Thesis of PhD dissertation

CHARACTERIZATION OF CHANGES IN SOIL STRUCTURE AND DISTRIBUTION OF SOIL ORGANIC MATTER BY NEW METHODS IN LONG-TERM TILLAGE EXPERIMENTS

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1. Introduction, antecedent premises of the investigation

Supplying the constantly growing population of the Earth with foodstuff and similar basic products is assured by agriculture, specifically cropping *(Várallyay, 2002)*. This role is permitted by the soil, since soil gives the medium of crop growing, and as such permits food production for agriculture. Structure is a relevant property of soil, because it modifies fertility of soil in numerous ways: the structure of soil permits the transport of crop nutrient elements, the transformation of these elements into crop uptakeable forms, decomposition of the soil organic matter and the stabilization of soil organic matter against decomposition, gives basic medium for the chemical compounds and reactions, and among these roles, permits the flow of the gas- and liquid-phase of soil, and moderates biological activity of soil.

Nevertheless nowadays the more and more intense land-use and the applied plant-growing technologies, in contrast with their primary aim, may cause the deteriorate of soil structure: may cause the decrease of the amount of soil organic matter, water-retention capacity and therefore reduces soil aeration, and tillability, endangering fertility of soil, furthermore increasing the surface runoff and erosion *(Megyes et al. 2008)*. Finally they cause such unfavorable consequences like increased tillage expenses, or decreased crop yields *(Chan et al., 1999)*.

Adequacy for crop production, and supplying of crop nutrient elements of soil is determined by soil structure and its quality, resistance of soil structural units to water and tillage instruments, which is summed up as agronomic soil structure *(Várallyay, 2002)*.

For describing the adequacy of soil for crop production the knowledge of soil structure and its quality is needed. Furthermore detection and assessing of soil structural changes caused by tillage and crop production is needed.

Our aims were to detect the changes in agronomical structure and the organic matter pool of soil caused by different tillage methods and organic fertilizer supplements, for which soil structural status was assessed by three different indices, soil organic matter pool was assessed by a fourth index, furthermore relationship between soil agronomical structural changes and amount of soil organic matter was described.

2. Aims and scopes

2.1. Hypothesis for investigation, objectives, summarizing schema of the investigations

Nowadays good agronomical quality and structure of soil, namely tilled layer has deteriorated because of the too intense land use and inappropriate soil tillage. Therefore organic matter pool of tilled soils has decreased to a high extent. Therefore in contrast with the original aim of land use, the ability of water intake and providing crop nutrient elements of soil is decreased, and therefore the formal favourable crop results may be reached only by increased tillage expenses.

Agronomical structure and organic matter pool of soil depends on the applied soil tillage methods, moreover the type of the studied soil, the qualities of grown plants, and the applied crop caring systems.

Summing up these factors during the experiments our aims were to investigate the agronomical structure of soil, estimate its quality and characterize the amount and quality of soil organic matter under the effect of the different tillage (ploughing, disking) and crop caring systems (nutrient supply, irrigation) on the soil samples originating from two different soil typed sampling site, Keszthely and Látókép.

Sampling sites were chosen in such a way that our investigations cover the two most important Hungarian soil types, the Chernozem (Látókép) and brown forest soil (Keszthely) types. The studied treatments were organic matter supply (farmyard manure, wheat – corn – barley stubble crop residues) at Keszthely, soil tillage methods (winter ploughing, spring ploughing and disking) and crop care (mineral fertilization and irrigation) at Látókép *(Tables 1-2.)*.

Table 1.

The studied treatments at Keszthely

	Grown crop		**Treament**
Keszthely	Fallow instead of potatoe (without crop)	1	untilled control (forest belt, shelter belt)
		2	tilled control
		3	corn stem ploughing
		4	wheat straw ploughing
	corn	1	untilled control (forest belt, shelter belt)
		2	tilled control
		3	3x dose stockpiled farmyard manure (*)
	corn	1	untilled control (forest belt, shelter belt)
		2	tilled control
		3	barley straw and green manure ploughing

(*)105 t·ha^{-1} farmyard manure pro 5 years (in 2 portions, in the 1st and 3rd year of the rotation)
(this is equal with 21 t·ha^{-1} / pro year).

Table 2.

The studied treatments at Látókép

	Grown crop		Treatment
Látókép	winter wheat	0	untilled control (forest belt, shelter belt)
		1	winter ploughing – irrigated – without mineral fertilization
		2	winter ploughing – irrigated – with mineral fertilizer
		3	winter ploughing – not irrigated – without mineral fertilizer
		4	winter ploughing – not irrigated – with mineral fertilizer
		0	untilled control (forest belt, shelter belt)
		6	spring ploughing – irrigated – without mineral fertilizer
		7	spring ploughing – irrigated – with mineral fertilizer
		8	spring ploughing – not irrigated – without mineral fertilizer
		9	spring ploughing – not irrigated – with mineral fertilizer
		0	untilled control (forest belt, shelter belt)
		11	disking – irrigated – without mineral fertilizer
		12	disking – irrigated – with mineral fertilizer
		13	disking – not irrigated – without mineral fertilizer
		14	disking – not irrigated – with mineral fertilizer

Changes in the agronomic soil structure and organic matter pool of the tilled layer on the effect of the examined tillage and crop care methods were compared to soil samples originating from (1) the depth of the tillage depth, from the forest belt (shelter belt), and (2) from the 10cm thick layer under the tilled layer.

3. Methods of investigations

3.1. Description of the sampling sites

3.1.1. Keszthely

Soil samples originating from the field experiments of the University of Pannonia, Georgikon Faculty of Agriculture, Department of Crop Production and Soil Sciences, called 'Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers' (established in 1960-1963) and 'IOSDV (Long-term Experiment for Comparing the Effect of International Organic and Nitrogen-mineral Fertilizers, established in 1983)'. Soil samples were taken in July of 2006.

3.1.1.1. Description of the soil and meteorological conditions of the sampling site

On the examined site, Ramann-type brown forest soil could be found (sandy loam texture - Eutric Cambisol (soil type FAO), Alfisol (soil type USDA)). The soil of the experimental field is poor in available phosphorus, moderate in potassium, low in OM (0.5-0.6%). Soil pH_{KCl} is 5.9; the content of $CaCO_3$ is 0.1%; and the percentage of clay (<0.002mm fraction) is

24% *(Table 3.)*. The mean annual precipitation is 654mm, the mean annual temperature is 10.4°C *(Table 4.)*.

Table 3.

Agrochemical properties of the studied soil at Keszthely (1960)

Agrochemical property	Sampling depth (cm)				
	0-20	20-40	40-60	60-80	80-100
Humus (%)	1,70	1,37	1,14	0,99	0,90
Total N (%)	0,12	0,08	0,07	0,05	0,05
Total P_2O_5 (mg kg^{-1})	60,40	45,40	54,50	45,90	46,30
Total K_2O (mg kg^{-1})	406,80	414,50	386,30	350,50	313,20
P_2O_5 (AL) (mg kg^{-1})	22,00	10,00	5,00	3,00	2,00
K_2O(AL) (mg kg^{-1})	135,00	117,00	75,00	38,00	29,00
pH (H_2O)	7,70	7,90	8,00	8,10	8,10
pH (KCl)	7,30	7,30	7,40	7,50	7,60
Hy	1,18	1,16	1,09	0,90	0,73
CaCO3 (g kg^{-1})	-	-	73,80	252,00	304,00
y_1	2,20	2,10			
Silt and clay particles < 0,002 mm (%)	32,70	37,30	41,30	36,70	40,50
Bulk density (g/cm^3)	1,45	1,50	1,43	1,50	1,50

(Kismányoky et al. 1996)

Table 4.

Mean annual precipitation and temperature data of Keszthely (of the past 50 years)

Month	Precipitation (mm)	Air humidity (%)	Temperature (°C)	Mean daily temperature range (°C)	Duration of sunshine hours
I	38	88	-0,8	5,5	63
II	36	85	0,9	7,1	94
III	40	76	6,2	8,7	142
IV	55	71	11,2	9,8	178
V	74	72	16,3	10,0	242
VI	74	72	19,4	10,5	260
VII	71	70	21,5	10,8	281
VIII	77	73	20,6	10,8	265
IX	64	78	16,7	10,3	189
X	63	83	11,5	8,6	129
XI	59	86	5,5	6,0	71
XII	49	90	1,2	4,9	48
Sum	700				1962
Average		79	10,8	8,6	

(Kismányoky et al. 1996)

3.1.1.2. Data of the tillage methods

In case of the 'Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers', the effect of corn stem, wheat straw and increased amount of stockpiled farmyard manure; in case of the 'IOSDV (Long-term Experiment for Comparing the Effect of International Organic and Nitrogen-mineral Fertilizers), the effect of barley straw and green manure on the properties and organic matter amount of the soil structural units (also called aggregates) were studied.

