Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 2, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

COMPARATIVE ANALYSIS ON A BALANCED FERTILIZATION FOR QUALITY OF SOME ARABLE SOILS FROM SOUTH OF ROMANIA

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Abstract

One of the requirements of quality management of soils in general, and of arable soils in particular, is knowledge of the dynamics of physical and chemical characteristics especially of those which are the most sensitive under human activities. The main objectives of the present paper were to measure the physical, chemical and hydrological properties of soil collected from three agricultural soils, and to carry out the fertilization plan accomplished by using modern agricultural practices and technologies for a balanced fertilization in order to preserve soil fertility and environment. Soil samples were collected from three locations around South of Romania. The selected soils for this study are located in the Calarasi county, namely: profile P1 in Sarulesti location - Typical Chernozem (Calcic Chernozem), profile P2 in Tamadau Mare location - Cambic Chernozem (Haplic Chernozem), and Arges county respectively: profile P3 in Costesti location - Vertic-Stagnic Preluvosol (Vertic-Stagnic Luvisol). The investigated soils are medium to fine textured, starting from medium clayey-loam, clayey-silty loam to loamy clay. High contents in clay result in higher values for bulk density and penetration resistance. On the contrary, the saturated hydraulic conductivity (K_{sat}) of such fine textured soils records low values, the most significant decrease being encountered in the soil profile P3. The highest values of K_{sat} were recorded in the topsoil layer of the soil profile P2 where the total porosity was also the highest. The deeper layers of the soil profiles (> 80 cm depth) have lower values for S index. That means the soil physical quality as quantified by S is better in the topsoil horizons than in the subsoil horizons. The soil reaction values highlighted a lightly acid soil in P3, a lightly acid to lightly alkaline soil reaction in P2, and a lightly alkaline soil reaction in P1. The total nitrogen content of all three soils varied from very low-low to moderate values. The available phosphorus content ranged from very low-low in P3, low-high in P2, up to moderate-high in P1. As for the available potassium content, all the studied soils were moderately supplied. The fertilization plans were accomplished based on agrochemical studies. For each of the three sites cartograms were done for soil reaction, phosphorus and potassium. Also synthetic cartograms with the average values of soil reaction (pH), humus content, available phosphorus (P_{AL}), available potassium (K_{AL}), and nitrogen index (IN) for the established fertilization parcels from each location were realized. The fertilization plans contained economic and technical optimum doses - DOE and DOT (which ensure a certain level of crop yield at which the maximum benefit is achieved) for a four years crop rotation in case of P1 and P2 soils and five years crop rotation in case of P3 soil.

Key words: *soil quality, balanced fertilization, arable soils, optimum economic dose.*

INTRODUCTION

One of the requirements of quality management of soils in general, and of arable soils in particular, is knowledge of the dynamics of physical and chemical characteristics especially of those which are the most sensitive under human activities.

It was widely recognized and accepted that soil structure represents the most important physical characteristic for all aspects of soil use and management due to its great impact on other soil physical properties.

Soil structure can change as a result of the use of various agricultural practices and can, in turn, influence both the productivity arising from agricultural practices and the impact of these practices on the environment. In order to have soil with a high physical quality it is necessary to have two main structural features: firstly, the soil must be stable. That means, the clay particles must flocculate and not disperse.

Flocculation is enhanced by calcium ions adsorbed on the clay surfaces and by maintaining the electrolyte concentrations above certain critical values. Also high levels of organic matter content are essential for the stability of micro-aggregates. Secondly, the soil must have a wide distribution of pore sizes and a high total porosity that will make the soil able to absorb, store and release water for plant use in response to transpirational demand. Such soils will have also a good aeration status and will be more easily penetrable by plant roots.

The interactions between soil chemical, physical and microbiological properties define a specific soil's "quality" and influence how effectively the soil carries out ecosystem functions such as: a) retain and release nutrients and other chemicals, b) distribute rainfall at the soil surface into runoff and infiltration, c) hold and release soil water to plants, streams and groundwater, d) withstand wind and water erosion, and e) buffer against the concentration of potentially toxic materials (Larson and Pierce, 1991; Karlen et al., 1997). Moreover, soil quality is an inherent property of a soil, a result of the factors of soil formation (i.e. climate, vegetation, parent material, time and topography). Therefore, from a productivity point of view, each soil has an innate capacity to function, and some soils will be inherently more productive than others.

