EFFECTS OF THE AGRICULTURAL TECHNOLOGIES ON THE SOIL ENVIRONMENT WITHIN AN ORGANIC CERTIFIED FARM: RECOMMENDATIONS FOR A REDUCED TILLAGE

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Abstract:*Organic agriculture reduces external inputs by controlling pests and diseases naturally, with both traditional and modern methods. Official statistics indicate that in Romania, the organic sector is continuously growing within the last decade although research in organic farming is rather random. Field research has been performed in one of the first organic farms settled in Romania (S.A. Stepa, Stupina, Constanța, certified since 2000 and complying at present to UE Council Regulation 837/2007), with the aim of assessing the agricultural practices impact on the soil physical and chemical state within a PNCD-2 Project 51-047 „Agri-environmental technologies to protect the quality of the soil environment, applied in some broad acre macro-zones in Romania-TACME". The entire range of usual analyses were conducted for soil samples collected from five different agricultural plots, cropped differently, under farm's crop rotation plan. The analytical determinations included physical analyses (particle size distribution, bulk density, porosity, hydro stability, permeability etc) and chemical analyses (reaction, organic carbon, macro-nutrients). From the physical side, the findings rose the issue of the high risk of farm's soils macro and micro-destruction as well the soil profile shallow layers structural instability within the general context of a low soil organic matter content. As one task of the project is the preparation of some sets of technological measures to conserve the soil quality in relation with the specific aspect of the physical and chemical characteristics of field environment, the soil indicators are still to be improved whether several tillage approaches are to applied. In this view, recomandation are drawn including conservation tillage practices which can contribute to increase the farming and farm sustainability. Reducing field traffic allows the farmer to manage greater amounts of land with reduced energy and machinery inputs. Although the investigated farm is located in a semi-arid zone, it succeeds to produce organic crop yields superior of those recorded at county level.*

Key words: *organic farming, conservation tillage, soil environment, soil physical parameters*

INTRODUCTION

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2009).

Whilst chemically-based degenerative farming systems lead to declines in resource abundance and environmental quality, leaving natural systems in worse shape than they were originally by depleting soils and damaging the environment (LASALLE ET AL, 2008), the organic agriculture dramatically reduces external inputs by controlling pests and diseases naturally, with both traditional and modern methods uses local and regional resources in natural systems (IFOAM, 2009, STOLZE ET AL, 2000). A compilation and review of scientific literature, reveals that the yields from organic farming in developed countries are about the same as the yields from conventional agriculture. Furthermore, in some university-based research studies comparing conventional and organic practices yields for organic production are even slightly higher (LASALLE ET AL, 2008).

In Romania, official statistics indicate that the organic sector is continuously growing. In 2009, almost 2% of the agricultural land was reported as organic certified (MADR, 2009) and is seen as a field of promises and opportunities although the national research in organic farming seems random (ŞTEFĂNESCU AND DUMITRAŞCU, 2007).

Within the frame of the PNCD-2 Project 51-047 „Agri-environmental technologies to protect the quality of the soil environment, applied in some broad acre macro-zones in Romania-TACME", field research has been performed in one of the first organic farm set in Romania, S.A. Stepa located in Stupina, Constanța county. The farm is organic certified since 2000 and complies at present to UE Council Regulation 837/2007). The aim of the conducted research was to assess the agricultural practices impact on the soil physical and chemical state. To some extent, the organic practices in the farm are accompanied periodically by technological approaches close to „conservation tillage" operations. The actual definition of conservation tillage does not specify any particular, optimum level of tillage but does stipulate some tillage reductions with a residual coverage on the soil surface. Recomandation are drawn for systemtic use of tillage practices as such, which can contribute to increase the farming and farm sustainability. The impact of tillage reductions looks first to the level of physical soil parameters (GOVAERTS ET AL, 2007), that are less or higher than expected, under organic practices.

The investigations were carried within a larger context of the recent examination of the paradigms of input efficiency and system redesign, which frame discussions about transitions in agriculture, beyond organics (LAMINE AND BELLON, 2009).