Table 5. shows the applied amounts of the organic and inorganic fertilizers. In the sampling year, in the case of the 'Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers', grown plants were sugar beet – corn – corn – winter wheat – winter wheat (in the 'A' crop rotation), and corn – corn – potato – winter wheat – winter wheat (in the 'B' crop rotation), in the case of the 'IOSDV (Long-term Experiment for Comparing the Effect of International Organic and Nitrogen-mineral Fertilizers), corn – winter wheat –

winter barley (triculture) (in the text shown). Soil samples were taken in June of 2006, in the phase of 6-8 leaves of the corn.

Soil samples were taken in accordance with the depth of the studied tillage (called upper layer), and a 10cm thick layer were taken from the lower than the tillage depth (called lower layer).

Table 5.

Applied organic and inorganic manure amounts at Keszthely (kg·ha^{-1})

Name of the experiment	Grown crop	Treatment	Organic manure (t·ha^{-1})	N (kg·ha^{-1})		P_2O_5 (kg·ha^{-1})	K_2O (kg·ha^{-1})
				Autumn of 2005	Spring of 2006		
Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers – crop rotation 'B'	Fallow instead of potato (without crop)	0/ not tilled forest belt (shelter belt)	0	0	0	0	0
		1/ tilled control	0	0	146 (*)	80 (*)	100 (*)
		2/ corn stem ploughing	1.56 t·ha^{-1} corn stem (****)	26	120 (*)	80 (*)	100 (*)
		3/ wheat straw ploughing	0.5 kg·ha^{-1} wheat straw (****)	0	146 (*)	80 (*)	100 (*)
				(*) Plus NPK amount of 35 t·ha^{-1} farmyard manure in every treatment			
Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers – crop rotation 'A'	corn	0/ not tilled forest belt (shelter belt)	0	0	0	0	0
		1/ tilled control	0	0	0	0	0
		2/ 3x dose stockpiled farmyard manure	105 t·ha^{-1} farmyard manure pro 5 years (in 2 portions, in the 1st and 3rd year of the rotation) (this is equal with 21 t·ha^{-1} / pro year) (*****)	0	0	0	0
IOSDV (Long-term Experiment for Comparing the Effect of International Organic and Nitrogen-mineral Fertilizers)	corn	0/ not tilled forest belt (shelter belt)	0	0	0	0	0
		1/ tilled control	0	0	210	100	100
		2/ barley straw + green manure ploughing (**)	5 t·ha^{-1} barley straw	50 (***)	210	100	100

(*) Plus NPK amount of 35 t·ha^{-1} farmyard manure + N 640, P_2O_5 360, K_2O 360 kg·ha^{-1} pro 5years, every year, in every treatment
(**) green manure: oilradish *(Raphanus sativus var. oleiformis)*
(***) 1kg N surplus / 100kg strem dry matter – to avoid pentosan effect
(****) Data counted from Cereals Equivalent of crop quantity grown on the sampling site.
(*****) Farmyard manure was applied in the Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers – crop rotation 'A' in the crop rotation 'sugar beet – corn – corn – winter wheat – winter wheat' in the 1st and 3rd years of crop rotation, in our case one year before soil sampling.

3.1.1.3. Tillage methods at Keszthely

Table 6. shows the tillage methods at Keszthely.

Table 6.

Az alkalmazott talajművelési eljárások és művelési mélységek Keszthelyen – Tillage methods and depths at Keszthely

Name of the experiment	Grown crop	Treatment	Tillage methods and depths
Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers – crop rotation ‘B’	Fallow instead of potato (without crop)	0/ not tilled forest belt (shelter belt)	
		1/ tilled control	autumn ploughing (20cm) seedbed preparation with combinator
		2/ corn stem ploughing	autumn ploughing (25cm) seedbed preparation with combinatory spring land planeing and combinator
		3/ wheat straw ploughing	autumn ploughing (20cm) seedbed preparation with combinator ploughing down the wheat straw (fallow land planeing with disk (12cm))
Long-term Experiment for Comparing the Effect of Organic and Inorganic Fertilizers – crop rotation ‘A’	corn	0/ not tilled forest belt (shelter belt)	
		1/ tilled control 2/ 3x dose stockpiled farmyard manure (*)	autumn ploughing (25cm) seedbed preparation with combinator spring land planeing and combinator
IOSDV (Long-term Experiment for Comparing the Effect of International Organic and Nitrogen-mineral Fertilizers)	corn	0/ not tilled forest belt (shelter belt)	
		1/ tilled control 2/ barley straw + green manure	stubble clearing with disking (12cm) autumn ploughing (25cm) harrowing seed bed making, sowing

(*)105 $t \cdot ha^{-1}$ farmyard manure pro 5 years (in 2 portions, in the 1^{st} and 3^{rd} year of the rotation) (this is equal with 21 $t \cdot ha^{-1}$ / pro year).

3.1.2. Látókép

Soil samples were taken from the ‘Long-term multifactorial soil tillage experiment’ Experimental Site of the University of Debrecen, Centre for Agricultural and Applied Economic Sciences, which was set up by Prof. János Nagy.

3.1.2.1. Description of the soil conditions of the sampling site

The sampling site is found in the Hajdúság Loess Plaeau, in the west side of Pece-creek, at 113-118m (Adriatic) height. On the bigger part of the site ‘calcareous chernozem’ (FAO: chernozem) soil types could be found. On the lower parts, in smaller surfaces ‘leached chernozem’ (FAO: phaeozem) soil types could be found. Main physical and chemical characteristics of the studied soil type and the soil profile are shown on in the *Tables 7-8th*.

Table 7.

Main physical characteristics of the studied soil type and the soil profile at Látókép

Depth	Clay and silt	Saturation percent according to Arany	Soil hydroscopcity	Bulk density	Pore volume	Minimal water capacity of the soil	Wilting point
cm	%	K_A	hy	g cm^{-3}	P %	$VK_{mintf\%}$	$HV_{tf\%}$
0-20	56.8	42	2.25	1.41	46.7	33.7	12.69
20-40	58.6	43	2.25	1.43	46.0	31.1	12.87
40-60	57.1	43	2.13	1.31	50.5	29.1	11.16
60-80	57.5	44	2.51	1.29	51.3	28.6	12.51
80-100	58.6	48	2.07	1.30	50.9	29.1	10.76
100-120	54.1	47	2.18	1.24	53.3	27.4	10.81
120-140	55.3	46	1.91	1.24	53.3	27.8	9.47

(Megyes, 2001)

Table 8.

Main chemical characteristics of the studied soil type and the soil profile at Látókép

Depth	pH		$CaCO_3$	humus	Total N	AL-soluble	
cm	H_2O	KCl	%	%	%	P_2O_5	K_2O
						ppm	
0-20	7.3	5.6	0	2.72	0.150	133.4	240.0
20-40	7.2	5.4	0	2.31	0.120	48.0	173.6
40-60	7.2	5.8	0	1.68	0.100	40.4	123.0
60-80	8.0	7.2	1.1	1.02	0.086	32.4	96.5
80-100	8.4	7.5	11.6	0.81	0.083	39.8	93.6
100-120	8.4	7.5	10.6	-	-	40.6	86.1
120-140	8.4	7.5	7.5	-	-	31.6	78.0

(Megyes, 2001)

3.1.2.2. Technical data of the experiment

At Látókép, the main treatments were tillage methods (winter ploughing, spring ploughing and disking), sub-treatments were the application of the mineral fertilizer and irrigation. A block of tillage is sub-divided into an irrigated and a not irrigated part. In the long-term tillage experiment winter ploughing (to the depth of 27cm), spring ploughing (to the depth of 22cm) and disking (to the depth of 12cm) are studied. In our experiment, $N_0P_0K_0$ means the treatment without mineral fertilizer, and $N_{240}P_{180}K_{212}$ kg ha^{-1} dose means the treatment with mineral fertilizer *(9^th Table)*. On the experimental site winter wheat – corn crop rotation was applied, in our investigation the pre-crop was corn in monoculture. Soil samples were taken in May of 2006, before wheat ear-phase.