An important measure from the Code of Good Agricultural Practices (2015), which transposes the European Nitrates Directive in Romania, refers to the standards on maximum quantities of nitrogen fertilizers which may be applied on agricultural lands in order to prevent or reduce water pollution with nitrates. For this, fertilizer plans at farm level are recommended to be carried out. A fertilization plan is based on a soil agrochemical study. Within the agrochemical study, the maximum nitrogen doses which might be applied in soil are calculated. For calculation of the maximum nitrogen doses, soil nitrogen content, soil physical and chemical properties as well as the expected crop yields are taken into account. If the maximum calculated nitrogen (mineral and organic) dose is lower than 170 kg nitrogen/ha/year, the maximum nitrogen dose from animal manure which might be applied on agricultural land should not exceed this value.

In order to obtain high yields and to increase the soil fertility, a proper fertilizer dose should be applied for increasing soil nutrients content as well as the soil fertility without losing nitrates by surface runoff or by leaching and avoiding water bodies pollution.

The fertilization plan is accomplished for a period of 4-6 years for crops within a certain rotation at farm level and contains nutrients economic optimum doses (which ensure a certain level of crop yield at which the maximum benefit is achieved) and technical doses (which take into account the ecological potential and the amount of nutrients needed to maintain/increase the soil fertility and to achieve high crop yields without a certain benefit and possible losses) (Lacatusu, 2016). All the fertilization doses are established in kg/ha.

The main objectives of the present paper were to measure the physical, chemical and hydrological properties of soil collected from three agricultural soils, and to carry out the fertilization plan accomplished by using modern agricultural practices and technologies for a balanced fertilization in order to preserve soil fertility and environment.

MATERIALS AND METHODS

Sample collection and preparation

Soil samples were collected from three locations around South of Romania. The selected soils for this study are located in the Calarasi county, namely: profile P1 in Sarulesti location, profile P2 in Tamadau Mare location, and Arges county respectively: profile P3 in Costesti location. According to the Romanian soil classification - SRTS 2012 (Florea and Munteanu, 2012) and FAO-WRB (1998), the soil types used in this paper are: P1-Typical Chernozem (Calcic Chernozem), P2- Cambic Chernozem (Haplic Chernozem), P3-Vertic-Stagnic Preluvosol (Vertic-Stagnic Luvisol).

All the investigated areas were under the arable land use. The soils were characterized according to the instructions for accomplishing the agrochemical studies by using standardized measurement methods.

Fertilization plan execution

The fertilization plan was carried out going three stages, namely: field stage, laboratory stage and desk stage. The field stage included activities such as: obtaining information about the farm specific conditions (physical blocks, crop location on physical blocks, previous agrochemical treatments, soil types). Two soil samples were collected from one physical block within the Sarulesti sampling point, 11 soil samples were collected from four physical blocks within Tămădău Mare sampling point

and 10 soil samples were collected from one physical block within Costești sampling point.
The laboratory stage included the measurement of soil indicators used for nitrogen doses calculation, such as: soil reaction (pH), organic carbon (Corg), available phosphorus (P_{AL}), available potassium (K_{AL}). The nitrogen index (IN) was calculated. During the desk stage cartograms related to soil reaction (pH) and availability of phosphorus (P_{AL}) and potassium (K_{AL}) were accomplished.

RESULTS AND DISCUSSIONS

Comparative analysis of soil quality

The soils from this study were characterized in terms of hydro-physical and chemical properties. In Table 1 the hydro-physical characterization of the soils is presented. It can be observed that the investigated soils are medium to fine textured, starting from medium clayey-loam (P1), clayey-silty loam (P2) to loamy clay (P3). High contents in clay result in higher values for bulk density (BD) and penetration resistance (RP). On the contrary, the saturated hydraulic conductivity (K_{sat}) of such fine textured soils records low values, the most significant decrease being encountered in the soil profile P3.
Soil penetration resistance and bulk density are often used in studies concerning soil degradation by compaction. In this investigation, in case of soil profiles P2 and P3, the values of penetration resistance and bulk density increased down the soil profile, the subsoil layers showing a greater mechanical strength than the topsoil layers. Plots of penetration resistance and bulk density as functions of soil depth are presented in Figure 1. The compacted layer is observed just below the ploughing depth, values of both bulk density and penetration resistance increasing sharply at this depth.
Penetration resistance is used to simulate the mechanical impedance encountered by growing roots (Whitebread et al., 2000). Several authors (e.g. Ferreras et al., 2000) suggested that the level of mechanical strength, as recorded by penetrometer, can severely restrict root growth, particularly in the plough pan. A value of penetration resistance of 2-2.5 MPa is quoted in the literature as a critical value above which root growth is reduced significantly (Busscher et al., 1986).
Degradation of soils due to compaction is a worldwide problem, and the problems caused by this were intensively studied and reported in many articles (e.g. Defossez and Richard, 2002). Lipiec and Nosalewicz (2004) showed that a characteristic response of a root system to increasing soil compaction level is a decreased root length, retarded root penetration and shallower rooting depth. The authors in their work showed that irrespective of soil type and site the soil compaction resulted in greater concentration of roots in upper soil (0-10 cm) and reduced root growth in deeper soil, mostly due to excessive mechanical impedance such as hard pan.
Soil structure represents one of the major attributes of soil quality (Dexter, 2004a). It affects the soil pore system and through it the water movement processes in soil. The highest values of saturated hydraulic conductivity (K_{sat}) were recorded in the topsoil layer of the soil profile P2 where the total porosity (PT) was also the highest (Figure 2).

