THE ANNALS OF “VALAHIA” UNIVERSITY OF TARGOVISTE
2013

PRELIMINARY STUDIES FOR MANAGEMENT ZONE DELINEATION IN PRECISION AGRICULTURE IN AN APPLE ORCHARD

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Abstract

The aim of this preliminary study was to analyse the soil and the properties of the soil, the distribution of the most important elements to develop a simplified procedure for the delineation of management zones in apple orchard. To achive this objective, field data were collected; it was realised a soil profile, the horizons were analysed and the type of soil was established; also, the humus content, the nitrogen index, the soil reaction and cation exchange capacity were analysed and a few interpolated maps were produced. By using GPS data, from GPS Garmin Etrex EURO and Surfer 8 software, the sampling mapping was created, indicating the position of each of the 50 sampling mapped. Due the genetic resistance at diseases of the Florina cultivar, the number of treatments is smaller and a better protection of soil and environment is assured. As a result of carrying out the tests on the eutricambisol profile and interpretation of data we can say that this soil presents physical and chemical parameters favourable to apple culture.

Keywords: Management zone delineation, Soil properties, Nitrogen Index, Spatial variability, Kriging

1. INTRODUCTION

Precision agriculture is a recent concept for our country and the studies into an apple orchard are at the beginning.
Fleming et al. (2000) have evaluated farmer defined management zone maps for variable rate fertilizer application. The research was initiated to determine if farmer-developed management zone maps based on soil color from aerial photographs, topography, and the farmer’s past management experience can be effective in developing variable rate application maps. The analised parameters (soil organic matter, clay, nitrate, potassium, zinc, conductivity) followed the trends indicated by the management zones.
In 2000, Murphy et al. study the size and function of both soluble organic N extracted from soils (SON) and dissolved organic N present in soil solution and drainage waters (DON) in arable agricultural soils. They established that SON it’s affected by mineralisation, immobilisation, leaching and plant uptake in the same way as those of mineral N, but its pool size is more constant than that of mineral N and Leached DON may take with it nutrients, chelated or complexed metals and pesticides.
The delineation of site-specific management zones by unsupervised classification of topographic attributes and soil electrical conductivity was study by Fraisse et al., in 2001. The elevation and bulk soil electrical conductivity were more important attributes than slope and Compound Topographic Index for defining claypan soil management zones.
In 2003, Koch et al. have the objective of their study to assess the economics of uniform versus variable-rate nitrogen (N) fertilizer application under two N application scenarios, into a corn field, using the global positioning system and geographic information system technology. They showed that variable-rate N application utilizing site-specific management zones are more economically feasible than conventional uniform N application.
Schepers et al. (2004) characterised spatial variability of soil properties in an irrigated corn field. It appears that landscape attributes can be used to delineate MZ that characterize spatial variation in soil chemical properties. But the most limiting factor, in many situations, was the water. Uses of MZ for variable application of inputs like N have been appropriate only for irrigated field, under the restriction of variable environmental conditions.
Kitchen et al. (2005) used unsupervised fuzzy c-means clustering to delineate soil productivity zones (SPZ) by analyzing apparent soil ECa and elevation data of the research fields cultivated with corn and soybean. They also delineated yield productivity zones (YPZ) by analyzing yield mapping data. Outcomes of YPZ and SPZ were matched and degree of agreement was calculated with an overall accuracy statistic (the number of correctly matched cells divided by the total number of cells in the dataset).
Zaman and Schuman, in 2006 have like objectives of the study to identify soil factors causing tree performance decline in a variable citrus grove, and to develop soil-specific management zones based on easily measured soil/tree parameters for variable rate applications of appropriate soil amendments.
Yan et al. in 2007 observed the NDVI data, soil salinity data, cotton yield and fuzzy c-means clustering for define management zone. The optimal number of management zones was establised at 3 areas. They observed the significantly statistical differences of soil samples between the 3 areas. The defined management zones can provide an effective decision-making support for variable input in precision agriculture.
Kyaw et al. (2008) study the vegetation indices derived from aerial imagery, on-the-go measurement of soil pH and apparent soil electrical conductivity for their potential to delineate clorosis management zones. The combination

of aerial imagery and soil ECa information provides a good basis for delineating chlorosis-prone areas within fields. Although NDVI and GNDVI were the properties most significantly related to yield in this study, the combination of EC_ad with NDVI in the delineation process improved our ability to predict yield and insured that areas of reduced yield were associated with Fe chlorosis.

In 2010, Guastaferro et al. compared different procedures for creating management zones and determined the relation of the MZs delineated with potential yield. They compared 3 differents techniques and illustrated the importance of temporal variation in spatial variation of yield in rainfed conditions, which limits the use of the MZ approach.