Soil samples were taken in accordance with the depth of the studied tillage treatment (called upper layer), and a 10cm thick layer were taken from the layer under the tillage depth (called lower layer).

Table 9.

Name of the experiment	Grown crop	Tretment	N	P_2O_5	K_2O
Long-term multifactor soil tillage experiment	winter wheat	0/ untilled control (forest belt, shelter belt)	0	0	0
		1/ winter ploughing – irrigated – without mineral fertilization	0	0	0
		2/ winter ploughing – irrigated – with mineral fertilizer	240	180	212
		3/ winter ploughing – not irrigated – without mineral fertilizer	0	0	0
		4/ winter ploughing – not irrigated – with mineral fertilizer	240	180	212
		0/ untilled control (forest belt, shelter belt)	0	0	0
		5/ spring ploughing – irrigated – without mineral fertilizer	0	0	0
		6/ spring ploughing – irrigated – with mineral fertilizer	240	180	212
		7/ spring ploughing – not irrigated – without mineral fertilizer	0	0	0
		8/ spring ploughing – not irrigated – with mineral fertilizer	240	180	212
		0/ untilled control (forest belt, shelter belt)	0	0	0
		9/ disking – irrigated – without mineral fertilizer	0	0	0
		10/ disking – irrigated – with mineral fertilizer	240	180	212
		11/ disking – not irrigated – without mineral fertilizer	0	0	0
		12/ disking – not irrigated – with mineral fertilizer	240	180	212

(Nagy, 1996)

3.1.2.4. Tillage methods at Látókép

Table 10th shows the tillage methods used at Keszthely.

Table 10.

Tillage methods at Látókép

Year	Tillage method	Winter ploughing	Spring ploughing	Disking
2005/06	stem chopping	2005.10.26.	2005.10.26.	2005.10.26.
	mineral fertilizer ($N_{120,240}$PK)	2005.10.27.	2005.10.27.	2005.10.27.
	disking (2x, 12 cm)	2005.10.28.	2005.10.28.	2005.10.28.
	winter ploughing (25-27 cm)	2005.11.18.	-	-
	land planeing	-	-	-
	disking (12 cm)	-	-	2006.05.04.
	spring ploughing (22 cm)	-	2006.04.26.	-
	seed bed making	2006.05.04.	2006.05.04.	2006.05.04.
	sowing	2006.05.05.	2006.05.05.	2006.05.05.
	crop protection	2006.05.09.	2006.05.09.	2006.05.09.
	harvesting	2006.10.11.	2006.10.11.	2006.10.11.

(Vad et al. 2009)

3.2. Method

Soil samples were investigated and experimental data were calculated in the Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research of the Hungarian Academy of Sciences.

The investigations were carried out in three ways:

1.) Firstly, changes in quality of agronomical soil structure as affected by the different tillage and crop care methods were studied in laboratory conditions by wet sieving (i.e. particle-size fractionation) *(Tyulin (1928) in Di Gléria et al., 1957),* which technique is used to measure the different particle-sized aggregate fractions of soils. The obtained four different particle-size fractions were used to calculate three different indices, which assess soil agronomical structure:

1.) the *Mean Weight Diameter (MWD)* proposed by *van Bavel (1953, in Kemper et al., 1986)*
2.) the *Normalized Stability Index (NSI (Six))* proposed by *Six et al. (2000c),*
3.) the new *Normalized Stability Index (NSI (Huisz))* proposed by *Huisz (2009).*

2.) Secondly, changes in the amount of three different organic matter fractions as affected by the different organic matter additions, soil tillage and crop care methods were studied in laboratory conditions by density fractionation proposed by *Six et al., 1998.* The obtained different organic matter fractions were used to calculate an index *(Organic Matter Index, OMI)*, which assesses the distribution of the soil organic matter pool.

3.) Our third aim was to describe the relation between the changes of the soil structure and soil organic matter amount. For this aim *correlation coefficient* was calculated between one of the soil structure characterizing index (the *Normalized Stability Index (NSI Huisz)* proposed by *Huisz (2009)*) and two soil organic matter fraction values.

The studied soil samples were taken in accordance to the different sampling sites, tillage and crop care methods. Soil samples were taken from three or four plots per treatment, from four-four points per plot; firstly from the tilled layer, secondly from the layer lower than the tilled layer.

Samples from the same plot, from the same sampling depth were homogenized in situ. After delivering to the laboratory, and air-drying, soil samples were analyzed in 3-3 parallel analysis (replicates) per plot (therefore 9 or 12 investigations were done per treatment): with two pre-treatments *(Slaking and Capillary wetting)* in the case of the soil structure experiments, and with one pre-treatment *(Capillary wetting)* in the case of the soil organic matter experiments *(Table 11., Figure 1.)*. Results were accepted when the replicate showed less than 5% difference compared to the average of the other two replicate; or the replicate showed less than 5% weight loss.

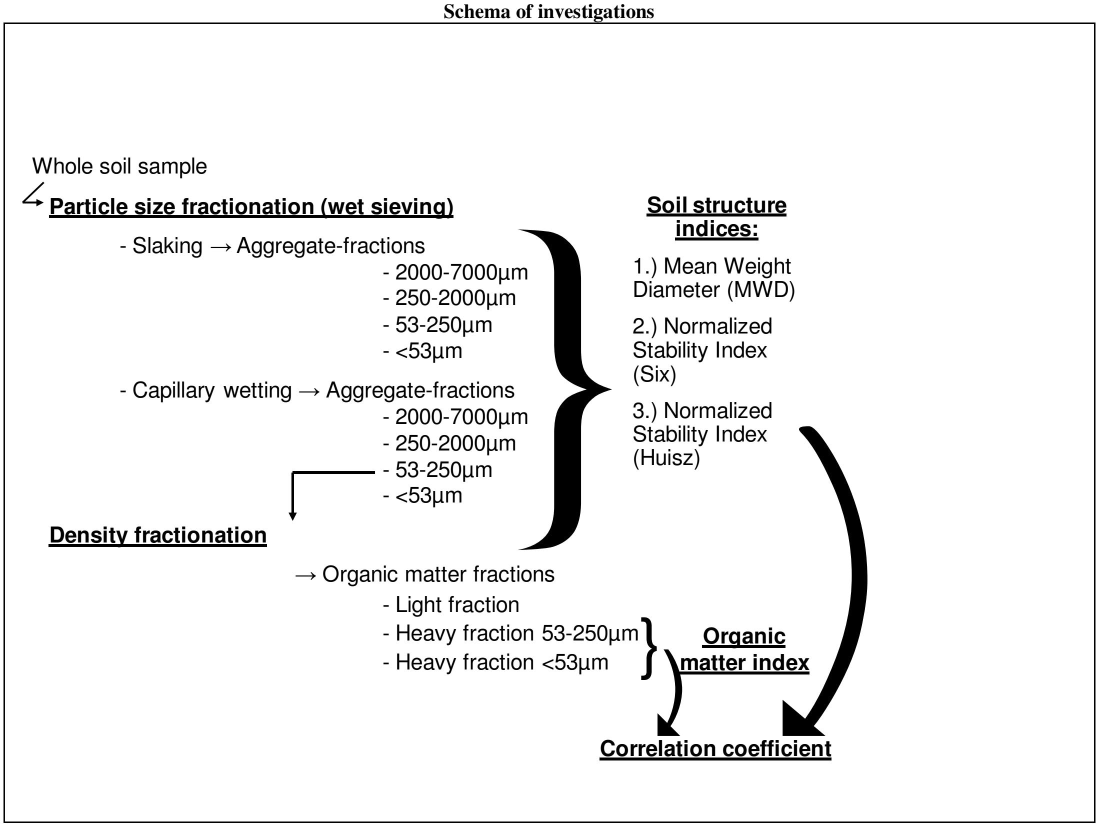
Table 11.

Sample pre-treatment methods

	Investigation of soil structure (wet sieving – particle size fractionation)	Investigation of soil organic matter (density fractionation)
Capillary wetting	x	
Slaking	x	x

Figure 1.