Table 1. Physical characterization of the soil profiles

Location	Profile No.	Depth	Particle size distribution			Soil texture class	BD	RP	K_{sat}	PT	$W_{pF\,0}$
			sand	silt	clay						
		(cm)	(% g/g)				(g/cm^3)	(MPa)	(mm/h)	(% v/v)	
Sarulesti	P1	0-18	37.2	27.7	35.1	TT	1.45	4.4	3.95	45.9	45.2
		18-28	40.0	27.6	32.4	LL	1.44	3.9	7.24	46.2	45.5
		28-45	37.7	29.1	33.2	TT	1.37	3.1	4.44	48.9	45.3
		45-65	37.6	29.8	32.6	TT	1.27	2.4	18.23	52.7	45.6
		65-92	35.2	32.5	32.3	LP	1.28	2.6	13.49	52.1	46.4
		92-138	40.1	30.0	29.9	LL	1.46	3.4	2.14	45.7	44.7
Tamadau Mare	P2	0-16	37.1	28.2	34.7	TT	1.18	2.5	16.93	56.0	47.8
		16-28	34.8	28.0	37.2	TT	1.45	4.0	5.70	45.9	41.5
		28-45	34.8	26.5	38.7	TT	1.40	4.7	1.21	47.6	41.3
		45-63	37.6	24.0	38.4	TT	1.43	4.8	1.04	46.8	42.1
		63-90	28.8	31.6	39.6	TT	1.40	4.3	2.07	47.9	41.7
		90-130	33.8	32.5	33.7	TP	1.48	4.0	3.46	44.9	41.1
		130-150	37.9	29.9	32.2	LL	1.36	3.0	5.87	49.3	42.4
Costesti	P3	0-20	29.6	29.2	41.2	TT	1.61	2.5	0.95	39.2	48.7
		20-39	33.2	24.7	42.1	TT	1.46	5.5	14.20	44.9	41.1
		39-57	21.1	23.5	55.4	AL	1.48	5.3	2.40	44.2	47.4
		57-74	20.9	22.8	56.3	AL	1.47	6.2	1.18	44.5	49.7
		74-96	19.9	24.5	55.6	AL	1.50	6.2	1.18	43.4	49.2
		96-138	23.1	23.1	53.8	AL	1.51	6.9	0.80	43.0	44.7

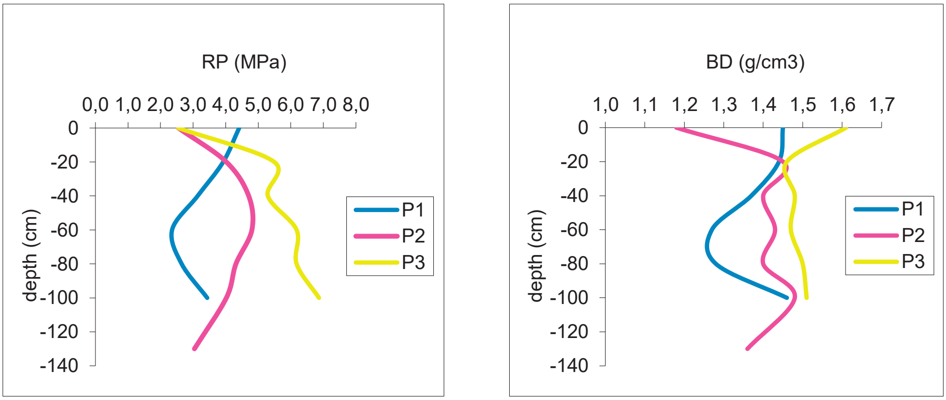


Figure 1. Plots of penetration resistance and bulk density as functions of soil depth