Zhang et al. (2010) have developed a web-based decision support tool, zone mapping application for precision farming to automatically determine the optimal number of management zones and delineate them using satellite imagery and field data provided by users. They demonstrated that ZoneMAP can serve as an effective and easy-to-use tool for those who practice precision agriculture.

Jiang et al. (2011) used Management Zone Analyst software to delineate irrigation management zones. The method had a high precision and could provide the basis management delineate decision.

The study of Tagarakis et al. (2012) focused on delineating management zones using fuzzy clustering techniques and developing a simplified approach for the comparison of zone maps. The study show that management zones can be used to perform variable rate applications (irrigation, fertilization etc.) leading to more efficient management of the vineyard according to the desired specifications of the end product.

Xue et al. (2013) studied different N rates for early rice with an active sensor in south China. It was established a spectrally-determined N topdressing model (SDNT) and used in combination with a target yield strategy and split-fertilization scheme.

Thöle et al. (2013) used crop sensors to reduce environmental impacts, by adapting spatial N variability in agricultural fields.

Soil ECa measurements are suitable to analyze spatial variability for static soil properties, such as salinity, texture (Corwin and Plant 2005) and organic matter (Shaner et al. 2008).

The objective of this preliminary study was to analyse the soil and the properties of the soil, the distribution of the most important elements to develop a simplified procedure for the delineation of management zones in apple orchard.

2. MATERIALS AND METHODS

Study site

The studied surface (0.9 ha) is located in the middle of fruit growing basin Dambovita (25^0 14' 268'' E and 45^0 05' 211'' N, altitude 423 m), at SRDP Voinesti, in an orchard planted in 2004 with Florina cultivar. The area is characterized by a continental climate, attenuated by orographic, hydrographic and biosphere factors. A better environmental protection is ensured by reducing the number of treatments and the number of tillage. The maintaining soil system is lying between row and intra-row tree.

For the studied area, the altitude varies between 423 - 433 m and is shown in Figure 1.

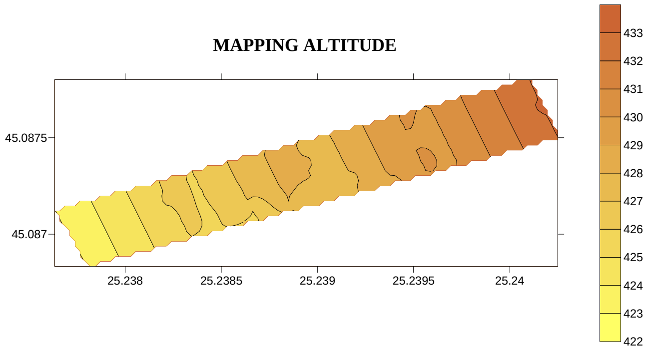


Fig.1. Mapping altitude for the study area

The soil on which it was located the experiences at apple is eutricambisol, a type of soil from the spodosols class.

This soil was formed under the terms of a young relief, in the presence of native vegetation, in generally devoid of acidophilic components and in the present of a humid climate, with a percolativ hydric system which did not allow emphasizing processes of weathering and leaching.

Under these conditions there have been no migration processes of clay in the upper part of the soil profile, with a horizon Bt training (clay), but a horizon Bv (cambic); the clay from its level (Bv) is the result of alteration in situu (on the spot).

The groundwater is at variable depths ranging between 6 and 10 m and, it can not influence the processes to the ground.

The eutricambisol from experimental area showing the sequence of horizons Ao-Bv-C and the following morphological characteristics (Fig. 2):

Fig. 2. Eutricambisol

- Horizon Ao - thickness 0-28 cm, color in dry: light brown (10 YR 5/3), color in wet: Brown (10 YR 4/3),

medium texture, clay, grain structure, weak adhesive, weak plastic, moderately compacted;
- Horizon A/B - thickness 28 – 40 cm- color in dry: pale yellowish brown (10 YR 6/4), color in wet: yellowish brown (10 YR 5/4), spots of Fe oxide - 15%, clay medium, poliedric structure underdeveloped, weak adhesive, weak plastic, weak compacted, with fine and rare roots;
- Horizon Bv - thickness 40 – 92 cm, color in dry: pale brown (10 YR 6/3), color in wet: light brown (10 YR 5/3), medium texture, clay, poliedric structure, well developed, moderately adhesive, moderately plastic, weak compacted;
- Horizon C - thickness 92-120 cm, color in dry: yellow rust (10 YR 6/6), color in wet: yellow rust-brown (10 YR 5/6), medium texture, without structure.

