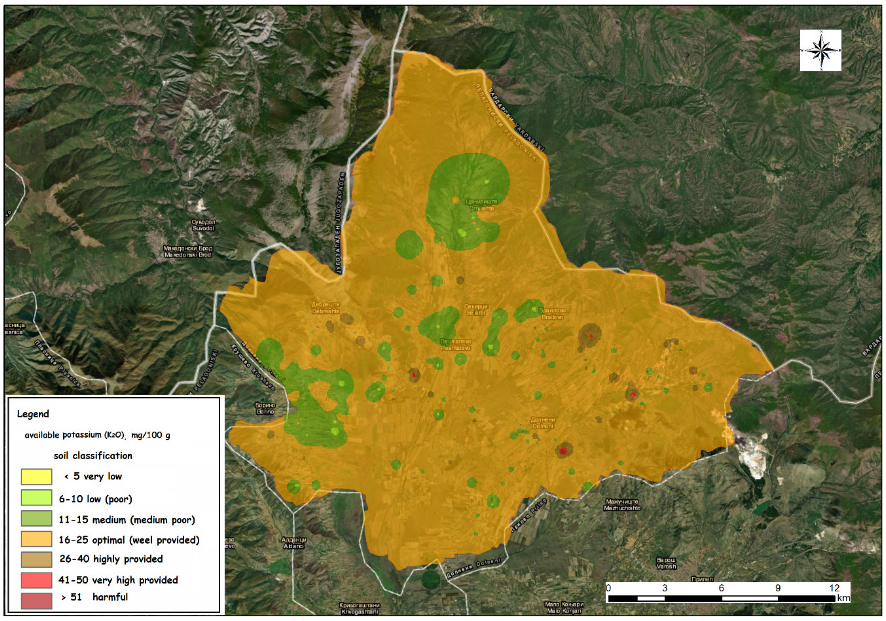

Figure 8. Spatial distribution of available potassium content (K_2O)

CONCLUDING REMARKS

Based on the results, we can conclude that monitoring soil fertility parameters is essential for sustainable tobacco production. Most of the soil samples have low nitrogen content, a slightly acid pH, and a light mechanical composition, making them ideal for the production of high-quality raw tobacco. To maintain fertility and prevent soil depletion, it is necessary to apply fertilizers in quantities derived from yields. It is recommended that soils with very high and extremely high levels of phosphorus and potassium to be fertilized only with nitrogen. This approach will significantly reduce costs per unit of production and avoid environmental burden. Given the fact that soil fertility is a dynamic value, further and extended monitoring is crucial in order to test and validate appropriate interpolation methods for estimating the spatial distribution of soil parameters. It is important to expand the availability of soil resource information maps to facilitate the planning of appropriate tobacco soil management practices, including fertilization for agricultural production and environmental protection.

REFERENCES

AbdelRahman, M.A.E., Zakarya, Y.M., Metwaly, M.M., Koubouris, G. (2021). Deciphering Soil Spatial Variability through Geostatistics and Interpolation Techniques. *Sustainability*, 13: 194. https://doi.org/10.3390/su13010194

AbdelRahman, M.A.E., Shalaby, A., Aboelsoud, M.H., Moghanm, F.S. (2018). GIS spatial model based for determining actual land degradation status in Kafr El-Sheikh Governorate, North Nile Delta. *Modeling Earth Systems and Environment*, 4: 359–372.

Barandovski, L., Frontasyeva, M. V., Stafilov, T., Šajn, R., Pavlov, S. S., Enimiteva, V. (2012). Trends of atmospheric deposition of trace elements in Macedonia studied by the moss biomonitoring technique, Journal of Environmental Science and Health, Part , 47: 2000-2015.

Bölenius, E., Stenberg, B., Arvidsson, J. (2017). Within field cereal yield variability as affected by soil physical properties and weather variations – a case study in east central Sweden. *Geoderma,* 11: 96–103.

Boruvka, L., Donatova, H., Nemecek, K. (2002). Spatial distribution and correlation of soil properties in a field: a case study. Rostlinná Výroba, 48(10): 425–432.

Bouma, J. (1997). Precision agriculture: and introduction to and temporal variability of environmental quality. *Precision agriculture*. Wiley, Chichester: 5-17.

Brodsky, L., Vanek, V., Szakova., Stipek, K. (2001). Spatial heterogeneity of soil properties. *Rostlinna Vyroba*, 47:521-528.

Denton, A., Aduramigba-Modupe, A.O, Adeoyolanu, O.D., Are, K.S., Adelana, A.O., Oyedele, A.O., Adetayo, A.O., Oke, A.O. (2017). Assessment of spatial variability and mapping of soil properties for sustainable agricultural production using geographic information system techniques (GIS). *Cogent Food & Agriculture,* 3: 1279366.

Dumurdzanov, N., Serafimovski, T., Burchfiel, B.C. (2005). Cenozoic tectonics of Macedonia and its relation to the South Balkan extensional regime. *Geosphere*, 1(1):1-22. https://doi.org/10.1130/GES00006.1

Goovaers, P. (1992). Factrorial kriging analysis a useful tool for exploring the structure of multivariate spatial soil information. *European Journal of soil science,* 43(4):597-619.

Goovaerts, P. (1999). Geostatistics in soil science: State-of-the-art and perspectives. *Geoderma*, 89: 1–45.

Hengl, T., Heuvelink, G.B.M., Rossiter, D.G. (2007). About regression-kriging: From equations to case studies. *Computational geosciences*, 33:1301–1315.

