SOIL FERTILITY OR SOIL QUALITY ?

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ABSTRACT

Soil fertility or soil quality is first a scientific problem and then a practical one, depending on the perception of researchers, agronomists or farmers. All think of the same phenomenon, but not all define it in the same manner. Depending on the definition, we have a correct or false method for quantifying the value of an agricultural soil. In this paper, we have tackled the confusion between the notions: soil fertility and soil quality. This confusion is not new, but today, when state authorities are alarmed about the degradation of soils, the technical measures for estimating the level of fertility, for controlling the crops and for avoidance of the degradation of soils, the semantic content of the notions: soil fertility and soil quality must be solved. In our opinion, the soil fertility is the correct expression, and in this conception, we have given a new definition and a methodology, verified in different soil types in Romania, for quantifying the level of fertility.

Key words: soil fertility, soil quality

INTRODUCTION

Since the end of 20th century and the first years of this one, scientific literature debates, preponderantly, the serious problems of soil degradation by the used intensive agricultural technologies. Alarm signals, concerning the continuous increase of prices for maintaining a high level of yields and at the same time, the increase of the farming stocks, determined the European Commission for Agriculture to propose, in 1991, in Brussel, a new Community Agricultural Policy, to stimulate the farmers to use of less intensive crop management practices, reducing, in this way, the impact on the environment and the crop surplus. Modern agriculture was put under the question, because it was considered that the environment is a victim of the chemical treatments and that in some zones, especially in Europe and North America, the agriculture is a diffuse source of pollution (Nistorescu et al., 1995).

This new attitude of European Community determined a chain reaction, from the financial domain to that of production, and at last, in that of the agricultural and soil sciences.

Scientific agriculture in 20th century was interested to invent the best conditions for growth and development of plants. Although, the indispensable role of the fertile soil to crop production has been known, it was mainly considered, as a passive support for providing the need of water and minerals for obtaining crops.

Soil biology, discovering the evolution laws from the sterile rock to fertile soil, intervened vigorously in agriculture practice, recommending crop management practices which do not contravene to these laws. Thus, since 1924, Steiner initiated the doctrine of Biodynamic Agriculture, that his continuer Pfeiffer (1938) experimented in Europe, South Africa, Korea and USA, and Howard (1941) initiated the doctrine of Organic Agriculture in England and USA. After the second World War, agricultural practices, based on soil biological laws, were diversified, being framed in different trends of Biological Agriculture. Offensive of Ecological Organizations against any manner, of nature and human habitat degradation, was also reflected in soil cultivation, generating the doctrine and practices of Ecological Agriculture that includes, all other Biologic Agriculture types.

Under the pressure of a new orientation of agrarian politics, in the biological science domain, the old theme of the definition and estimation of agricultural soil fertility was revised.

a. Soil fertility, defined in a biological conception

Vaillant (1901) wrote: *„the higher the humus content is, the more fertile is the soil and this fertility seems to be due, especially, to a large number of dinitrogen fixing organisms living here”*. Hence, after few years only from the beginning of the soil microbiology research, the conviction appeared that soil fertility is due to humus content and to the number of dinitrogen fixing bacteries. Remy (1902), quoted by Waksman (1932), pointed out that some tests in differentiate between soils used the decomposition rate of nitrogen organic compounds in soil, making evident the conception that soil fertility can be estimated by biological criteria. Then, Winogradsky (after 1890), discovering variation of the number and

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activity of soil microflora, emitted the idea that the soil is a *living organism.* Between 1910-1915, Christensen (quoted by Waksman, 1932) was the first researcher who suggested that the power of a soil for disintegrating cellulose can serve as index of soil fertility. Waksman (1932) described the best the correlation of the vital and chemical processes in soil. Although he devoted a chapter (Part D: 543-569) in his monumental work *„Principles of soil microbiology",* to the subject: *„Microbiological processes of soil and soil fertility".* However, he did not succeed to distinguish between the concept of soil fertility and that of soil productivity. But sometimes, his conclusions about the nature of soil fertility and about the possibility to estimate it can be considered very correct and well correlated with the soil vital processes. So, appeared his clear expression: *„Soil fertility and the rate of oxidation were found to be influenced by the same factors and to same extent so that it was suggested that the latter* (the oxidation – N.B.) *could be used as a measure of the former* (of the fertility – N.B.). Here, surely appears the biologic concept of the notion *„soil fertility".* In 1949, Pavlovschi and Groza stated: *„If so far the feature of a living organism was not recognized to the soil, nobody contests that the arable soil is an organized biological medium".*