Due to the medium size texture, non-differentiated on the profile and relatively good structural state, the rest of the physical properties and physical-mechanical properties are favorable.

Thus, the total porosity is medium, permeability is medium and edaphic volume is very high. On a reduced surface, due to the content of clay and drainage conditions, it is noticed a weak activity of stagnogleysation proces, which determine the appearance of oxidation and reduction spots, in a small proportion, on the horizon Bv.

Sampling

Each soil sampling position was recorded with GPS Garmin Etrex EURO.

By using GPS data, from GPS Garmin Etrex EURO and Surfer 8 software, the sampling mapping was created, indicating the position of each of the 50 sampling mapped. Surfer (v. 8, Golden Software) soft was used to produce interpolated maps.

To characterize the soil from the agrochimic point of view, samples were taken from 50 points of the study area, on the depth of 0 - 40 cm, in June 2013.

The following analysis were made:
- soil reaction – potentiometric method, in water suspension;
- humus content in agrochemical layer - Tiurin method;
- content of mobile phosphorus – metoda Egner Riechm Domingo;
- content of mobile potassium – metoda Egner Riechm Domingo;
- Nitrogen Index – IN;
- cation exchange capacity;
- particle size distribution.

The soil reaction is one of the most important soil chemical parameters, assuring optimal nutritive supply for plants. Soil reaction has importance for general characterization of soil and agricultural practice. The values of soil reaction depend on the soil percentage base saturation.

Humus is the basic constituent of soil, resulting from the biocenosis action during soil formation process. This has a physical, chemical and trophical functions, contribute to the soil structure formation, water absorption, cation adsorption and exchange, and supplying nutrients as a result of organic matter mineralization (Chirita, 1974). Different form of humus occur under aerobic conditions (acid mull, calcic mull, moder, moder mull, raw humus) and peat and anmorr under anaerobic conditions (Duchaufour, 1970, quoted by Chirita, 1974).

Assessment of soil after humus content and pH values was made taking account of Tables 1 and 2:

Table 1. Assessment of soil after humus content

Humus content	**Assessment Soil texture**	
	Medium and fine	coarse
≤ 0.5	extremely weak	very weak
0.6-1.0	very weak	weak
1.1-2.0	weak	medium
2.1-3.0		
3.1-4.0	medium	good
4.1-8.0		
5.1-8.0	good	very good
8.1-15.0	very good	excessive
15.1-35.0	excessive	
≥ 35	organic soils	

Table 2. Assessment of soil reaction after pH values

pH	**Assessment of reaction**
≤ 3.50	extremely acidic
3.51-4.30	very strongly acidic
4.31-5.00	strongly acidic
5.01-5.40	moderate acidic
5.41-5.80	
5.81-6.40	weakly acidic
6.41-6.80	
6.81-7.20	neutral
7.21-8.40	weakly alkaline
8.41-9.00	alkaline
≥ 9.01	strongly alkaline

The content of exchangeable bases (EB me/100g soil) was determined by Kappen method. Fonction of result, the assessment of content of exchangeable bases was realised in accordance with Table 3:

Table 3. Classes of EB

Limits (em/100g soil)	**Assessment**
0.1-2.0	very low
2.1-4.0	low
4.1-6.0	moderate
6.1-8.0	high
≥ 8.1	very high

The soil percentage base saturation is one of the important chemical indicators. The values of this indicator were determined by calculation (for acid soils), or as the percentage ratio between the content of exchangeable bases (EB me/100g soil) and total cation exchange capacity. After the calculation, the soils have been included in one of the following classes (Table 4):

Table 4. Soil classification according to the values of base saturation degree

Base saturation degree	Soil classification
≤ 10	extremely oligobasic
11-30	oligobasic
31-55	oligomezobasic
56-75	mezobasic
76-90	eubasic
≥ 91	saturated in bases

The mobile phosphorus content in soil was determined by Egner-Riehm-Domingo procedure, by extraction in the ammonium lactate acetate. The phosphorus is the second indispensable macronutrient, with importance in the constitution and physiology of plants and their development, fruiting and seed formation. More than 50% of the total phosphorus content of soil is found in the humic horizon. The phosphorus content of plants is not so high than that of nitrogen, potassium and calcium, but it can become a limiting factor because of low soluble content of this element in soil (Chirita, 1974). The phosphorus solubility depend of the soil reaction and its chemical combinations. Thus, the solubility of the Al and Fe phosphates increases as the soil reaction increases, and that of the Ca phosphates decreases as the pH decreases (Scheffer and Schachtschabel, 1970, quoted by Chirita, 1974).