Schema of investigations



3.2.1. Wet sieving according to the particle size

The more aggregate-destructing effect was modeled by the (1) *Slaking pre-wetting pre-treatment*: air-dry soil samples were poured onto the surface of a sieve which was former emerged into a bowl filled with water till the surface of the sieve, and after that soil samples were left for soaking for 5minutes. This slaking pre-wetting pre-treatment method cause the disintegration of the soil aggregates, because the escape of the air entrapped in the aggregates blows up the aggregates, before the wet sieving. Therefore the aggregate falls apart into smaller aggregates, crumbs of aggregates and loosening organic and inorganic soil particles.

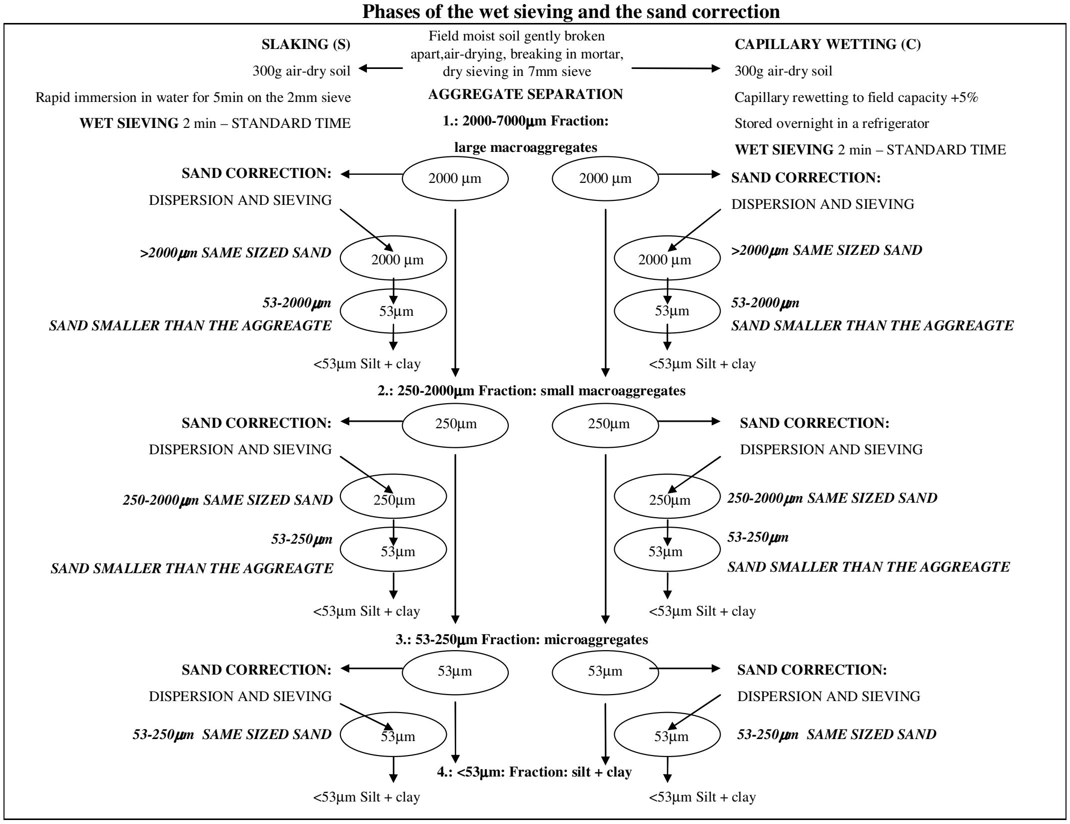
The less aggregate-destructing effect was modeled by the (2) *Capillary pre-wetting pre-treatment*: soil samples were wetted till they reached field water-holding capacity: air-dry soil samples were wetted through filter-paper and nylon filter. Capillary pre-wetting before the wet sieving permits removing the air encapsulated into the aggregates without the destruction of the aggregates, therefore the aggregate stays intact.

After the two different wetting pre-treatment methods soil sub-samples were wet sieved with a Retsch AS 200 BASIC typed wet sieving machine in constant water flow. The machine was set up to 70 stroke per minute. The sieving was done for 2 minutes, with 2mm, 250µm and 53µm sieves. Therefore four different particle sized fractions resulted: (1.) >2000µm large macro-, (2.) 250-2000µm small macro-, (3.) 53-250µm microaggregate, and (4.) <53µm silt and clay fractions.

After settling, fractions were dried and weighted. After these, 5grams of both pre-treated 1., 2. and 3. fractions were shaked with 15 ml 5gL^{-1} sodium-hexameta-phosphate solution for 18 hours, after the liquid phase was sieved again with the same sieve that was used to separate the aggregate fraction. Therefore 3-2-1 sand fractions resulted. Sand fractions were dried at 105^{o}C and weighted *(Figure 2.)*. The method mentioned before is called *'sand correction'*.

Figure 2.

Phases of the wet sieving and the sand correction

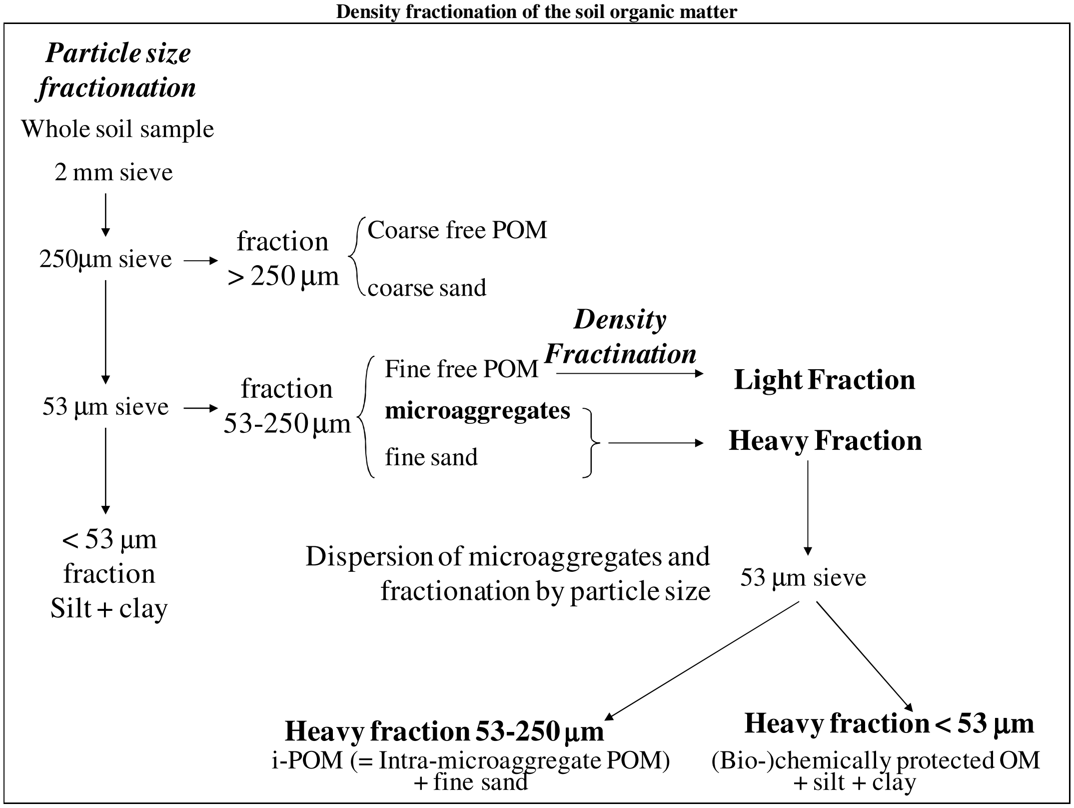


3.3.2.2. Density fractionation of the organic matter

53-250µm size, free (not associated to mineral particles) organic matter forms, which could be inside or outside of the microaggregates *(Ligth and 53-250µm Heavy fractions)* were separated from the <53µm organic matter which are inside the microaggregates, and adhered to mineral particles *(<53µm Heavy fraction)* according to their differing density with the method proposed by *Six et al. (1998)*, with 1.88 g/cm^3 Sodium Polytungstate ($Na_6(H_2W_{12}O_{40})H_2O$), SPT) solution *(Figure 3.)*. After separation organic matter fractions were dried and measured.