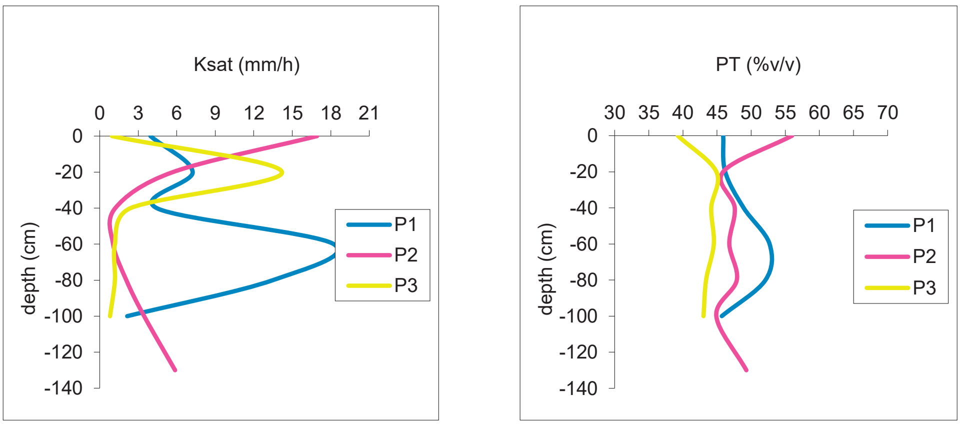


Figure 2. Plots of saturated hydraulic conductivity and total porosity as functions of soil depth

Pagliai et al. (2004) stated the significant role played by soil porosity in evaluation of the impact of management practices on the quality of soil structure. They found that adopting alternative tillage systems, such as ripper subsoiling, on a cambisol the macro-porosity was generally higher and more-homogeneously distributed through the profile when compared with a conventional tillage system, and the resulting soil structure had a better quality, as confirmed by the higher hydraulic conductivity measured in the soil tilled by ripper subsoiling.

As a general trend, the topsoil layers had greater values of water content at saturation (W_{pF0}) when compared with subsoil layers, except for the profile P1 where the values of water content at saturation were constant within the soil profile (Table 1). This may be attributed to a decrease of organic matter content and an increase of bulk density values within the soil profiles.

Figure 3 shows the soil water retention curves of the three investigated soils. The soil water retention curves were obtained after using the Arya-Paris model for estimating the van Genuchten parameters (Arya and Paris, 1981).

The differences in shape of water retention curves between topsoil and subsoil layers may be as a result of either externally-applied mechanical stress by agricultural machinery which can lead to compaction of the layer below ploughing depth, or internally-applied mechanical stress due to drying of the soil which causes shrinkage due to the effective stresses generated by the pore water suction and the surface tension in the water menisci. It is known that both increasing bulk density and soil drying reduces the volume of the soil pores (Vizitiu et al., 2010).

The fitted van Genuchten (van Genuchten, 1980) parameters were then used to calculate *S* index using Eq. (1) from below.

$$S = -n\left(\theta_{sat} - \theta_{res}\right) \cdot \left[1 + \frac{1}{m}\right]^{-(1+m)} \qquad (1)$$

where: *n, m* - adjustable shape factors;
θ_{sat} - water content at saturation (kg kg^{-1});
θ_{res} - residual water content (kg kg^{-1}).

The van Genuchten parameters were used to calculate the values of *S* index by using the equation 1.

The resulting values of *S* are presented in Figure 4 and show that these soils have different pore size distributions along the soil profile which is mainly due to differences in their micro-structure. According to Dexter's theory (2004a,b,c) the values of *S* index were in the range of the *S* values defining a poor (S = 0.028-0.034) and good (S = 0.036-0.088) soil physical quality, with the mention that based on the S index values, all the soil profiles fall into the class of good soil physical quality.