MATERIALS AND METHODS

The agricultural area of S.A. Stepa is featured by a semi-arid flat plain on Chernozems and insularly, Kastanozems aged on loess deposits. The shallow water level is bellow 30 m and the precipitations are scarce, reaching peaks in May-June and December-January over the year. The climate is dry with very warm summers and cold winters, the averaged temperature of the warmest month being > 22^0C. The drought is common in summer season.

Systematic sampling was performed in autumn 2008, after crop harvesting, in 5 plots cropped differently, within the crop rotation farm's plan. Within the plots smaller areas or „stationary" perimeters of about 1000 m^2 were delimited. Within these perimeters four agro-physical profiles were dug. Soil samples were taken at different levels from the soil profile according to the depth of tillage works: 5, 15, 25, 35 and 45 cm in undisturbed (rings of 200 cm^3) and disturbed state. Disturbed samples were used for laboratory measurements: texture, soil water aggregate stability and dispersion, water storage and availability. The water content at different levels was evaluated by determining specific indicators: wilting point, field capacity, available water holding capacity and holding capacity. Chemical analyses were performed including organic carbon content (Walkley-Black), pH (H_2O), content of mobile phosphorus and potassium (Ēgner-Riehm-Domingo) and total nitrogen (Kjeldahl). Undisturbed soil samples were used for measurement and calculation: bulk density, saturated water hydraulic conductivity, total porosity and degree of soil compactness. A statistically characterization of each stationary perimeter were carried out using standard deviation (s), averaged standard deviation ($S\bar{x}$), variation coefficient (Cv) and confidence intervals (IC), as a high variability of the local conditions occured.

Tillage, input applications and crop yields have been recorded over the 2005-2008 period (tables 1-5).

Table 1

Brief tillage record in plot 1

Year	2005	2006	2007	2008
Crop	Wheat	Sunflower	Left aside	Wheat
Organic fertilisers	-	Milled plant residue	-	-
Soil tillage	Moldboard plowing	Moldboard plowing	Moldboard plowing	-
	Disking	Harrow	Disking	Disking
	-	Combinator	Disking	Combinator
	Sowing	Sowing	-	Sowing
	Brushing	Weeding+beataxe	-	Brushing
Yield (kg/ha)	2700	1200	-	4250

Table 2

Brief tillage record in plot 4

Year	2005	2006	2007	2008
Crop	Barley	Millet	Sunflower	Maize
Organic fertilisers	Milled plant residue	-	-	Animal manure
Soil tillage	Moldboard plowing	Moldboard plowing	Moldboard plowing	Moldboard plowing
	Disking	Harrow	Disking	Harrow
	-	Combinator	-	Combinator
	Sowing	Sowing	Sowing	Sowing
	-	Rolling	Weeding+beataxe	Weeding+beataxe
Yield (kg/ha)	2500	1100	1000	3000

Table 3

Brief tillage record in plot 7+8

Anul	2005	2006	2007	2008
Crop	Sunflower	Mustard	Wheat	Millet
Organic fertilisers	-	Milled plant residue	Milled plant residue	-
Soil tillage	Moldboard plowing	Moldboard plowing	Moldboard plowing	Moldboard plowing
	Disking	Disking	Disking	Harrow
	-	Combinator	Combinator	Combinator
	Sowing	Sowing	Sowing	Sowing
	Weeding 1+2	Rolling	Brushing	Rolling
Yield (kg/ha)	1700	800	3000	1000

Table 4

Brief tillage record in plot 9A

Anul	2005	2006	2007	2008
Crop	Alfa-alfa	Maize	Mustard	Wheat
Organic fertilisers	-	-	-	Milled plant residue
Soil tillage	-	Moldboard plowing	Moldboard plowing	Moldboard plowing
	-	Harrow+Disking	Harrow+Disking	Disking
	-	Combinator	Combinator	Combinator
	-	Sowing	Sowing	Sowing
	-	Weeding	Rolling	Brushing
Yield (kg/ha)	5000	5000	700	4750

Table 5

Brief tillage record in plot 9B

Anul	2005	2006	2007	2008
Crop	Wheat	Mustard	Foeniculum	Foeniculum
Organic fertilisers	-	-	-	-
Soil tillage	Moldboard plowing	Moldboard plowing	Moldboard plowing	-
	Disking	Disking	Disking	-
	Disking	Combinator	Combinator	-
	Sowing	Sowing	Sowing	-
	Brushing	Rolling	Rolling	-
Yield (kg/ha)	3500	600	200	650

The average yields of the main crops in the farm were compared with the average yields in the county Constanța (INS, 2006, 2007, 2008), with the assumption that overall in the county, the conventional agriculture largely prevails (as organic farming slightly reaches 2% of the total agricultural area at country level).