Ibrahim, A.M., Nasser, R. H. N. (2015). Comparison between Inverse Distance Weighted (IDW) and Kriging. *International Journal of Science and Research*, 2319-7064.

Jerzy L., Bogusław, U. (2018). Spatial relationships among cereal yields and selected soil physical and chemical properties. *Science of the Total environment*, 633: 1579-1590.

Jovanovski, G., Boev, B., Makreski, P. (2012) *Minerals from the Republic of Macedonia with an Introduction to Mineralogy*. Macedonian Academy of Sciences and Arts: Skopje.

Kumhalova, J., Matejkova, Š. (2017). Yield variability prediction by remote sensing sensors with different spatial resolution. *Agrophys*, 31:195–202. https://doi.org/10.1515/intag-2016-0046.

Kuzyakova, I.F., Romanenkov, V.A., Kuzyakov Ya, V. (2001). Geostatistics in soil agrochemical studies. *Eurasian Soil Science,* 34 (9):1011–1017.

Lazarevski, A. *Climate in Macedonia*; Kultura: Skopje, **1993** (in Macedonian).

Mitreski M. (2012). Comparative studies of production technological and quality properties in some varieties of tobacco of type Prilep. *Doctoral dissertation*. Scientific Tobacco Institute-Prilep.

Pelivanoska, V. (2012). *Handbook for Agrochemical Testing of Soil* (in Macedonian), Sientific Institute Prilep Press, Prilep, Macedonia.

Pelivanoska, V., Jordanoska, B., Risteski, I., Trajkoski J. (2017)**.** Some manufacturing properties of semi-oriental tobacco bred in the region of Prilep, Western Macedonia**.** *Agriculture&Forestry,* 63(3):75-84.

Pelivanoska, V., Jordanoska, B. (2018). Efects of different nitrogen rates on the yield and quality of orinetal tobacco produced in Pelagonia region.*Tobacco/Тутун*, 68 (1-6): 75-82.

Robinson, T.P., Metternicht, G. (2006). Testing the performance of spatial interpolation techniques for mapping soil properties. *Computers and Electronics in Agriculture*, 50: 97–108.

Stafilov T. and Sajn R. (2017). *Geochemical atlas of the Republic of Macedonia*, Faculty of Natural Sciences and Mathematics, Skopje, R. Macedonia. https://doi.org/10.20450/mjcce.2017.1243

Sun, W., Whelan, B.M., Minasny, B., McBratney, A.B. (2012). Evaluation of a local regression kriging approach for mapping apparent electrical conductivity of soil (ECa) at high resolution. *Journal of Plant Nutrition and Soil Science*, 175: 212–220.

Usowicz, B., Lipiec, J. (2017). Spatial variability of soil properties and cereal yield in a cultivated field on sandy soil. *Soil Tillage Research*, 174: 241–250.

Wu, Y-H., Hung, M-C. (2016). Comparison of spatial interpolation techniques using visualization and quantitative assessment. *Applications of Spatial Statistics*. IntechOpen.

Zhang, S.W., Shen, C.Y., Chen, X.Y., Ye, H.C., Huang, Y.F., Lai, S. (2013). Spatial interpolation of soil texture using compositional kriging and regression kriging with consideration of the characteristics of compositional data and environment variables. *Journal of Integrative Agriculture,*12: 1673–1683.

Zhang, Z., Yu, D., Shi, X., Weindorf, D.C., Sun, Y., Wang, H.; Zhao, Y. (2011). Effects of prediction methods for detecting the temporal evolution of soil organic carbon in the Hilly Red Soil Region, China. *Environmental Earth Science*, 64: 319–328.

ПЛОДНОСТА НА ПОЧВАТА КАКО ПРЕДУСЛОВ ЗА ОДРЖЛИВО ПРОИЗВОДСТВО НА ТУТУН ВО ОБЛАСТА НА ОПШТИНА ДОЛНЕНИ

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Резиме

Производството на тутун во Република Северна Македонија има долга историја, затоа прецизното определување на параметрите кои ја отсликуваат плодноста на почвата е од суштинско значење. Главна цел на оваа студија беше одредување на просторна распределба од почвените параметри за почвите каде се одгледува тутун, како корисна стратегија за насочување на земјоделското производство и управувањето со теренот во одредена област. Како составен дел од одрживото производство на тутун, со дијагностицирањето на плодноста на почвата се обезбедуваат правилни и рационални препораки за ѓубрење. На 153 површински почвени примероци (0-30 cm) беа проучени следните параметри: pH, содржина на хумус, вкупен азот, достапни форми на фосфор и калиум, карбонати и механички состав. Примероците се земени од површината на општина Долени, која е составен дел на Пелагониски тутуно-производен регион кој зафаќа речиси 50% од вкупните површини за производство на тутун во државата.

Резултатите покажуваат дека својствата на почвата просторно се разликуваат. Врз основа на извршените класификации, 54 % од примероците почва имаат ниска содржина на хумус и азот, 65 % од примероците имаат ниска содржина на достапен фосфор и само 6,5 % имаат ниска содржина на достапен калиум. Реакцијата на почвата варира во граници кои се поволни за производство на тутун, а повеќето од анализираните почви се илести. Согласно истражувањето, комплексните ѓубрива како 10:30:20, 6:24:12 и 8:22:20 се најсоодветни за обезбедување оптимални услови за плодноста во истражуваната област.

Клучни зборови: *почвени параметри, Пелагонија, просторна распределба*