Although Steiner (1924) and Pfeiffer (1938) elaborated the theory and practice of *Biodynamic agriculture,* in Götheanum Institute - Dornach (Switzerland) and substantiated the conception that the soil behave like a living organism, ecologically integrated, the first definition of the soil fertility (known to us) was given by Howard (1941), the founder, in England, of Organic farming: *„Soil fertility is the condition of a soil rich in humus, in which the growth processes are getting on fast and efficiently, without interruption....... there must be permanently an equilibrium between the growth processes and those of decomposition. The key of fertile soil and a thriving agriculture is the humus".* In fact, fertility state does not exist only in a soil rich in humus, in uninterrupted development of the growing processes and having permanently equilibrium between growing processes and those of decomposition. Those elements of the definition (underlined by us) reveal the wishes of the farmer, and are not objective features of soil fertility. Within a certain time interval, the nature of processes from soil, of increase or decomposition of organic matter (inclusive of humus) does not stand under the equilibrium sign. Agricultural activity itself strongly influences this equilibrium, with a special value in plant nutrition. We subscribe to the assertion that the humus (between certain limits) is the key of soil fertility and agriculture thriving.

Maliszewska (1969) compared the biologic activities of various soils and suggested that respiration, proteolytic and cellulolytic activities are the most suitable parameters which correlate with soil fertility. Batistic and Mayaudon (1977) investigated the soil respiration and its enzymic activity under the influence of different treatments with N, P, K fertilizers and/or liquid dejections from cattle and concluded that the outstanding increase of respiration and enzymic activities of the soil, was only produced in organically fertilized treatments, that showed an increase of biological fertility of soil. Ştefanic's definition (1994) approaches the most the fundamental biologic feature of soil fertility: *„Fertility is the fundamental feature of the soil, that results from the vital activity of micropopulation, of plant roots, of accumulated enzymes and chemical processes, generators of biomass, humus, mineral salts and active biologic substances. The fertility level is related with the potential level of bioaccumulation and mineralization processes, these depending on the programme and conditions of the ecological subsystem evolution and on anthropic influences".* This definition has the quality to be analytical. Understanding the definition in detail, the analyses of soil samples can be used for quantifying the level of soil fertility. Also, Ştefanic (2005) gave a synthetic definition of soil fertility: *„Soil fertility is the feature of the terrestrial loose crust to host complex processes (biotical, enzymical, chemical and physical) which store biomass, humus and minerals",* easier understood and used by farmers for realizing a sustainable, ecological agriculture. According to this definition, the agrotechnical measures applied to soil must improve and maintain the soil fertility and phytotechnical measures must ensure the plant growth, without damaging the vitality and cultural condition of a soil.

b. Biological quality of agricultural soils

Scientific and technical literature from the last 5 decades discussed, at length, the definition of soil fertility as attribute of vital, complex and pedogenetical processes from the superficial terrestrial layer. The vegetal cover is indispensable to acceleration and maintenance of the soil forming processes by autotrophic synthesis of largest quantity of organic matter. Viliams (1947) masterly explained the appearance of fertile soil, mentioning that the soil is qualitatively different of rock, regardless of how rich in clay and sand, and well imbibed with water would be that. But Viliams' definition of soil fertility: *„Soil capacity for satisfying, in a measure or other, the plant needs in terrestrial factors of their life”* (also used today by many authors) have comprised the mistake of including the necessities of the vegetal cover among soil specific characteristics.

Just this shift of soil fertility perception, from the soil biological processes of humus accumulation and mineralization, to that of satisfying the plant necessities (external of soil) generated the idea that the soil is conscious of its mission to feed the plants and to provide the indispensable water. By this perception, most people ignore, in fact, that the plants are adapted to benefit from the soil vital activity (soil fertility) and also, from fertilizers. For the same reason, the crop size cannot be a good index of soil fertility.