RESULTS AND DISCUSSIONS

The physical as well the chemical data collected from all 5 plots do not differ significantly, as a result of the relatively homogeneous soil cover and the similar technologies applied within the last decade. The proportion of cumulated sand and loam in the soil texture (medium loam) is high, ranging from 75.7-77.4 % in plot 1, 78.4-79.7 % in plot 4, 75.8-78.4 % in plot 7+8, 74.8-77.3 % in plot 9A and 75.1-77.7 % in plot 9B.

The soils water content at different availability levels indicates an unfavorable water regime due to the texture as well soil air potential conditions. The volume of the pores with sizes greater then 10-30µ is high and very high and the volume of the pores under 0.2µ has low values.

The wilting point had medium values and the humidity equivalent low levels (ranging from 16.4-18.0 %), pointing the low availability of the water in all plots and to all crops. The available water holding has high values, determined by the high soil air porosity, inducing infiltration water losses. There is no water logging risk across the whole area. However, no changes of the soil water regime occurred due to the tillage applied.

The water stability of soil aggregates was evaluated by determining the amount of stable macro-aggregates and the amount of unstable micro-aggregates (dispersion).

Generally, the soils in all plots reveal a high risk of destruction al macro-structural level, due to the environment natural evolving but also to the anthropogenic interventions (long term intensive agricultural undertakings). All plots recorded high values of unstable micro-aggregates to the water impact indicating a clear soil vulnerability to the micro-destruction within the soil upper (and active) layer (examples in tables 6-8). The structural instability is determined primarily to the high proportion of loam and sand and the low proportion of clay within the soil texture.

Table 6

Soil structural hydro-stability in plot 1

Depth (cm)/ indicator	*Sampled profiles*				*Statistical indicators*				
	P1	*P2*	*P3*	*P4*	$\overline{x}$	s	Cv	s $\overline{x}$	IC
Macro-hydro-stability (%)									
0 – 5	2	2	2	2	2	0	0	0	2 – 2
5 – 15	2	2	2	2	2	0	0	0	2 – 2
15 – 25	4	4	5	6	5	1	20	0	2 – 8
25 – 35	12	12	10	16	13	3	20	1	5 – 20
35 – 45	12	15	17	15	15	2	14	1	9 – 21
45 - 55	12	16	17	15	15	2	14	1	9 - 21
Dispersion (%)									
0 – 5	8	8	8	8	8	0	0	0	8 – 8
5 – 15	8	8	8	8	8	0	0	0	8 – 8
15 – 25	7	8	8	8	8	1	6	0	6 – 9
25 – 35	8	8	7	9	8	1	10	0	6 – 10
35 – 45	8	9	7	7	8	1	12	0	5 – 11
45 - 55	8	10	7	7	8	1	18	1	4 - 12
Structural instability index (-)									
0 – 5	3.98	3.87	3.89	3.92	3.92	0.05	1.22	0.02	3.77 – 4.06
5 – 15	4.08	4.47	4.39	4.03	4.24	0.22	5.18	0.11	3.60 – 4.88
15 – 25	1.75	1.99	1.60	1.33	1.67	0.28	16.58	0.14	0.86 – 2.47
25 – 35	0.68	0.67	0.74	0.55	0.66	0.08	12.06	0.04	0.43 – 0.89
35 – 45	0.68	0.59	0.41	0.47	0.54	0.12	22.50	0.06	0.18 – 0.89
45 - 55	0.67	0.64	0.44	0.48	0.56	0.11	20.52	0.06	0.22 – 0.89