Figure 3.

Density fractionation of the soil organic matter



3.3.3. Calculation of indices

3.3.3.1. Calculation of soil structure indices

3.3.3.1.1. Calculation of the new Normalized Stability Index (NSI (Huisz)) proposed by Huisz (2009)

The new *Normalized Stability Index (NSI (Huisz))* proposed by *Huisz (2009)* is the modified version of the Normalized Stability Index (NSI (Six)) proposed by *Six et al. (2000c).*

1.) The Disruption level of a size class upon slaking

1. $$DLS_i = \frac{\left[\left(\left(P_{i0}-S_{i0}\right)-\left(P_i-S_i\right)\right)+\left|\left(\left(P_{i0}-S_{i0}\right)-\left(P_i-S_i\right)\right)\right|\right]}{2} \text{ x } \frac{1}{\left(P_{i0}-S_{i0}\right)}$$

where:

DLS_i = disruption level for each size class I (I= {i1, i2, i3, i4})

P_{i0} = total sample weight in size class I in the Capillary rewetted pre-treatment

P_i = total sample weight in size class I in the Slaked pre-treatment

S_{i0} = weight of aggregate-sized sand in size class I in the Capillary rewetted pre-treatment

S_i = weight of aggregate-sized sand in size class I in the Slaked pre-treatment

$P_{i0} - S_{i0}$ = sample weight corrected by aggregate-sized sand in size class I in the Capillary rewetted pre-treatment (= same-size sand corrected weight of size class I in the Capillary rewetted pre-treatment)

$P_i - S_i$ = sample weight corrected by aggregate-sized sand in size class I in the Slaked rewetted pre-treatment (= same-size sand corrected weight of size class I in the Slaked rewetted pre-treatment)

All above was expressed in gram fraction / gram soil. Indices of soil particle size classes: soil fractions were resulted in this order during wet sieving.

For the weight correction the amount of the aggregate and aggregate-sized sand fractions, 'Tap water factor' was used for calculating.

Remark 1. $$f_{tw} = \frac{Fr_{tw\ measured}}{Fr_{DW\ measured}}$$

Where
f_{tw} – tap water factor
$Fr_{tw\ measured}$ – fraction amount in the case of wet sieving done with tap water
$Fr_{DW\ measured}$ – fraction amount in the case of wet sieving done with distilled water

Remark 2. $$Fr_{DW} = Fr_{tw\ measured} \times f_{tw}$$

Where
Fr_{DW} – fraction amount in the case of wet sieving done with distilled water (calculated)
$Fr_{tw\ measured}$ – measured fraction amount in the case of wet sieving done with tap water
f_{tw} – 'tap water factor'
Indices of soil particle size classes: soil fractions were resulted in this order during wet sieving.
i = 1 = 1. fraction = >2000 µm large macroaggregate fraction
i = 2 = 2. fraction = 250-2000 µm small macroaggregate fraction
i = 3 = 3. fraction = 53-250 µm microaggregate fraction
i = 4 = 4. fraction = <53 µm silt and clay fraction

2.) The whole soil disruption level

2. $$DL = \frac{1}{n}\sum_{i}^{n}\left[(n+1)-i\right] \times DLS_i$$

where:
DL = disruption level of the whole soil
n = number of aggregate size classes
DLS_i = disruption level for each size class I (I= {i1, i2, i3, i4})
i = 1 in here 4. fraction = <53 µm silt and clay fraction
i = 2 in here 3. fraction = 53-250 µm microaggregate fraction
i = 3 in here 2. fraction = 250-2000 µm small macroaggregate fraction
i = 4 in here 1. fraction = >2000 µm large macroaggregate fraction

3. $$DL_{Huisz} = \frac{((1 \times DLS_{1.fr.}) + (1 \times DLS_{2.fr.}) + (1 \times DLS_{3.fr.}) + (1 \times DLS_{4.fr.})}{4}$$

3.) The maximum disruption level

4. $$DLS_{i\ max} = \frac{\left[(P_{i0} - P_p) + (P_{i0} - P_p)\right]}{2\,(P_{i0} - S_{i0})}$$

Where:
$DLS_{i\ (max)}$ = the maximum disruption
P_{i0} = total sample weight in size class I in the Capillary pre-treatment
P_p = primary sand particle content with the same size as the aggregate size class after complete disruption of the whole soil = total = summarized sand content (= all sand fraction which is >53µm = which has the diameter from 53µm till the aggregate-size) of all the 3 aggregate classes after dispersion with SHMP for each pre-treatment

5. $$DL_{(max)} = \frac{1}{N}\sum_{i}^{n}\left[(n+1)-i\right] DLS_{i\ (max)}$$

N = 1, 2, 3

In parallel with the calculation of the values of DL:

6. $$DL_{max\ (Huisz)} = \frac{((1 \times DLS_{max\ 1.fr.}) + (1 \times DLS_{max\ 2.fr.}) + (1 \times DLS_{max3.fr.}) + (1 \times DLS_{max4.fr.})}{4}$$

4.) The Normalized Stability Index

7. $$\mathrm{NSI} = 1 - \left(\frac{\mathrm{DL}}{\mathrm{DL}_{max}} \right)$$

3.2.3.2. Calculation of the Mean Weight Diameter (MWD) proposed by van Bavel (1953)

1. $$\mathrm{MWD} = \frac{\sum_i^n X_i \times S_{int}}{W}$$

Where
MWD = Mean Weight Diameter (in mm)
X_i = same-size sand corrected weight of size class I on the different sieves (separated to Slaking and Capillary wetting pre-treatments)
S_{int} = average mesh size of the two (transferring and uptaking) sieves
W = same-size sand corrected weight of whole soil sample

3.2.3.3. Calculation of the Organic Matter Index (OMI) proposed by Huisz

The *Organic Matter Index (OMI),* which was proposed in this way firstly in our work, is calculated from the ratio of the amounts of the free and total (free plus mineral particle-associated) organic matter fractions found inside of the microaggregates (the 53-250µm fine organic matter i.e. the 53-250µm Heavy fraction – the amount of which could be modified by tillage methods and organic manure application; and the <53µm mineral associated organic matter fraction – the amount of which could not be modified by tillage methods and organic manure application) in the following way:

1. $$\mathrm{OMI} = \frac{\text{53-250µm Heavy fraction}}{(\text{53-250µm Heavy fraction} + < \text{53µm Heavy fraction})}$$

3.3. Evaluation of the results

Data were evaluated by the statistical program IBM SPSS Statistics 19 *(Huzsvai 2004-2010, Ketskeméty et al. 2005).* Changes in the soil structure and organic matter amounts as affected by the studied tillage and crop care methods were detected by:

1.) firstly the measured dry matter amounts of the four different particle-sized aggregate-frations,
2.) secondly the calculated values of the three different soil structure characterizing indices *(NSI (Six), NSI (Huisz), MWD)* originating from the measured dry matter amounts of the four different particle-sized aggregate-frations,
3.) thirdly the measured dry matter amounts of the three different organic matter fractions,
4.) fourthly the calculated values of the *Organic Matter Index (OMI)* originating from the measured dry matter amounts of the two different organic matter fractions

(after Test of Normality) were compared by ANOVA (One-way analysis of variance). (Excluding of the outlier values were decided by the Dixon's Q-test.)

Correlations between the changes of the soil structure and soil organic matter content were studied by (after Test of Normality) calculating *correlation coefficient* between the soil structure characterizing index *(Normalized Stability Index* proposed by *Huisz (NSI Huisz))* and the dry matter amounts of the two organic matter fractions.

4. Results and discussion

In our experiments the effects of different tillage (ploughing, disking) and crop care (application of organic and inorganic fertilizers, irrigation) methods were studied on the agronomical structure and organic matter content of soil on soil samples originating from two different sampling sites: Látókép (chernozem soil, texture: clay loam) and Keszthely (Ramann-type brown forest soil, texture: sandy loam).

In the first part of the Keszthely experiments, the effects of addition of (1) decomposed (3x (increased dosage) stockpile **farmyard manure)** and (2) fresh **(barley straw and green manure)** organic matter on the agronomical structure and organic matter content of soil were studied on sandy loam soil. As we have reported, the water-resistability of the *>2000μm large* and the *250-2000μm small macroaggregate fraction,* which are the most valuable for crop production, has increased not only by the fresh **Barley straw and green manure** application, but with the addition of the **Stockpiled farmyard manure**, therefore both organic matters have ameliorated the structure of soil *(Figure 2-3.)*.

