ASSESSING THE ANTHROPOGENIC IMPACT ON ENVIRONMENT BY HEALTH SOIL CARD

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Abstract

Deterioration of soil health due to the current intensive agricultural practices for increasing the level of food production, in terms of both quality and quantity, should be a concern of major interest to the health of plants, animals, humans and environment. Soil health is the net result of the processes of preservation and degradation, depending on the biological component of soil ecosystem that affects plant and environmental health, food safety and quality. This research aimed to assess the main physical, chemical and biological indicators of soil health and the indicators of soil residual pollution in the intensive olericultural systems in transition to organic systems for ensuring a sustainable management. Our research was carried out in conventional olericultural systems of North-Eastern Romania in conversion to organic systems. The conversion into organic systems has reduced the effects of intensive practices, creating the premises for an optimal biological activity and production of healthier vegetables.

Key words: *olericultural systems, anthropogenic impact, Health Soil Card*

Introduction

According to the current practices of intensive agriculture, the food production has increased and will greatly increase by massive inputs in agricultural production systems. This fact is often associated with an increase in environmental pollution and degradation of natural and non-renewable soil resources (Huber et al., 2001; Bireescu et al., 2010). In the mid of 1990s, the term "soil health" was introduced and many definitions have been proposed over the last few decades. According to Kibblewhite et al. (2008) a healthy agricultural soil is one that is capable of supporting the production of food and fibre, to a level and with a quality sufficient to meet human requirements, together with continued delivery of other ecosystem services that are essential for maintenance of the quality of life for humans and the conservation of biodiversity. Soil health is the net result of the processes of preservation and degradation, depending on the biological component of soil

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ecosystem, which affects plant health, environmental health, food safety and quality (Halvorson et al., 1997; Knoepp et al., 2000; Martinez-Salgado et al., 2010). According to Allen et. al (2011) the terms "health" and "quality" are synonymous, however the term "health" put a greater emphasis on the role of soil biodiversity and ecological functions that make the soil to be a living and dynamic system with a self-organization capacity.
This research aimed to assess the main physical, chemical and biological indicators of soil health and the indicators of soil residual pollution in some olericultural systems in conversion from conventional to organic systems.

Material and methods

After analyzing the own research results and data from literature (National Service for Conservation of Natural Soil Resources, NRCS-USA, 1999) referring to different ways of assessment of anthropogenic impact of agricultural technologies on soil, we purpose a new and original model for Romania, named Health Soil Card (HSC). Our research was developed in the frame of national project for the substantiation of the optimized technological flow in organic vegetables for the food safety and sustainability. The research was carried out in three olericultural systems where tomatoes were cultivated in past using conventional practices of North-Eastern Romania and actually, in conversion into organic systems. The complex study of the main physical, chemical and biological properties of the soil, as well as the residual pollution with heavy metals, pesticides and nitrates, allowed the identification and evaluation of soil qualities and excesses. As reported in the literature (Kibblewhite et al., 2008), no single indicator will encompass all aspects of soil health, nor would it be feasible or necessary to measure all possible indicators. Thus, the calculation of an unique synthetic Soil Health Index (SHI) has covered the following several stages of gradual work:
- establishing a Minimum Data Set (MDS) that includes 12 indicators of soil health: physical (texture, air porosity, soil consistency), chemical (soil reaction, soil organic matter, base saturation, N, P and K content), biological (Indicator of Vital Activity Potential, Indicator of Enzymatic Activity Potential and Biological Synthetic Indicator), plus eight indicators of residual pollution (contents of Pb, Cd, Cu, Zn, Mn, DDT-HCH, organophosphates and nitrates);
- establishing the matching tables for each of 20 indicators including, also, the SHI;
- analysis, developing and promoting the HSC as final document that farmers can get knowledge about the actual status of the land, in order to take measures for preventing and limiting the negative environmental effects by adopting sustainable management.

The values of selected indicators for the SHI calculation, as well as the scale of assessments of the main 12 indicators of soil health, plus 8 indicators of residual pollution was developed according to the specific methodology of analysis developed by the Research Institute of Soil Science and Agrochemistry from Bucharest, Romania (Florea et al., 1987). SHI is obtained by the summing up the values of the single indicators of soil health according to the following formula:

SHI = $\sum_{1}^{20}$ (Tx, AP, Con, pH, SOM, BS, N, P, K, IVAP, IEAP, BSI, Pb, Cd, Cu, Zn, Mn, DDT-HCH, phosphates, nitrates), where: SHI=Soil Health Index; Tx=texture; AP=air porosity; Con=soil consistency; pH=soil reaction; SOM=soil organic matter; BS=base saturation; N=nitrogen; P=phosphorus; K=potassium; IVAP=Indicator of Vital Activity Potential; IEAP=Indicator of Enzymatic Activity Potential; BSI=Biological Synthetic Indicator; Pb=lead; Cd=cadmium; Cu=copper; Zn=zinc; Mn=manganese; DDT-HCH= organo chlorines; phosphates; nitrates).
The final SHI value is explained according to the classification proposed by Bireescu (2011).