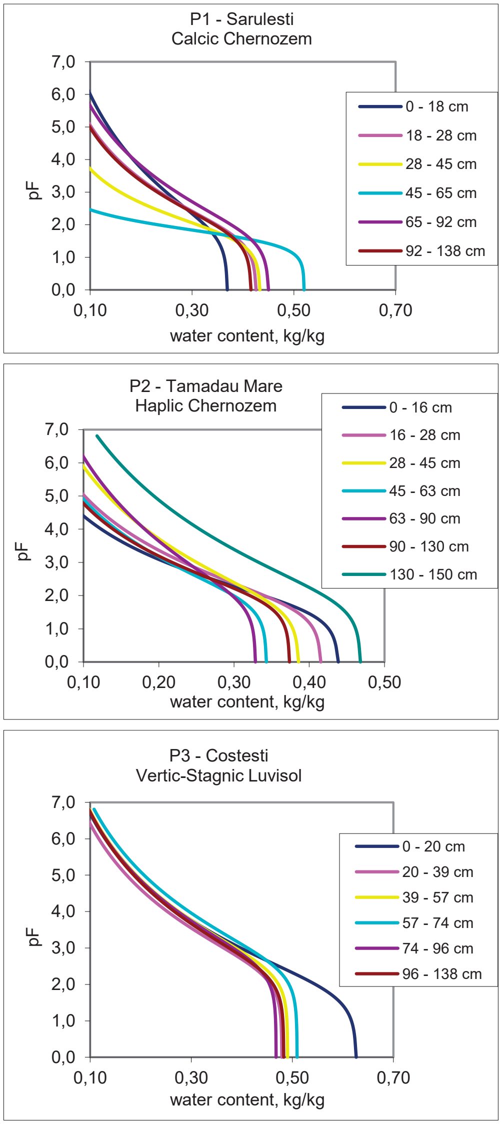


Figure 3. The soil water retention curves of the soils

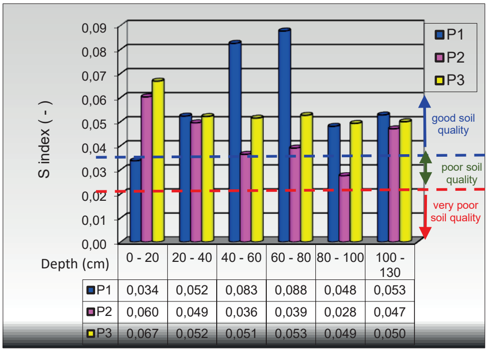


Figure 4. Values of the S index for the studied soils

From the Figure 4 it can be seen that the deeper layers of the soil profiles (> 80 cm depth) have lower values for *S* index. That means the soil physical quality as quantified by *S* is better in the topsoil horizons than in the subsoil horizons, except for the profile P1 where the values of *S* index in the top-soil layer is the lowest, and then showed an increase up to 80 cm depth and then decreased again with depth. This can be due to both higher contents in organic matter of the top-soils and lower values of bulk density.

The soil fertility and availability of the nutrients are strongly affected by the soil properties. Because of these, it is very important to evaluate periodically the soil fertility and to correlate the applied fertilization doses with the plant needs.

The chemical characterization of the studied soils is presented in Table 2. The soil reaction values, in case of P3 soil profile, varied between 5.5 and 6.7, which highlighted a lightly acid soil. The soil profile P2 had soil pH values ranging between 6.7 and 8.2, which means that this soil has a lightly acid to lightly alkaline soil reaction. At last, the soil profile P1 had values of pH between 7.5 and 8.5, meaning that this soil had a lightly alkaline soil reaction.

Organic matter content of the studied soils varied between very low and low contents (0.6-3.3% and 0.9-2.7% respectively) in case of fine textured soils (P2 and P3 respectively) up to low – moderate contents (1.2-3.9 %) in case of medium textured soil profile P1.

The total nitrogen content of all three soils varied from very low - low to moderate values (0.090-0.225%). The available phosphorus content ranged from very low - low (2-12 ppm) in case of soil profile P3, low - high (17-56 ppm) in case of soil profile P2, up to moderate - high (22-52 ppm) in case of soil profile P1. As for the available potassium content, all the studied soils were moderated supplied (100-200 ppm).

Table 2. Chemical characterization of the soil profiles

Location	Depth	pH	Hu-mus	N_{total}	P_{AL}	K_{AL}
	(cm)	(-)	(%)	(%)	(ppm)	
Sarulesti	0-18	7.5	3.9	0.225	52	180
	18-28	8.1	3.6	0.179	28	159
	28-45	8.4	2.6	0.158	22	179
	45-65	8.5	2.3	0.157	22	180
	65-92	8.5	2.3	-	-	-
	92-138	8.5	1.2	-	-	-
Tamadau Mare	0-16	6.7	3.3	0.186	56	170
	16-28	6.7	3.3	0.183	51	167
	28-45	6.7	3.0	0.144	23	177
	45-63	7.1	2.5	0.118	17	200
	63-90	7.3	2.4	-	-	-
	90-130	7.3	1.2	-	-	-
	130-150	8.2	0.6	-	-	-
Costesti	0-20	5.5	2.7	0.196	12	100
	20-39	5.8	2.1	0.153	2	109
	39-57	5.8	1.3	0.090	2	131
	57-74	6.0	1.0	-	2	171
	74-96	6.2	0.9	-	4	138
	96-138	6.7	1.0	-	3	123

The nutrients uptake by absorption in plants from the soil, by leaching or by other processes related to the natural dynamics of the soils, result in a decrease of the contents of mobile forms of nutrients and the gradual decline of soil production capacity. Therefore, both nutrients consumption by crops and decreased nutrient availability through natural processes (adsorption, fixation, immobilization in humic substances, etc.) is necessary to be compensated by applying of mineral and organic fertilizers (Borlan et al., 1994).

Fertilization plan - a tool for managing and controlling the fertilizers use

To maximize their productive potential, the cultivated plants need appropriate amounts of water, light, carbon dioxide and mineral nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and a number of trace elements). Soil is the main source of mineral nutrients and water for plants. Its capacity to provide the nutrients needed by plants varies depending on its fertility level.

The plant nutrients availability and soil fertility are strongly influenced by soil properties.