Figure 2-3.

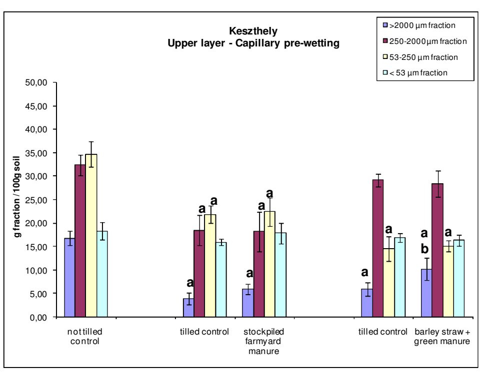


Figure 2. Particle size fractions – Keszthely – Farmyard manure and Barley straw treatments – Upper layer – Capillary pre-wetting

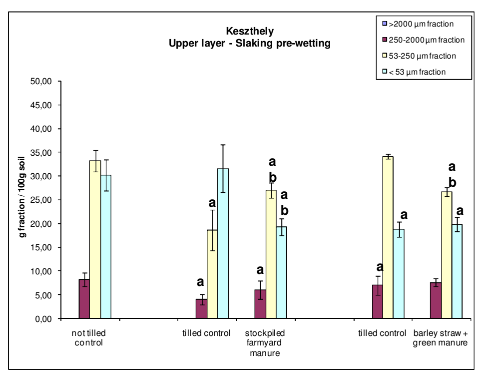


Figure 3. Particle size fractions – Keszthely – Farmyard manure and Barley straw treatments – Upper layer – Slaking pre-wetting

Significant difference: Changes in dry mass of fractions at the level of the standard deviation at P>0.05 on the effect of the investigated treatments compared to the untilled control (forest belt, shelter belt) are indicated by 'a', compared to the tilled control are indicated by 'b'.

Our conclusions were proved by the values of the *Normalized Stability Index (NSI Huisz)* and *Mean Weight Diameter (MWD)*. Because of the different decomposing characteristics of the two organic matter, **Barley straw and green manure** addition has increased the amount the free organic matter fraction which is outside of the microaggregates *(Light fraction)*, while due to the effect of the **Stockpile farmyard manure** the amount of the mineral-associated organic matter inside the microaggregate (*<53µm Heavy fraction*) has increased, and therefore ameliorated the structure of soil.

Because of the different distribution of the organic matters, the *correlation coefficient* calculated between the *53-250µm Heavy fraction* and the *Normalized Stability Index (NSI (Huisz))* showed close correlation only in the case of the **Barley straw and organic matter** treatment, and therefore proved, that in contrast with the results showed by *Christensen (1986),* in our experiment, the **Barley straw** addition has increased the amount of the free organic matter inside the microaggregate (*53-250µm Heavy fraction*) and therefore ameliorated the structure of soil.

Furthermore our results led us to that conclusion, that in the case of the Keszthely sandy loam soil, because of the lack of the enough amount of the *<53µm silt and clay fraction,* which is needed to the effective improvement of soil structure, nor the fresh, nor the already decomposed organic matters could increase the amount of the <53µm mineral-associated organic matter *(<53µm Heavy fraction)* pool.

In the second part of the Keszthely experiments, the effect of two differently decomposing fresh organic matter: corn stem and wheat straw on the agronomic structure and organic matter content of soil were compared in **Corn stem** and **Wheat straw** combinations. As we observed, the effects of the two differently decomposing organic matter were modified by the different aeration conditions of the two studied sampling soil layer. In the ***upper (0-20cm) sampling layer***, the water-resistance of the soil aggregates was ameliorated in the **Corn stem > Wheat straw** order. The improvement of the soil structure was proved by the order of the values of the *Normalized Stability Index (NSI Huisz)*, and the *Mean Weight Diameter (MWD).* Tillage has decreased the amount of soil organic matter, but the **Corn stem** treatment has increased the amount of the free organic matter inside the microaggregate *(53-250µm Heavy fraction).* By calculating the *correlation coefficient* between the amount of the free organic matter inside the microaggregate *(53-250µm Heavy fraction)* and the *Normalized Stability Index (NSI Huisz)* close correlation was found, which proves that the accumulation of the free organic matter inside the microaggregate caused by the organic matter addition by tillage is in relationship with improvement of soil structure *(Figure 4-5.)*.

Figure 4-5.

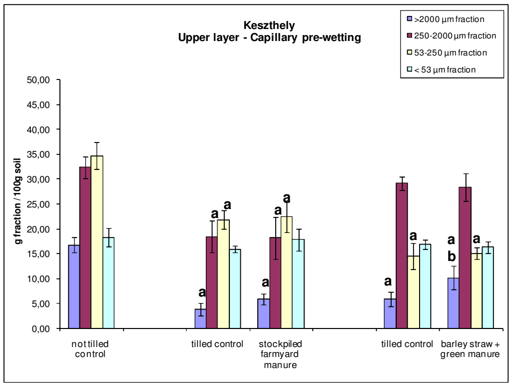


Figure 4. Amounts of organic matter fractions – Keszthely – Farmyard manure and Barley straw treatments – Upper layer

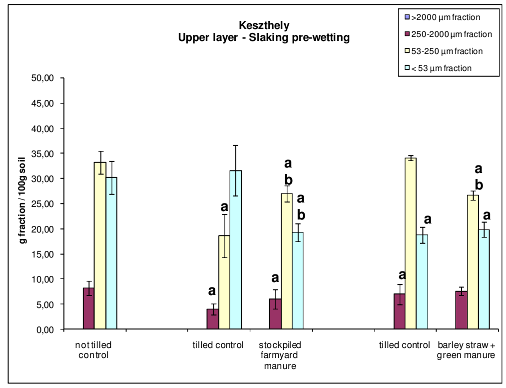


Figure 5. Amounts of organic matter fractions – Keszthely – Farmyard manure and Barley straw treatments – Lower layer

Significant difference: Changes in dry mass of fractions at the level of the standard deviation at P>0.05 on the effect of the investigated treatments compared to the untilled control (forest belt, shelter belt) are indicated by 'a', compared to the tilled control are indicated by 'b'.

Compared to the soil samples originating from the **not tilled control treatment (forest belt (shelter belt))**, every tillage method has decreased the amount of the *larger particle-sized aggregate fractions*, and increased the amount of the *smaller particle-sized aggregate* and *<53μm silt and clay fractions*, therefore caused the deterioration of the agronomical structure of soil, which effect could not be compensated by the addition of the studied organic matters. These conclusions were proved by the values of the *Normalized Stability Index (NSI Huisz)* and *Mean Weight Diameter (MWD).*

The largest amount of free and mineral-associated organic matter forms has found in the **not tilled, control (forest belt (shelter belt)) treatment.** Therefore the former assumption, that tillage methods cause the decomposition of the soil organic matter, and this effect could be ameliorated slightly, but could not be compensated fully, was proved. Similar results were reported by *Hoffmann et al. (2006)*, and these results were proved by the values of the **Organic Matter Index (OMI)**, too.

For the Látókép experiments the effect of tillage methods **(winter ploughing and spring ploughing, disking),** crop care **(mineral fertilization and irrigation)** of different intensity on the agronomical structure and organic matter content of soil were studied on clay loam soil.

The soil structure disintergrating effect exerted by tillage methods of different intensity (i.e. that ploughing disintegrates soil structure to a higher extent, and disking disintegrates soil structure to a lower extent) was proved by the amounts of the *>2000μm larger macro- and 250-2000μm small macroaggegates* (which are the most valuable for crop production), and the decreasing of the values of the *Mean Weight Diameter (MWD)* in the **Disking > Spring ploughing >Winter ploughing** order.

The values of the *Normalized Stability Index (NSI Huisz)* could detect not only the different intensity of tillage methods, but also the effect of the extreme precipitation conditions before the spring ploughing *(Balogh, 2009)* and the soil structure disintegrating effect of the water logging, therefore decreased in the **Winter ploughing > Disking > Spring ploughing** order *(Figure 6-11.)*.