Sébillotte (1989) remarked: *„...the idea of fertility* (of soil - N.B.) *belongs more to social representations than to a scientific conception”.* This assertion is also sustained by Mamy (1993) who came to the conclusion that: *„......in fact, the quality of a soil is a subjective notion........it is defined in relation with people interests”.* Chaussod (1996), continuing in the same direction, becomes more firm: *„...the notion of biological quality of soils is, evidently, bound to the more general notion of soil quality, that tends to replace the old notion of soil fertility”.*

The confusion between two soil features: fertility and capacity to sustain crop production - productivity - generated in USA the decision to found, in 1993, the Soil Quality Institute (SQI) as part of the Natural Resources of Conservation Service (NRCS). The activity of this institute exceeds the difficulties of defining the soil fertility and has in view the protection of natural resources and environment, by the soil biological analyses, but also by those of agriculture.

A discussion on the above conceptions is essential.

Discussing about soil fertility, we have in view that this expression denominates the phenomenon „fertility of the soil” which can be measured by different specific parameters. Quality is a philosophical category; it is identical with the existence of things and processes; it includes the ensemble of determinations which confers to the objects and processes a certain individuality in relation with the coexisting objects and processes and a certain stability in the running time. But, besides the quantitative determination, all processes and phenomena are also characterized by a quantitative determination, through: number of its component parts, size, development rhythm, volume etc.

In conclusion, quality includes different categories of phenomena; the quality may be appreciated (good, bad etc.), but the phenomena may be quantified (by parameters).

Chaussod (1996) proposed the notion of soil biological quality instead of that of soil fertility. In fact, there is here a semantic confusion: the notions soil fertility and soil biologic quality do not belong to the same semantic domain. For a better understanding: we cannot compare the apples with the fruits. The apples are phenomena (which can be described by parameters) and the fruits are the quality, an abstract notion (appreciate only as good, bad etc.).

Under natural conditions, also in subsistence agriculture, the dependence of yield size (under favourable climatic conditions) is evidently correlated with the soil fertility. But, under intensive crop management this correlation disappears.

Evaluation of soil fertility level of agricultural soils

Biologic and chemical researches in Romania, beginning from 1940 (Pavlovschi and Ionescu, 1941; Pavlovschi and Băjescu, 1943; Pavlovschi and Groza, 1949) lead to their conclusion: *„Soil fertility depends not only on the presence of nutritive substances, in physiologically - balanced quantities, but it is characterized by other factors, identified only by special methods. By these methods, the functions accomplished by the arable soil can be ren-*

dered evident and pursued in the cooperation system with the plants and microorganisms".

Other Romanian researches, after 1950, having in view the soil fertility as a result of the biologic, enzymic and chemical processes in arable soils (Papacostea, 1976; 1981; Kiss et al.*,* 1972; Ştefanic, 1994; Ştefanic et al., 1998; Ştefanic et al., 2001; Ştefanic et al., 2003) also considered like their predecessors, that soil as any living organism is a complex organized system and this is the explanation why its fertility, as fundamental, objective and inseparable feature, cannot be well characterized and estimated by only one or few parameters. Medical science offers such as example for how a man's health and effort should be surveyed and estimated. They are estimated by various tests which describe many of man's manifestations.

In the case of soil, we have acted in the same way. Considering the multitude of soil processes, accumulations and manifestations, we have considered only those for which we have objective methods of analysis. In table 1, we have suggested, for exemplification, the main directions of research for estimating soil fertility.

Table 1. Physiologic and enzymic potentials and chemical contents necessary for determining the soil fertility

Main physiological potential	Main enzymic potentials	Main chemical contents
1. Respiration	1. Catalase	1. Humus (Ct%)
2. Biomass	2. Saccharase	2. Extractable organic carbon (Ce%)
3. Cellulolyse	3. Urease	3. Huminic acids (Cha%)
4. Di-nitrogen fixation	4. Total phosphatases	4. Fulvic acids (Cfa %)
5. Ammonification		5. Total nitrogen (Nt%)
6. Nitrification		6. Organic phosphorus (Po%)
		7. Acidity (in H_2O)
		8. Base saturation

The methods used by us, elaborated after 1991, for putting together the results from various tests in a coherent estimation of soil fertility, represent a variant of numerical taxonomy which mainly consists of:

1. The transformation of the result of each test in percentage from the maximum value obtained from numerous soil analyses (MEV) as follows:

$$X\% = Xa \times 100 : MEV,$$

where: Xa = the absolute value obtained in the analytic test; MEV = Maximum Empiric Value (respiration = 150; cellulolyse = 100; catalase = 2000; saccharose = 2000; urease = 150; fosfatase = 25; Ct% = 4.25; Ce% = 1.40; Cah% = 0.80; Nt% = 0.250; V% = 100; $pH_{(H_2O)}$ = 8.30).