Consequently, is very important to periodically evaluate the soil fertility and to correlate the applied fertilization doses with the plant requirements. Moreover, in the Action Plan for water protection against nitrates pollution from agricultural sources it is mentioned that for the farms which practice irrigated agriculture and for that's where the planned crop yield requires higher amounts of nitrogen than those given by the maximum standards set out in the Code of Good Agricultural Practices (GAP) for water protection against nitrate pollution from agricultural sources (Dumitru et al., 2015), it is mandatory to accomplish the fertilization plan based on agrochemical study.

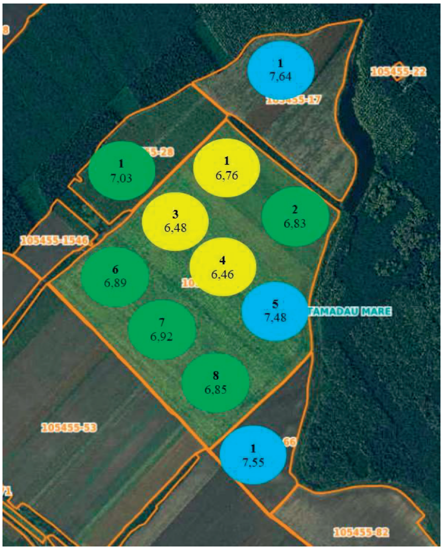
Cartograms of soil reaction, available phosphorus and available potassium were accomplished. In Figure 5 the cartograms of soil reaction and fertilization parcels are presented as an example for all the three studied areas. Each soil sample was located by numbers and agrochemical values on cartograms. It can be seen that the two soils from Calarasi county (P1 - Sarulesti and P2 - Tamadau Mare) had similar values as those found when soil smaples were collected from profiles. The pH values varied between 6.13 (P1) and 7.64 (P2). Also the soil from Arges county (P3 - Costesti) maintained its lightly acid reaction, with values ranging between 5.03-5.87.

The available phosphorus content ranged from low (8-15 ppm) in case of soil profile P1, low - high (26-91 ppm) in case of soil profile P2, up to low - moderate (15-33 ppm) in case of soil profile P1. As for the available potassium content, the studied soils from Calarasi county (P1, P2) were good - very good suppled (143-267 ppm), while the soil from Arges county (P3) was moderately supplied (87-132 ppm).

The nutrients uptake by absorption in plants from the soil, by leaching or by other processes related to the natural dynamics of the soils, result in a decrease of the contents of mobile forms of nutrients and the gradual decline of soil production capacity. Therefore, is necessary to compensate by applying of mineral and organic fertilizers, both nutrients consumption by crops and decreased nutrient availability through natural processes (adsorption, fixation, immobilization in humic substances, etc.) (Borlan et al., 1994).

Within the investigated physical blocks, one fertilization parcel (P 1-2) was established in case of P1 - Sarulesti, four fertilization parcels were established in case of Tamadau Mare - P2 and one fertilization parcel was established in case of P3 - Costesti by fitting the agrochemical subparcels with agrochemical values included in the same variation range.

P1 - Sarulesti



P2 - Tamadau Mare

P3 - Costesti

Figure 5. Cartograms of the soil reaction

In Figure 6, as an example, the average values of soil reaction (pH), humus content, available phosphorus (P_{AL}), available potassium (K_{AL}), and nitrogen index (IN) for the established fertilization parcels in case of P2 - Tamadau Mare are presented.

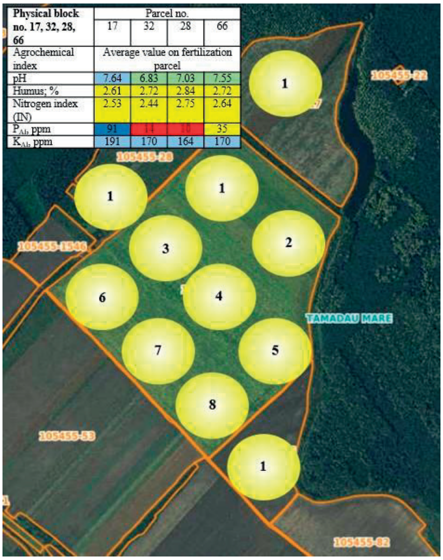


Figure 6. Fertilization parcels established within the physical blocks in case of P2 - Tamadau Mare

The soil pH values within the studied physical block varied between 6.83 and 7.64, which highlighted a lightly alkaline soil (Figure 6). The lightly alkaline reaction of soil indicates a high degree of bases saturation of the soil, which indicates a good soil fertility.

Soil nitrogen content was evaluated by using the nitrogen index (IN) and it was moderate (the IN values were at the lower limit of the variation range) (Figure 6). The average value of nitrogen index (IN) was classified as medium nitrogen content (2.61-2.84). This indicates a good fertility level of the soil in those specific parcels of the farm.