Table 1. *Classes of Soil Health Index (SHI) (Bireescu et al., 2011 – National Project No. 52-141 / 2008)*

Assessment of impact			**Degree of vulnerability**	**Negative ecological effects**
Value points	***Notes***	***Qualificatives***		
0-20	5	Soil quality, fertility and health are very strong affected by anthropogenic impact. **Not healthy soil**	Very high vulnerability degree to anthropogenic impact	Strong degraded ecosystem and improper conditions for biological activity and plant nutrition
21-40	4	Soil quality, fertility and health are strong affected by anthropogenic impact	High vulnerability degree	Anthropogenic impact causes disorders on biological activity and plant nutrition and put in danger the equilibrium of ecosystem
41-50	3	Soil quality, fertility and health are medium affected by anthropogenic impact	Medium vulnerability degree	Discomfort status for biological activity and equilibrium of ecosystem
51-75	2	Soil quality, fertility and health are low affected by anthropogenic impact.	Low vulnerability degree	Equilibrium of ecosystem, plant nutrition and biological activity are low affected
75-100	1	Superior soil fertility and quality. **Healthy soil.**	Very low vulnerability degree. Non-vulnerable soil	Unaffected equilibrium of ecosystem. Unaffected biological activity. Optimal nutrition regime.

Results

In the table 2 it analyses the values of the main 12 indicators of soil health, plus eight indicators of residual pollution, in terms of conventional, in conversion and organic vegetable.

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Table 2. *Soil health indicators and SHI under conventional, in conversion and organic olericultural systems*

Indicators	*Qualifier*	**Tomatoes crop – experimental field – Haplic Chernozem Conventional system**	**Tomatoes crop – experimental field – Haplic Chernozem Conversion system**	**Tomatoes crop– experimental field – Haplic Chernozem Organic system**
Texture (% clay)	*value*	***38.1***	***35.2***	***34.1***
	score	***4***	***4***	***5***
Summer soil consistency	*value*	***very hard***	***hard***	***moderate cohesive***
	score	***1***	***3***	***4***
Soil reaction (pH_{H2O})	*value*	***6.2***	***6.6***	***7.1***
	score	***3***	***4***	***5***
SOM content (%)	*value*	***2.810***	***3.381***	***3.655***
	score	***3***	***4***	***4***
Base saturation (%)	*value*	***80***	***85***	***90***
	score	***3***	***4***	***5***
Total nitrogen content (%)	*value*	***0.149***	***0.201***	***0.263***
	score	***3***	***4***	***4***
Mobile P (ppm)	*value*	***20***	***46***	***68***
	score	***2***	***4***	***4***
Exchangeable k (ppm)	*value*	***130***	***201***	***265***
	score	***2***	***4***	***4***
Air porosity (%)	*value*	***16***	***18***	***23***
	score	***3***	***3***	***4***
IVAP (%)	*value*	***20.67***	***25.16***	***34.11***
	score	***2***	***4***	***5***
IEAP (%)	*value*	***10.12***	***13.78***	***22.57***
	score	***2***	***4***	***5***
BSI (%)	*value*	***15.40***	***19.47***	***28.34***
	score	***2***	***4***	***5***
Pb (ppm)	*value*	***30.1600***	***0.0520***	***traces***
	score	***3***	***4***	***5***
Cd (ppm)	*value*	***0.7501***	***0.0006***	***traces***
	score	***3***	***4***	***5***
Cu (ppm)	*value*	***0.0680***	***0.0280***	***0.0030***
	score	***2***	***3***	***4***
Zn (ppm)	*value*	***0.1180***	***0.0260***	***0.0130***
	score	***2***	***3***	***3***
Mn (ppm)	*value*	***0.8141***	***0.6442***	***0.2570***
	score	***2***	***3***	***4***
HCH + DDT (ppm)	*value*	***0.2600***	***traces***	***traces***
	score	***2***	***4***	***5***
Other pesticides (ppm)	*value*	***0.2200***	***traces***	***traces***
	score	***4***	***5***	***5***
Nitrates (ppm)	*value*	***581.52***	***33.80***	***15.40***
	score	***1***	***3***	***4***
Soil Health Indicator (SHI)	*score*	***50***	***75***	***84***
	qualifier	*medium affected*	*low affected*	*healthy soil*
	degree of vulnerability	*medium*	*low*	*very low*
	ecological effects	*discomfort status for biological activity and equilibrium of ecosystem*	*low affected equilibrium of ecosystem, plant nutrition and biological activity*	*- unaffected equilibrium of ecosystem; - superior biological activity; - optimal nutrition.*