2. Indicator of Vital Activity Potential (IVAP %):

$$IVAP\ \% = (R\% + C\%) : 2,$$

where: R% = respiration potential; C % = cellulolyse potential.

Note: The formula 2 can be amplified by introducing other analytical parameters such as: biomass, number of *Azotobacter chroococcum,* the most probable number of autotrophic nitrification bacteria etc.

3. Indicator of Enzymic Activity Potential (IEAP %):

$$IEAP\ \% = (K\%+S\%+U\%+P\%) : 4,$$

where: K % = catalase; S % = saccharase; U % = urease; P % = total phosphatase (Ştefanic's method; Irimescu and Ştefanic, 1998).

4. Biological Synthetic Indicator (BSI %):

$$BSI\ \% = IPAV\ \% + IPAE\ \% : 2.$$

5. Chemical Synthetic Indicator (CSI %):

$$CSI\% = [(Ct\%+Ce\%+Cha\%+Nt\%+Po\%):5] + pH:2;$$

where all chemical parameters are transformed by MEV like the biotical and enzymical tests.

6. Pedo-Genetic Indicator (PGI %):

$$PGI\ \% = HGI \times 100 : MEV;$$

for that calculation it is: for different intervals of humus content (Ct%) one gives a note: < 1 = 1; between 1 - 1.49 = 2; between 1.5 - 1.99 = 3; between 2 - 3 = 4. Then the Humic Global Indicator (HGI) and Pedo-Genetic Indicator (PGI%) are calculated. An example for calculating is given in the table 2:

Table 2. Calculation for determining Humic Global Indicator (HGI) and Pedo-Genetic Indicator (PGI%) of certain soil type, MEV = 20 (for a very fertile soil from Mileanca, Botoşani County)

Soil type	Horizon	Thickness (dm)	Humus (Ct%)	Humic group	HGI Σ(3 x 5) columns	PGI%=HGI x100:MEV
1	2	3	4	5	6	7
Vermic-typical cher-nozem	ap 1 Ap 2h Am k Ac k	2.5 0.5 1.8 2.2	2.01 1.55 1.49 1.09	4 3 2 2	19.5	97.5
Albic luvisoil	Ap + Er	2.7	0.96	1	2.7	13.5

7. The modular and synthetic indicators, inclusive Synthetic Indicator of Soil Fertility (SISF%), which finally separates the soils in different categories of fertility, are presented as a model in table 3.

Table 3. Modular and synthetic indicators of fertility level of two soil types

Soil type	IVAP%	IEAP %	BSI % = (IVAP% + IEAP%)/2	CSI %	*VETL%= (BSI% + CSI%)/2	PGI% Pedo-Genetic Indicator	SISF% = (VETL% + PGI%)/2
Vermic-chernozem	a 31.15	a 48,46	a 38.17	a 70.93	a 54.55	97.5	a 76.02
Albic luvisoil	b 12.28	b 19.65	b 15.96	b 48.02	b 31.88	13.5	b 22.74
LSD 0.1%	5.76	4.01	3.32	3.32	2.35		2.35

Fertility, as a fundamental feature of soil, is an objective and quantitative parameter. The soil fertility level, determined on chemical and biological bases, estimated by trophic, energetic and vital level (VETL %) has a biological significance useful for the control of results produced by crop management practices. The level of soil fertility (estimated by the synthetic Indicator of Soil Fertility - SISF %) has an agronomical significance because it also introduces, besides the parameter VETL %, the Pedo-Genetic Indicator parameter (PGI%).

Evaluation of soil quality

In the last 20 years, in Soil Science, a very important problem was in attention of researchers, state administrations and diverse ecological organizations: that of soil quality. The Soil Quality Institute (SQI) of USDA - Natural Resources Conservation Service (NRCS) has developed a quantitative tool (the Soil Quality Card Design Guide) and a qualitative tool (the Soil Quality Field Test Kit Guide) for soil quality assessment in the field. (Ditzler and Tugel, 2002).