The soil available phosphorus content of P2 was classified as low - moderate - good, with average values between 10 and 91 mg/kg. The available potassium content of P2 was classified as good, with values ranging between 164 - 191 mg/kg. On such soils with a good fertility, the fertilizers doses containing phosphorus and potassium should be applied according to the plant needs, soil phosphorus and potassium contents, expected yield.

Table 3. Expected yields in the studied areas

Crop	Expected yields of the farmer for which optimum economic doses were established		
	P1	P2	P3
Wheat	7.0	7.0	6.5
Maize	9.0	9.0	9.0
Sunflower	4.0	4.0	4.0
Rape	4.0	4.0	4.0
Soybean			3.0

The expected yields at the farm level are presented in Table 3. Based on these expected yields, fertilization plans for the established fertilization parcels were accomplished. These contain economic and technical optimum doses - DOE and DOT (which ensure a certain level of crop yield at which the maximum benefit is achieved) for a four years crop rotation (winter wheat - maize - sunflower - rape) in case of P1 and P2 soils and five years crop rotation (winter wheat - maize - sunflower - rape - soybean) in case of P3 soil.

In Tables 4 a, b, c the fertilization plans are presented for the physical blocks of soils from Sarulesti (P1), Tamadau Mare (P2) and Costesti (P3).

Table 4 a. Fertilization plan in Sarulesti location (P1)

Crop	Physical block no.	**44**	
	Fertilization plan		
	Parcel no.	P 1-2	
	Doses of amendments, organic fertilizers		
	$CaCO_3$; t/ha		
	Partially decomposed animal manure; t/ha		
	Doses of nitrogen, phosphorus and potassium on parcels within the physical block		
	Dose type (kg/ha active subst.)	**DOE**	DOT
Wheat	Nitrogen (N)	**117**	198
	Phosphorus (P_2O_5)	**73**	146
	Potassium (K_2O)	**0**	77
Maize	Nitrogen (N)	**131**	232
	Phosphorus (P_2O_5)	**61**	132
	Potassium (K_2O)	**0**	93
Sun-flower	Nitrogen (N)	**70**	146
	Phosphorus (P_2O_5)	**70**	140
	Potassium (K_2O)	**0**	65
Rape	Nitrogen (N)	**82**	141
	Phosphorus (P_2O_5)	**83**	137
	Potassium (K_2O)	**0**	59

Table 4 b. Fertilization plan in Costesti location (P3)

Crop	Physical block no.	1348	
	Fertilization plan		
	Parcel no.	2 a+b	
	Doses of amendments, organic fertilizers		
	$CaCO_3$; t/ha		
	Partially decomposed animal manure; t/ha		
	Doses of nitrogen, phosphorus and potassium on parcels within the physical block		
	Dose type (kg/ha active subst.)	**DOE**	DOT
Wheat	Nitrogen (N)	**126**	214
	Phosphorus (P_2O_5)	**40**	118
	Potassium (K_2O)	**13**	83
Maize	Nitrogen (N)	**150**	261
	Phosphorus (P_2O_5)	**41**	120
	Potassium (K_2O)	**40**	126
Sun-flower	Nitrogen (N)	**86**	165
	Phosphorus (P_2O_5)	**66**	135
	Potassium (K_2O)	**31**	94
Rape	Nitrogen (N)	**96**	159
	Phosphorus (P_2O_5)	**54**	112
	Potassium (K_2O)	**26**	82
Soy-bean	Nitrogen (N)	**10**	72
	Phosphorus (P_2O_5)	**0**	55
	Potassium (K_2O)	**0**	64

For the calculation of the optimum economic doses (DOE) and technical economic doses (DOT) different aspects were taken into account: prices of mineral fertilizers, nutrients crop requirements, soil nutrients content and economic aspects. DOE and DOT are also calculated for achieving at farm level the expected yields.

It is necessary a proper management and fertilizers use at the level of each agricultural or agro-zootechnical holding, both for economic reasons and environmental protection requirements.

Particular emphasis, especially in areas highly vulnerable to water pollution with nitrates from agricultural sources, should be placed on the management of organic and mineral fertilizers with nitrogen, given the particularly complex behavior of this nutrient in soil and the easiness with which it can be lost as nitrates form together with infiltration waters and surface runoff (Code of Good Agricultural Practices, 2015).

Therefore, the fertilization plan is a useful tool both for establishing the organic fertilizers doses (produced within the farm or procured outside the farm) and mineral doses and for making economic decisions related to the availability of any excess organic fertilizers produced within the farm, and for the selection of proper times to purchase the necessary quantitative and qualitative mineral or organic fertilizers (if the farm does not have enough own reserves).