Soil texture has values between 38.1-34.1% of clay, giving it scores of 4 and 5 points. Soil consistency is a limitative factor, by excess, for the tomato cultivation, therefore soil needs intensive management that involves many interventions. Soil consistency is very hard, giving 1 point to the conventional system, hard to the conversion system (3 points) and moderate cohesive (4 points) on the organic system. Soil reaction registered values in the low acid–neutral domain (6.2-7.1 pH units), therefore the following scores have been assigned: 3 points to the conventional system, 4 points to the conversion and 5 points to the organic. SOM content has medium to high values (2.810-3.655%): 3 points for conventional system, 4 points for conversion and 4 points for the organic system. Base saturation registered high values (80-90%): from 3 points for the conventional system, to 4 points for conversion and 5 points in organic system. Total nitrogen content has medium to high values (0.149-0.263%): from 3 points for the conventional system, to 4 points for the conversion and organic systems. Mobile phosphorus content has medium to high values (20-68 ppm): from 2 points for the conventional system, to 4 points for the conversion and organic systems. Exchangeable potassium registered medium to high values (130-265 ppm): from 2 points into conventional system, to 4 points for the conversion and organic systems. Air porosity registered medium to high values (16%-23%): from 3 score for the conventional and conversion systems, to 4 score for the organic system. The Indicator of Vital Activity Potential (IVAP %) has medium to high values (20.67%-34.11%): from 2 points for the conventional system, to 4 points for the conversion and 5 points for the organic system. Indicator of Enzymatic Activity Potential (IEAP%) registered sub-medium to high values (10.12-22.57%): from 2 points for the conventional system, to 4 points for the conversion system and 5 points for the organic system. Biological Synthetic Indicator (BSI %) registered low-medium to high values (15.40-28.34%): from 2 points for the conventional system, to 4 points for the conversion and 5 points for the organic system. Soil health is improves by the conversion to organic system, by the reduction also of the negative impact of residual accumulation in the soil. Thus, the residual content of Pb has medium to low values (30.1600 mg/kg – traces) and residual content of Cd has low values to traces (0.7501 mg/kg -traces): from 3 points for the conventional system, to 4 points for the conversion and 5 points for the organic system. Residual content of Cu has sub-medium to low values (0.0680 mg/kg-0.0030 mg/kg): from 3 points for the conventional system, to 4 points for the conversion and 5 points for the organic system. Residual content of Zn and Mn also follow a descending trend, the value points having an ascending trend from the conventional system to organic system. Residual pesticides, have low values in the conventional system, and in organic they are not detectable (traces). This proves that, in these soils, few systemic pesticides are used and farmers are interested in conversion to organic vegetable.

SHI has been calculated by summing up the score for the 12 indicators of soil health plus the eight indicators of pollution in the three study cases. The total values ranged between 50-84 points, giving the following score and qualifiers:

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- in the conventional system, 50 points characterize an anthropogenic medium affected vegetable ecosystem with medium soil vulnerability to degradation; as ecological effects highlight discomfort status of biological activity and the disturbance of ecosystem equilibrium;
- in the conversion system, 75 points characterize an anthropogenic low affected vegetable ecosystem, with low soil vulnerability to degradation; as ecological effects highlight low affected equilibrium of ecosystem, plant nutrition and biological activity;
- in the organic system, 84 points characterize an anthropogenic unaffected vegetable ecosystem with very low soil vulnerability to anthropogenic degradation; as ecological effects highlight superior biological activity, optimal nutrition, unaffected and non-disturbed ecosystem equilibrium.