These initiatives are meritorious for world agriculture, but the concrete mode of application of the two Guides (quantitative or qualitative) suffer from the some confusions generated by utilization of the notion *„soil quality"* instead of *„soil fertility"*. As we discussed in the a and b divisions of this paper, the quality indicators give information about the quality of soil in relation with the soil features: good or bad for agriculture or viticulture, or fruit growing, lawn or woods.

In a similar mode we discuss the quantitative tool (Soil Quality Test Kit Guide) representing physical, chemical and biological properties of soil. These being parameters, give the measures, the size or the rate of the soil processes and they can be utilized for quantifying the *„soil fertility"* not *„the soil quality"*. Ditzler and Tugel (2002) made the remark: *„Results obtained with the „test kit" compare well to those from standard laboratory analyses. With the exception of soil respiration, no differences were found between test kit and laboratory measurements for indicators included in the field test kit".* Soil respiration potential is for the soil biologists the main test of soil fertility! Well thought-out and well realized as method, the respiration potential, alone, can give information about the level of soil fertility.

Soil organic matter is an other important parameter of soil quality (N.B., we say fertility). *It is considered to be key attribute of soil quality* (Larson and Pierce, 1991; Gregorich et al., 1994*), because it is involved in, and related to many soil chemical, physical, and biological properties.....as most economic models utilized to describe sustainability in agriculture often disregard or minimalize the natural-resource component* (Carter, 2000).

Liebig et al. (2001) have made a stride, giving in their paper : *„A simple performance - based index for assessing multiple agroecosystem functions"* a model of calculation to evaluate the relative sustainability of agricultural management systems.

We offer his technology of calculation and at the same time we make some comparisons with our technology (Ştefanic, 1994).

The procedure is initiated by surveying the data set for indicators that could be grouped within agroecosystem functions. Liebig et al. (2001) have mentioned that of the 17 functions presented by Costanza et al. (1997), 7 have direct applicability to agroecosystems: food production, raw materials production, nutrient cycling, erosion control, greenhouse gas regulation, water regulation, and waste treatment. Agroecosystem performance following these guidelines could be presented in the following manner:

1. Agroecosystem performance = *f* (food production, raw materials production, nutrient cycling, erosion control, greenhouse gas regulation, water regulation, waste treatment). Within each agroecosystem function, indicators are selected to characterize the performance of that function. For instance, indicators of food production might include data on grain yield, percentage of nutrients in grain, or storage and handling parameters. Indicators of greenhouse gas regulation may include CO_2 and CH_4 flux, N_2O emissions and selected soil properties such as soil organic C and near-surface soil NO_3. It is unlikely that all functions can be included when determining agroecosystem performance with this procedure, but it is possible in the following manner:

2. Food production = *f* (grain yield, grain N content).

3. Raw materials production = *f* (stover yield, stover N content).

4. Nutrient cycling = *f* (residual soil NO_3, soil pH).

5. Greenhouse gas regulation = *f* (soil organic C, early spring soil NO_3). Once indicators have been selected to represent agroecosystem functions, the relative importance of each function on agricultural sustainability is estimated.

Anyhow would be named the kind of reference to soil, in relation with its quality for agriculture (soil fertility; soil quality; soil biological quality or soil quality) the utilization of agricultural yield parameters is a wrong idea, because the yields are very strongly influenced by crop management, and besides the soil fertility.

CONCLUSIONS

The words fertility and quality of a soil are two distinct philosophical categories.

The fertility is the fundamental feature of an agricultural soil, having all characteristics of a body impregnated with life. Its level can be quantified by certain parameters, corresponding to certain physiologic and enzymic processes and certain specific substance accumulations.

Quality, and in this case, biological quality of soil (not for an auto-road or for a blockhouse construction), is a human representation, combining a number of general characteristics among the others, the fertility.

The quality (biologic) of a soil cannot be quantified or described by parameters, it can be appreciated as good, bad, useful, useless etc. To use the notion of soil (biologic) quality instead of that of fertility is a semantic mistake, which generates confusion in the human thinking. When some scientific or technical publications insert, among the parameters, those of crop yields, for soil fertility or soil quality level determination, they make other mistakes: firstly, by the confusion fertility - quality, and second, by ignoring the role of crop management practices which are capable to ensure high yields or low yields on the same soil fertility. The level of soil fertility must be quantified only on a base of soil intrinsic features.

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