Table 4 c. Fertilization plan in Tamadau Mare location (P2)

Crop	Physical block no.	17		32		28		66	
	Fertilization plan								
	Parcel no.	P1		P2		P3		P4	
	Doses of amendments, organic fertilizers								
	$CaCO_3$; t/ha								
	Partially decomposed animal manure; t/ha								
	Doses of nitrogen, phosphorus and potassium on parcels within the physical block								
	Dose type (kg/ha active subst.)	**DOE**	DOT	**DOE**	DOT	**DOE**	DOT	**DOE**	DOT
Wheat	Nitrogen (N)	**119**	199	**121**	204	**117**	201	**118**	202
	Phosphorus (P_2O_5)	**0**	75	**67**	142	**81**	156	**22**	97
	Potassium (K_2O)	**0**	74	**0**	75	**0**	74	**0**	75
Maize	Nitrogen (N)	**134**	235	**136**	244	**131**	240	**132**	240
	Phosphorus (P_2O_5)	**0**	74	**56**	132	**65**	142	**24**	100
	Potassium (K_2O)	**0**	70	**0**	88	**0**	87	**0**	88
Sunflower	Nitrogen (N)	**72**	141	**73**	152	**70**	148	**70**	150
	Phosphorus (P_2O_5)	**0**	73	**84**	153	**70**	140	**41**	110
	Potassium (K_2O)	**0**	57	**2**	65	**4**	67	**2**	65
Rape	Nitrogen (N)	**84**	144	**85**	147	**81**	143	**83**	144
	Phosphorus (P_2O_5)	**79**	56	**77**	133	**80**	130	**31**	87
	Potassium (K_2O)	**0**	50	**0**	58	**0**	57	**0**	58

CONCLUSIONS

The soils from this study were characterized in terms of hydro-physical and chemical properties.
The investigated soils are medium to fine textured, starting from medium clayey-loam (P1 - Sarulesti), clayey-silty loam (P2 - Tamadau Mare) to loamy clay (P3 - Costesti). High contents in clay result in higher values for bulk density and penetration resistance. On the contrary, the saturated hydraulic conductivity of such fine textured soils records low values, the most significant decrease being encountered in the soil profile P3.
The highest values of saturated hydraulic conductivity were recorded in the topsoil layer of the soil profile P2 (Tamadau Mare) where the total porosity (PT) was also the highest.
The topsoil layers had greater values of water content at saturation when compared with subsoil layers, except for the profile P1 where the values of water content at saturation were constant within the soil profile. This may be attributed to a decrease of organic matter content and an increase of bulk density values within the soil profiles.
The soil water retention curves were obtained after using the Arya-Paris model for estimating the van Genuchten parameters. The differences in shape of water retention curves between topsoil and subsoil layers may be as a result of either externally-applied mechanical stresss by agricultural machinery which can lead to compaction of the layer below ploughing depth, or internally-applied mechanical stress due to drying of the soil which causes shrinkage due to the effective stresses generated by the pore water suction and the surface tension in the water menisci.
The deeper layers of the soil profiles (> 80 cm depth) have lower values for *S* index. That means the soil physical quality as quantified by *S* is better in the topsoil horizons than in the subsoil horizons, except for the profile P1 where the values of *S* index in the topsoil layer is the lowest, and then showed an increase up to 80 cm depth and then decreased again with depth. This can be due to both higher contents in organic matter of the top-soils and lower values of bulk density.
The soil reaction values, in case of P3 soil profile highlighted a lightly acid soil. The soil reaction values highlighted a lightly acid soil in P3. The soil profile P2 had soil pH values that led to a lightly acid to lightly alkaline soil reaction. At last, the soil profile P1 had values of pH that led to a lightly alkaline soil reaction.
The total nitrogen content of all three soils varied from very low-low to moderate values. The available phosphorus content ranged from very low-low in case of soil profile P3 to low-high in case of soil profile P2 and up to moderate-high in case of soil profile P1. As for the available potassium content, all the studied soils were moderately supplied.
The fertilization plans were accomplished based on agrochemical studies. For each of the three sites cartograms were done for soil reaction, phosphorus and potassium. Also synthetic cartograms with the average values of soil reaction (pH), humus content, available phosphorus (P_{AL}), available potassium (K_{AL}), and nitrogen index (IN) for the established fertilization parcels from each location were realized.
Based on the expected yields, fertilization plans for the established fertilization parcels were accomplished. These contained economic and technical optimum doses - DOE and DOT (which ensure a certain level of crop yield at which the maximum benefit is achieved) for a four years crop rotation in case of P1 and P2 soils and five years crop rotation in case of P3 soil.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, project number PN-III-1.2-PCCDI-2017-0560/2017, within PNCDI III.

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