Table 7

Soil structural hydro-stability in plot 7+8

Depth (cm)/ indicator	*Sampled profiles*				*Statistical indicators*				
	P1	*P2*	*P3*	*P4*	$\overline{X}$	s	Cv	s $\overline{X}$	IC
Macro-hydro-stability (%)									
0 – 5	2	2	2	2	2	0	0	0	2 – 2
5 – 15	2	2	2	2	2	0	0	0	2 – 2
15 – 25	8	6	6	7	7	1	14	0	4 – 10
25 – 35	9	11	10	9	10	1	10	0	7 – 13
35 – 45	13	14	13	12	13	1	6	0	11 – 15
45 - 55	13	14	14	13	14	1	4	0	12 – 15
Dispersion (%)									
0 – 5	9	10	9	10	10	1	6	0	8 – 11
5 – 15	9	10	8	10	9	1	10	0	6 – 12
15 – 25	8	10	8	10	9	1	13	1	6 – 12
25 – 35	8	9	8	10	9	1	11	0	6 – 12
35 – 45	8	9	8	10	9	1	11	0	6 – 12
45 - 55	9	9	9	10	9	1	5	0	8 – 11
Structural instability index (-)									
0 – 5	4.51	5.01	4.49	4.99	4.75	0.29	6.08	0.14	3.91 – 5.59
5 – 15	3.77	4.97	3.39	4.89	4.26	0.80	18.69	0.40	1.93 – 6.58
15 – 25	0.96	1.67	1.33	1.43	1.35	0.30	21.90	0.15	0.49 – 2.21
25 – 35	0.89	0.86	0.80	1.11	0.92	0.14	14.78	0.07	0.52 – 1.31
35 – 45	0.66	0.68	0.62	0.83	0.70	0.09	13.16	0.05	0.43 – 0.97
45 - 55	0.66	0.68	0.64	0.75	0.68	0.05	7.01	0.02	0.54 – 0.82

Table 8

Soil structural hydro-stability in plot 9B

Depth (cm)/ indicator	*Sampled profiles*				*Statistical indicators*				
	P1	*P2*	*P3*	*P4*	$\overline{X}$	s	Cv	s $\overline{X}$	IC
Macro-hydro-stability (%)									
0 – 5	3	3	3	3	3	0	0	0	3 – 3
5 – 15	3	3	3	3	3	0	0	0	3 – 3
15 – 25	3	3	3	3	3	0	0	0	3 – 3
25 – 35	9	8	10	7	9	1	15	1	5 – 12
35 – 45	10	8	10	8	9	1	13	1	6 – 12
45 - 55	14	13	12	11	13	1	10	1	9 – 16
Dispersion (%)									
0 – 5	7	6	6	7	7	1	9	0	5 – 8
5 – 15	7	6	7	6	7	1	9	0	5 – 8
15 – 25	8	7	6	6	7	1	14	0	4 – 10
25 – 35	8	6	6	7	7	1	14	0	4 – 10
35 – 45	7	6	6	7	7	1	9	0	5 – 8
45 - 55	7	6	8	6	7	1	14	0	4 – 10
0 – 5	2.55	1.99	2.06	2.33	2.23	0.26	11.53	0.13	1.48 – 2.98
5 – 15	2.90	2.27	2.55	2.00	2.43	0.39	15.86	0.19	1.30 – 3.56
15 – 25	2.32	2.45	2.00	2.00	2.19	0.23	10.42	0.11	1.53 – 2.86
25 – 35	0.88	0.78	0.57	1.00	0.81	0.18	22.55	0.09	0.28 – 1.34
35 – 45	0.70	0.70	0.60	0.88	0.72	0.12	16.20	0.06	0.38 – 1.06
45 - 55	0.53	0.44	0.67	0.55	0.55	0.09	17.29	0.05	0.27 – 0.82

The soil bulk density has low values, ranging from 1.24-1.25 g·cm^{-3} within the layer 0-15 cm and 1.35 g·cm^{-3} within the layer 15-25 cm (plot 1) to 1.14-1.25 g/cm^{3} within the layer

0-25 cm (plot 9B) and the related compaction degree has low and very low values, ranging from -10 - -9 % v/v (plot 1) to -17 - -10 % v/v (plot 9B) in the tilled layer. The permeability for water reached high levels, mostly in the upper layer, as a consequence of the intense agricultural interventions, affecting the water and nutritient availability for crops.