Discussion

The research highlighted a process of assessing the anthropogenic impact on the environment in order to protect the natural resources, human health and environment through sustainable management (Doran, 2002). In order to develop the Health Soil Card (HSC), like synthetic representation of soil functionality, no single indicator is able to reflect the complex nature of soil (Palojärvi & Nuutinen, 2002). Larson and Pierce (1994) suggest a minimum data set consisting of the most important chemical, physical and biological indicators, as we also highlighted in our presented research. The selection of these indicators must be adapted for different agro-ecological zones, depending on ecological specific (Bireescu et al., 2010) and for use at regional, national and global levels (Arshad & Martin 2002). In the development of soil health indicator we took into consideration the main physical, chemical and biological indicators to which added the indicators of global pollution by heavy metals, pesticides and nitrates. Analysis of the values of 20 indicators took into study highlights the major impact of the conventional agriculture, through intensive fertilization and the use of pesticides, expressed by means of a synthetic indicator of soil health (SHI). It is well know that all agricultural soils have been altered from their natural status by human interventions for maximizing productions with negative consequences on soil, ecosystem and human health (Kibblewhite et al., 2008; Environment Agency, 2002; European Comission, 2005). On the other hand, the intensity of agricultural intervention varies enormously across different farming systems and may be expected to have quantitatively and qualitatively impacts on the soil health. The ecological effects highlighted a discomfort status for biological activity and for the equilibrium of ecosystem. Taking into consideration that the conversion to organic system is a process of transition from the conventional system based on an excess of chemicals, mechanization and financial investments, to specific techniques of organic farming associated with an increase in soil fertility, equilibrium of ecosystem and plant nutrition, our data have demonstrated these aspects. In case of olericultural system under conversion to organic, during 3 years in the case of tomatoes crop, the traceability analysis of the main risk factors on the soil health pointed out a significant reduction of the impact of residual soil pollution. The superiority of organic systems is clearly evidenced by the high values of the physical, chemical and biological indicators and low values or even lack of pollution indicators. In this case, the equilibrium of ecosystem is unaffected or very low affected by the anthropogenic impact. Also, the vulnerability to degradation is very low, and the soil biological activity, as well the plant nutrition, occurs at the optimum.

Conclusions

There is a need to better understand relationships between the status of soil health indicators and soil functions, to enhance agricultural and natural resource sustainability and to encompass all aspects of agroecosystem performance. For this reason, for the development of the Soil Health Index (SHI) we took into consideration the main physical, chemical and biological indicators, to which added the indicators of global pollution by heavy metals, pesticides and nitrates. In case of conventional vegetable ecosystem, the ecological effects are major, it being vulnerable to degradation and the ecological effects highlighted a discomfort status of soil biological activity and ecosystem equilibrium. The superiority of organic vegetable ecosystem is clearly evidenced by the high values of the physical, chemical and biological indicators and low values or even lack of pollution indicators.

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ÉVALUATION DE L'IMPACT HUMAIN SUR L'ENVIRONNMENT PAR LA CARTE DE SANTE DES SOLS

Résumé

La détérioration de la santé des sols due aux technologies intensives actuelles plus en plus plus polluantes pour augmenter la production d'aliments est d'intérêt général pour la santé des plantes, des animaux, des humains et de l'environnement. Cette recherche vise à évaluer les indicateurs-clés physiques, chimiques et biologiques de la santé du sol, à laquelle ont été ajoutés les indicateurs de pollution résiduelle du sol, dans les écosystèmes végétaux en conversion vers l'agriculture écologique, pour diagnostiquer la santé du sol, afin d'y assurer une gestion durable. Notre recherche a été menée dans les écosystèmes de légumes traditionnels dans le nord-est de la Roumanie qui sont en conversion vers l'agriculture écologique. Donc, par la conversion de l'écosystème végétal conventionnel en système organique, les effets de la technologie intensive de pollution résiduelle du sol ont été réduits, en créant le cadre pour une activité biologique optimale en vue d'obtenir des légumes sains.

Mots-clés: *écosystème de légumes, impact anthropique, Carte de Santè des Sols*

VALUTAZIONE DELL'IMPATTO ANTROPICO SULL'AMBIENTE MEDIANTE CARTA DI SALUTE DEL SUOLO

Riassunto

Il deterioramento del suolo in seguito a intensive pratiche agricole dovute ad una sempre maggiore richiesta di risorse alimentari è una preoccupazione di interesse generale per la difesa della salute delle piante, esseri umani e l'ambiente. Questa ricerca, e' stata condotta in sistemi ortivi in fase di conversione biologica, valuta i principali indicatori fisici, chimici e biologici di salute del suolo, a cui sono stati aggiunti indicatori di inquinamento residuale del suolo, con l'obiettivo di valutare in modo concreto lo stato di salute del suolo in un sistema di gestione agricola sostenibile. Questa ricerca è stata condotta in ecosistemi vegetali convenzionale gestiti secondo le comuni pratiche agricole applicate nel Nord-Est della Romania, e in conversione biologica vegetale. I risultati mostrano chiaramente che in un sistema di gestione convenzionale in fase di conversione in biologica si è ridotto drasticamente la presenza di indicatori di inquinamento residuale del suolo e l'attività microbiologica è migliorata.

Parole chiave: *ecosistema ortivo, impatto antropico, Carta di Salute del Suolo*

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