The mobile potassium content in soil was determined by Egner-Riehm-Domingo procedure, by extraction in the ammonium lactate acetate. The potassium is one of the important macronutrients for the plant nutrition, asked in high quantities, with a complex functional role in plant metabolism, being absolutely indispensable. Around 98% of the soil potassium content is in an unchangeable form, being a limitative factor for crop yields on the debasified or sandy soils, or soils with a low content of potassic minerals (Chirita, 1974). The potassium content in soil solution increases when the soil moisture decrease and a part of it is fixed (Davidescu and Davidescu, 1979).

Data analysis

For data analysis (summary statistics and correlation analysis) it was used S-PLUS 2000_ (MathSoft Inc., Seattle, WA, USA). The coefficient of variation (CV=standard deviation/mean) of a measured variable in a given year provides an estimate of the global spatial variation (each data point is obtained from a different location in the field) (Aggelopoulou and al. 2010).

The Isatis geostatistical software (v.8, Geovariances) was used to determine the spatial relationships of variables. Surfer (v.8, Golden Software) was used to produce interpolated maps. IRF-k kriging estimates a value at an unsampled location x_0 by minimizing the estimation variance (which is also the variance of residuals).

The function $K(\mathbf{h}) = \sum_{p=0}^{k} b_p K_p(\mathbf{h})$ is a generalized covariance function, b_p are the unknown coefficients to be determined (equivalent to variogram sills) and the K_p (h) are authorized generic structures (Aggelopoulou and al. 2010). In Isatis these may include a nugget, a linear generalized covariance, a spline generalized covariance or a third-order generalized covariance (Geovariances 2008). The IRF-k approach requires data on a regular grid (approximately the case for our orchard data), and Isatis uses a bilinear interpolator to migrate nearby observation locations to the target grid. Interpolation by kriging was done for pH, humus and IN data only.

3. RESULTS AND DISCUSSION

Summary statistics and spatial analysis for soil parameters

Summary statistics for the soil parameters are done in Table 5 and the spatial coefficients of variability are given in Table 6.

Table 5. Summary statistic for soil parameters

	Variable	Mean	Min	Max	SD_S
Soil parameters	Humus	2.78	2.15	3.25	0.36
	IN	2.09	1.61	2.53	0.28
	pH	5.82	5.59	6.00	0.13

$SD_S = \sqrt{var(Z)}$ is the standard deviation for a given year based on measurements at all spatial locations

Table 6. Spatial variability of soil parameters

	Variable	Coef. of variation (%)	Coef. of skewness (%)
Soil parameters	Humus	0.13	- 0.11
	IN	0.13	- 0.02
	pH	0.02	- 0.12

For all parameters, the coeficient of variation is very small (CV: 0.02 - 0.13%).

The coefficient of skewness has negative values; for negative skewness, most values are concentrated on the right of the mean, with extreme values to the left. The biggest asymmetry is found at soil pH, with an asymmetry to the right.

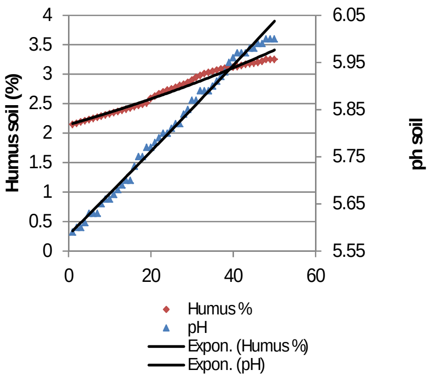
In terms of Agrochimic Index were recorded the following values: IN: 1.61 – 2.53; P-AL: 37 – 47; K-AL: 172 – 235.

The humus content is medium in Ao horizon and, in the same time being medium stocked with nitrogen and well stocked with P and K.

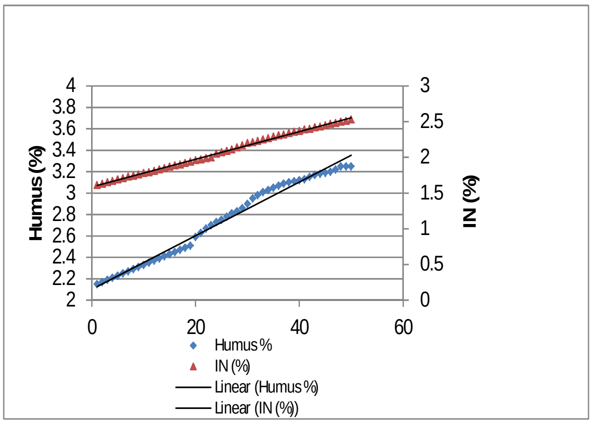
Thus, it appears that the pH is maintained weak acid all over the entire area mapped, with values between 5.59 and 6.00, because of weakly intensity of leaching process. In correlation with pH values we can observe the values directly proportional with the content of exchangeable bases, oscillating around 18 me per 100 g soil on almost the entire area. As a result of the determinations, the minimum of the exchangeable bases recorded is 15.9, and the maximum is 18.9. Also, the values of soil percentage base saturation are 77.9% in horizon Ao and 79.1% in horizon C, that indicate an eubasic soil.