The soil reaction is sligtly alkaline ranging from 8.44-8.54 in plot 1 to 7.74-8.68 in plot 9B due to the calcarous parental material, but within the limits providing good premises for crops. The soil organic content is relativley low (from 2.01-2.56 in plot 1, to 1.61-3.56 in plot 9B), in all investigated plots, the total nitrogen and mobile phosphorus have medium levels and mobile potassium medium to high levels.

The structural instability in the soil upper layer can be lowered by certain technological interventions such as the use of the mulch at soil surface, hidden crops or protection crops covering the soils surface a longer period (mostly when the soil is stronly affected by the exogen factors) or along the entire year and, the decrease of tillage intensification level.

This approach is included in what is usually called „conservation tillage" operations. The actual definition of conservation tillage does not specify any particular, optimum level of tillage but does stipulate some tillage reductions with a residual coverage on the soil surface. The impact of tillage reductions looks first to the level of physical soil parameters because this is the vulnerable issue under the environmental circumstances and organic practices carried in S.A. Stepa.

There are ways to decrease the mechanical interventions intensity and frequency either by soil disking and then sowing or chisel plough and then sowing, the level of soil destruction (loosening and grounding), being significantly reduced. And beyond, the "dry farming" is also stimulated via the reduction of the water losses and the needs for irrigation. Some other advantages are related with the reduction of the fuel consume and the presence, at a certain extent, of the vegetal residues at the soil surface, increasing the level of organic matter content. The only weak point of the conservation tillage relates with the higher risks of pests (due to the increased amount of the vegetal residues on soil top), but a good practiced crop rotation (as this is the case of S.A. Stepa), can control the issue.

Despite the location of the farm in almost harsh conditions (a semi-arid zone), the yields in the farm compared with those at county level reveals a certain superiority (figure 1), a signal to previous findings carried in the outstanding organic farming research centre, the Rodale Institute, Pennsylvania, USA (FNSEA, 2005).

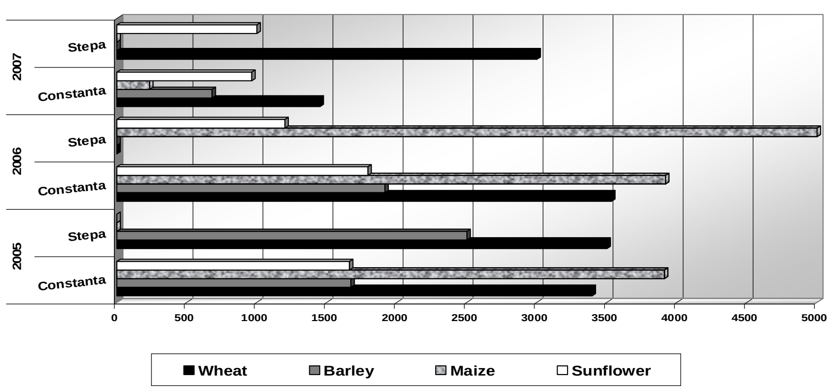

Figure 1: Avarage yields (kg/ha) between 2005-2007 in Constanta county vs Stepa „eco" farm

CONCLUSIONS

As a result of the relatively homogeneous soil cover and the repeatedly over time approaches (similar technologies) applied within the last decade, the physical and chemical data collected from all plots do not differ significantly. The results indicate an overall unfavorable air/water regime. The highest risk determined is the destruction at macro as well micro-structural level, due to the natural evolvement of the soil environment but also to the anthropogenic interventions (tillage).

Related to the native loosley state of the soil cover in the area (with sand and loam over 50% of the texture), no potential for secondary compaction or waterlogging has been identified.

The organic practices carried in the farm (S.A. Stepa) are not enough sufficient to assure the long term farming sustainability. The recommended approach is the introduction of „conservation tillage" operations.

Even if S.A. Stepa is located in a semi-arid zone, it succeeds to produce organic crop yields superior of those recorded at county level, in farms cropped mostly under conventional agriculture undertakings.

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