During the addition of the **Mineral fertilizer**, the accumulation of the NH_4^+ ion from the fertilizer caused the dispersion of the aggregate-gluing colloids, and therefore the decrease of the amounts of the *>2000μm large, and the 250-2000μm small macroaggregates,* therefore the disintegration of the soil structural elements in ***both tilled (0-25cm and 25-35cm) layers*** in the case of the **Winter ploughing,** furthermore in ***the upper (0-20cm and 0-10cm) layer*** in the case of the **Spring ploughing** and **Disking**. These conclusions were proved by the values of the *Mean Weight Diameter (MWD)* in every treatment, but by the values of the *Normalized Stability Index (NSI Huisz)* only in the **Winter ploughing** treatment.

The *Normalized Stability Index (NSI Huisz)* values of the ***lower sampling layer (20-30cm in the case of Spring ploughing, 10-20cm in the case of Disking treatment)*** in the **Irrigated** and **Mineral fertilizer added** in the case of **Spring ploughing** and **Disking,** which overcomes the **not tilled, control (forest belt (shelter belt)) treatment**, shows the increasing amount and the transport to the lower layers and after the accumulation of the *53-250μm microaggregate* and *<53μm silt and clay fraction*, and therefore the deteriorate of soil structure.

Compared to the **not tilled, control (forest belt (shelter belt))** treatment, the aggregate-disintegrating and therefore soil structure deteriorating effect of conventional tillage methods **(plouhing, disking)** were proved by the decreasing amount of the *larger particle sized aggregate fractions*, and the increasing amount of the *<53μm silt and clay fraction*.

Soil-surface structure deteriorating effect of the freezing-thawing, water logging events were proved by that the *Normalized Stability Index (NSI Huisz)* and the *Mean Weight Diameter (MWD)* values of ***the lower layers (25-35cm in the case of the Winter ploughing, 20-30cm in the case of the Spring ploughing, 10-20cm in the case of the Disking treatment)*** have overcome the *NSI (Huisz)* and *MWD* values of the upper layers (0-***25cm in the case of the Winter ploughing, 0-20cm in the case of the Spring ploughing, 0-10cm in the case of the Disking treatment***).

When the effect of different tillage (Winter ploughing, Spring ploughing and Disking) and crop care (Mineral fertiliztation, Irrigation) on the amount of organic matter in- and outside of the microaggregates were examined, we found that the amounts of the mentioned organic matter fractions were modified by the different aeration conditions of the studied tillage methods, soil sampling layers, and the time passed since the tillage.

Therefore the amount of the free organic matter *(Light and 53-250μm Heavy) fractions* has increased in the **Winter ploughing < Spring ploughing < Disking**, the amount of the mineral-associated organic matter forms *(<53μm Heavy fraction)* has increased in the **Disking < Spring ploughing < Winter ploughing** order.

Furthermore, the amount of the free organic matter forms *(Light and 53-250μm Heavy fractions)* has increased by **Irrigation** in every case, and by **Mineral fertilizing** in that case, when it was applied with irrigation.

The amount of the mineral-associated organic matter forms *(<53μm Heavy fraction)*, which are inside the microaggregates, has increased by Mineral fertilizing, with or without Irrigation. These conclusions were proved by the values of the *Organic Matter Index (OMI)*, too.

The lowest *Organic Matter Index (OMI)* values were found in the case of the **Not irrigated** and **Not mineral fertilized** treatments. This tendency was remarkable mainly in the ***lower sampling layer (25-35cm in the case of the Winter ploughing, 20-30cm in the case of the Spring ploughing, 10-20cm in the case of the Disking treatment)***.

This result is in parallel with our former expectations, and prove that soil structure disintegrating and organic matter decreasing effects of tillage, which could not be compensated by the increased amount of crop biomass caused by Irrigation or Mineral fertilization.

When the effect of different tillage methods on the soil aggregate-stability and organic matter content were studied by the calculation of *correlation coefficient* between the values of the *Normalized Stability Index (NSI Huisz)* and the amount of mineral-associated organic matter fraction (which is inside of the microaggregates) *(<53μm Heavy fraction),* slight-moderate connection was found.

This result led us to the conclusion, that in the case of the Látókép clay loam soil, agronomical quality of soil structure is influenced not by the amount of organic matter, but by the amount of *<53μm silt and clay fraction,* therefore the more intense deterioration of soil structure caused by conventional tillage leds to more intense decomposition and therefore the loss of soil organic matter, without the remarkable decrease of stability of soil structure, as it was reported by *Six et at. (2000),* too.

Figure 6-11.

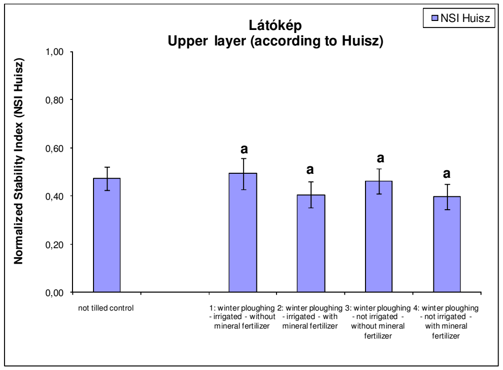


Fig. 6. Values of Normalized Stability Index (Huisz) – Látókép – Winter ploughing – Upper layer

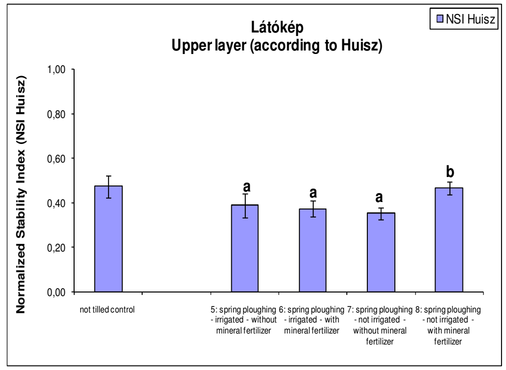


Fig. 7. Values of Normalized Stability Index (Huisz) – Látókép – Spring ploughing – Upper layer

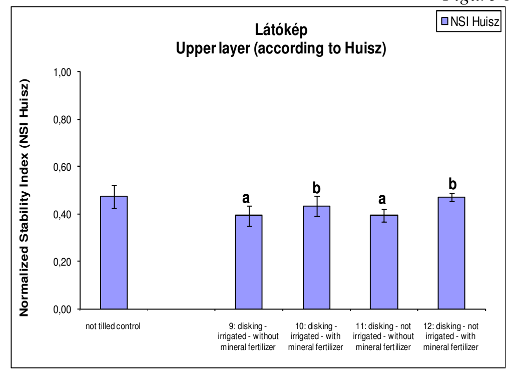


Fig. 8. Values of Normalized Stability Index (Huisz) – Látókép – Disking – Upper layer

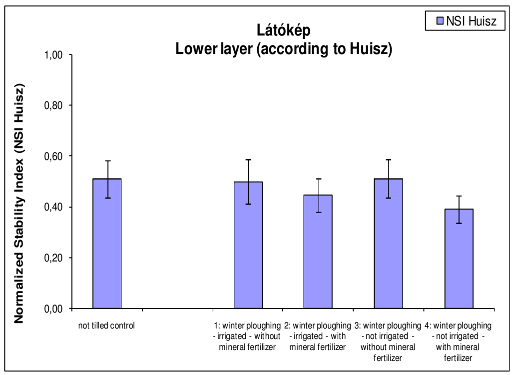


Fig. 9. Values of Normalized Stability Index (Huisz) – Látókép – Winter ploughing – Lower layer

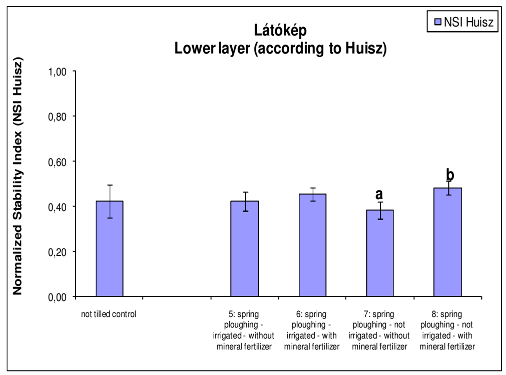


Fig. 10. Values of Normalized Stability Index (Huisz) – Látókép – Spring ploughing – Lower layer