The chemical properties of the soil on which were conducted the experiences speak for themselves about its suitability. So, the values of base saturation degree indicates a weak soil leachate, rich in alkaline elements, with an intens microbial activity, manifested by the formation of a quality humus and colloids (humus and clay) that are in irreversible state of coagulation; this fact leads to a good soil structure and to a favourable aerohidric regime.

A positive correlation can be made between humus, IN and pH. The higher the humus content is, the higher the IN it is (Fig. 3 b).



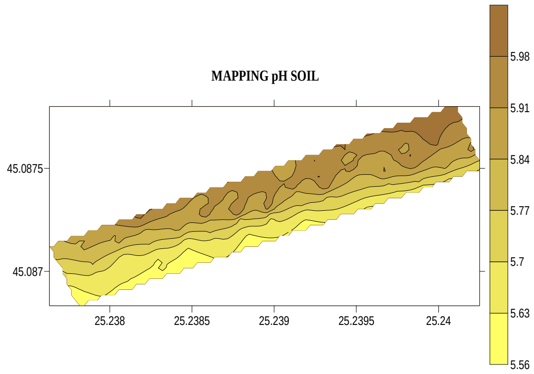
a)



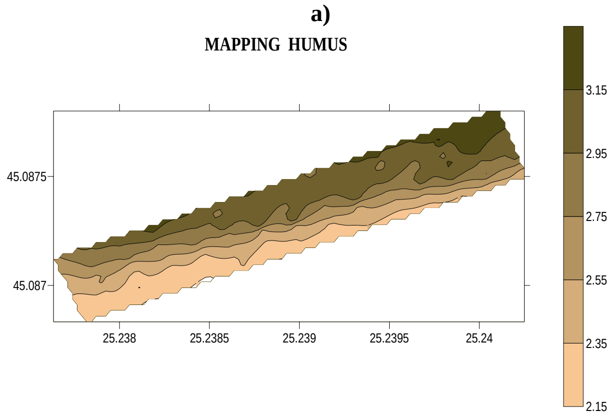
b)

Fig. 3. Correlation between (a) humus and pH, (b) humus and IN

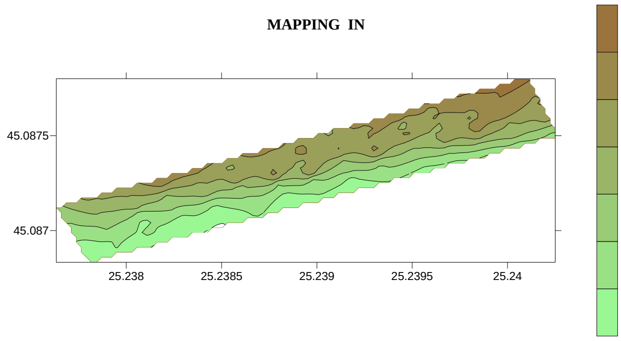
Interpolation by kriging was done for pH, humus and IN data only (Fig. 4).



a)



b)



c)

Fig. 4. Maps of a) pH soil, b) humus, c) nitrogen index. Interpolation was done by inverse-squared distance. The scale bar represents interpolated values; the symbols indicate measured data values.

Figure 4 illustrates typical patterns of variation across the orchard using three of the parameters variables as examples. All the parameters have different values in the northen ans southern parts of the orchard. Figure shows a NE-SW trend across the site, for all analysed parameters.

4. CONCLUSIONS

In this study, the acquired results indicate that the Agrochimic Index values were medium, the humus content is medium, the soil pH is maintained weak acid all over the entire area mapped and the values of base saturation degree indicates a weak soil leachate, rich in alkaline elements, with an intens microbial activity, manifested by the formation of a quality humus and colloids (humus and clay) that are in irreversible state of coagulation; this fact leads to a good soil structure and to a favourable aerohidric regime.

As a result of carrying out the tests on the eutricambisol profile and interpretation of data we can say that this soil presents physical and chemical parameters favourable to apple culture.

5. ACKNOWLEDGEMENTS

Thanks to the SRDP Voinesti, Dambovita for the technical support in this study.

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