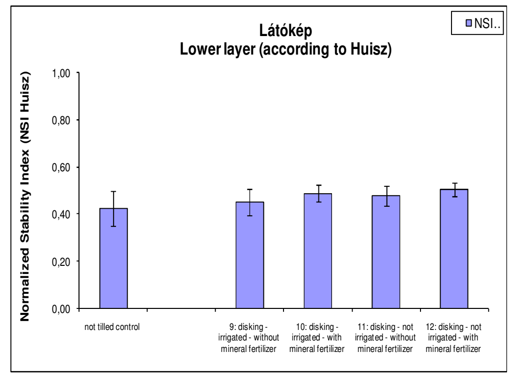


Fig.11. Values of Normalized Stability Index (Huisz) – Látókép – Disking – Lower layer

5. New and novel scientific results

During our studies, the following new and novel scientific results were obtained:

1.) During the Keszthely experiments, on sandy loam soil, due to the effect of the intensification of the microbial decomposition caused by the easily decomposable organic matters of **Farmyard manure** and **Wheat straw** addition, the decomposition and therefore the loss of the free organic matter forms (the *Light fraction* outside of the microaggregates, and the *53-250μm Heavy fraction* inside the microaggregates) of the original soil samples was observed.

2.) In our work, a new *Normalized Stability Index (NSI Huisz)* was proposed, which is able to detect the changes of the soil structure caused by the studied tillage and crop care methods.

3.) In the Látókép experiments, on clay loam soil, in the case of the **Spring ploughing** and **Disking** treatments, in the case of the **Mineral fertilization** and **Not irrigated** treatment-combinations, the transportation and accumulation of the *53-250μm microaggregate* and *<53μm silt and clay fraction* to the lower sampling layer was observed.

4.) The *Mean Weight Diameter (MWD)* values of the more aggregate-disrupting *Slaking pre-wetting pre-treatment,* which are not in connection with the different tillage **(ploughing and disking)** and crop care **(irrigation and mineral fertilization)** methods, but similar to the *MWD* values of the **not tilled control (forest belt, shelter belt)** treatment proves the independence from tillage methods and high structural stability of *53-250μm microaggregates*.

5.) A new, organic matter pool characterizing index was proposed. The *Organic Matter Index (OMI)* calculated from the ratio of the free and total organic matter forms which are inside the microaggregates is more sensitive to the changes caused by the different tillage methods, furthermore these changes could be interpreted easilyer, than the dry matter amounts of different organic matter fractions.

6.) To investigate the connection between soil organic matter forms and soil aggregate stability index, *Correlation coefficient* was calculated between the amounts of the 53-250μm fine free organic matter *(53-250μm Heavy)* and mineral-associated organic matter *(<53μm Heavy) fraction* and the values of the *Normalized Stability Index (NSI Huisz).* Organic matter fractions for the calculation of the *correlation coefficient* were selected in connection with the effect on the organic matter fractions of the studied treatments and the different particle size distribution of the two different sampling sites.

7.) Between the aggregate-stability and organic matter content of soil, slight-moderate correlation was found in the Látókép experiments. The reason for these results were caused because at the Látókép clay loam not the amount of organic matter, but the amount of the *<53μm silt and clay fraction* modifies soil structural stability, as it was reported by *Six et at. (2000).* Therefore the more intense aggregate-disrupting conventional tillage causes more intense microbial decomposition and therefore the loss of soil organic matters, without decreasing soil structural stability.

6. Scientific results applicable in practice

1.) To ameliorate soil agronomical structure and to increase organic matter content of sandy loam soil similar to the one of Keszthely, the addition of fresh (crop residues of different crops (**barley straw and corn stem**)) organic matters is more effective, than the addition of already decomposed (**stockpiled farmyard manure**) organic matters. Furthermore, it is not worthwile increase the amount of fresh organic matters over the optimal dosage.

2.) Adding to easily decomposable organic matters, like **stockpiled farmyard manure** and **wheat straw** causes the loss of the original 53-250μm free organic matter forms *(Light and 53-250μm Heavy fractions)* of soil, which causes the deterioration of soil structure mainly on the sandy loam soils, like Keszthely site.

3.) The effects of different tillage methods (**Spring ploughing, Winter ploughing, Disking**) on the agronomic soil structure is affected by the moisture conditions of soil at the tillage, which is modified by the precipitation and temperature of the studied year. Therefore the former assumption that tillage needed to be done in the optimal soil moisture conditions was proved.

4.) In connection with the above mentioned statements, precipitation, temperature and soil moisture regime modify the agronomic soil structure to high extent – as well as tillage, therefore tillage weather conditions might be considered.

5.) Aggregate-stability and agronomic soil structure and the ratio of the different organic matter fractions are not in direct relationship in every soil type: if structure of soil is determined not by the organic matter amount, then amount of *<53μm silt and clay fraction* determines it. Although conservation and improvement of soil organic matter pool is favourable in this cases, too.

7. List of publications regarging the subject of dissertation

7.1. Scientific publications in subject of dissertation

7.1.1. Scientific article in forein language, reviewed journals

1.) *Huisz, A.–Tóth, T.–Németh, T.:* 2009. Water-stable aggregation in relation to the Normalized Stability Index. *Comm. in Soil Sci. and Crop Anal.* 40. 1: 800-814. ISSN 0010-3624 print / 1532-2416. online
2.) *Huisz, A.–Tóth, T.–Németh, T.:* 2011. Assessing of soil structural stability of two different soil types by the new Normalized Stability Index. *Comm. in Soil Sci. and Crop Anal.* ISSN 0010-3624. print / 1532-2416. online (reviewed)

7.1.2. Scientific article in forein language, Hungarian printed reviewed journals

1.) *Huisz, A.–Sleutel, S.–Tóth, T.–Hofman, G.–De Neve, S.–Németh, T.:* 2006. Effect of cultivation systems on the distribution of soil organic matter in different fractions. *Cereal Res. Commun.* 34. 1: 207-210. ISSN 0133/3720.
2.) *Huisz, A.–Kismányoky, T.–Hoffmann, S.–Tóth, T.–Németh, T.:* 2007. Organic matter-induced changes in water-stable aggregation. *Cereal Res. Commun.* 35. 2: 497– 500. ISSN 0133/3720.
3.) *Huisz, A.–Megyes, A.–Tóth, T.–Németh, T.:* 2008. Interrelations of soil structure with cropping: effect of tillage on water-stability of soil aggregates. *Cereal Res. Commun.* 36. 1: 247-250. ISSN 0133/3720.
4.) *Huisz, A.–Tóth, T.–Németh, T.:* 2009. Normalized stability index and mean weight diameter in a combined nitrogen fertilization x irrigation experiment on Hungarian chernozem soil. *Cereal Res. Commun.* Suppl. 3. 443-446. ISSN 0133/3720.
5.) *Huisz, A.–Tóth, T.–Németh, T.:* 2010. Resilience of soil structure: maintaining and ameliorating soil structure by adding different kinds of organic matters. *Növényterm.* 59. Különszám. 2: 125-128. ISSN 0546-8191.

7.1.3. Scientific article in Hungarian language reviewed journals

1.) *Huisz A.–Sleutel, S.–Tóth T.–Hofman, G.–De Neve, S.–Németh T.:* 2006. Talajművelési rendszerek hatása a szervesanyag eloszlásra a talaj különböző szemcseméretű frakcióiban három év tapasztalatai alapján. *Acta Agr. Debr.* Különszám. 22: 22-30. ISSN 1587-1282.
2.) *Huisz A.:* 2007. A talaj aggregátum-stabilitása az egységes aggregátum-stabilitási mutató tükrében. *Acta Agr. Debr.* Különszám. 26: 83-99. ISSN 1587-1282.
3.) *Huisz A.–Tóth T.–Németh T.:* 2008. Tarlómaradványok hatása a talaj aggregátum-stabilitására. *Acta Agr. Debr.* Különszám. 30: 23-32. ISSN 1587-1282.
4.) *Huisz A.:* 2009. Talajaggregátumok stabilitásának vizsgálata: a homok-korrekció és jelentősége. *Acta Agr. Debr.* Különszám. 35: 29-47. ISSN 1587-1282.

7.1.4. Forein language conference brochures

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