Carbon balance of Hungarian soils

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In respect of arable land territory per capita, Hungary is in an advantageous situation among the Eastern European countries, as well as in comparison with West-European countries or the world average. While the **average arable land territory per capita** is 0.26 ha in the developing countries, 0.23 ha in the West-European countries, 0.30 ha on world average in 1990 (Lal, 1995) the **Hungarian average is as much as 0.48 ha.** The world trend shows a decrease on average to 0.25 ha in the year 2000, 0.15 ha in the year 2050 and about 0.10 ha in the year 2150. The only way to fulfil the needs of growing demands on 0.10 ha/capita is sustainable land use system that prevent or minimize (even restore) lost of resources and soil degradation processes.

Obviously the above mentioned favourable Hungarian data does not mean that Hungary should not pay particular attention to the maintenance or improvement of soil carbon sequestration and quality.

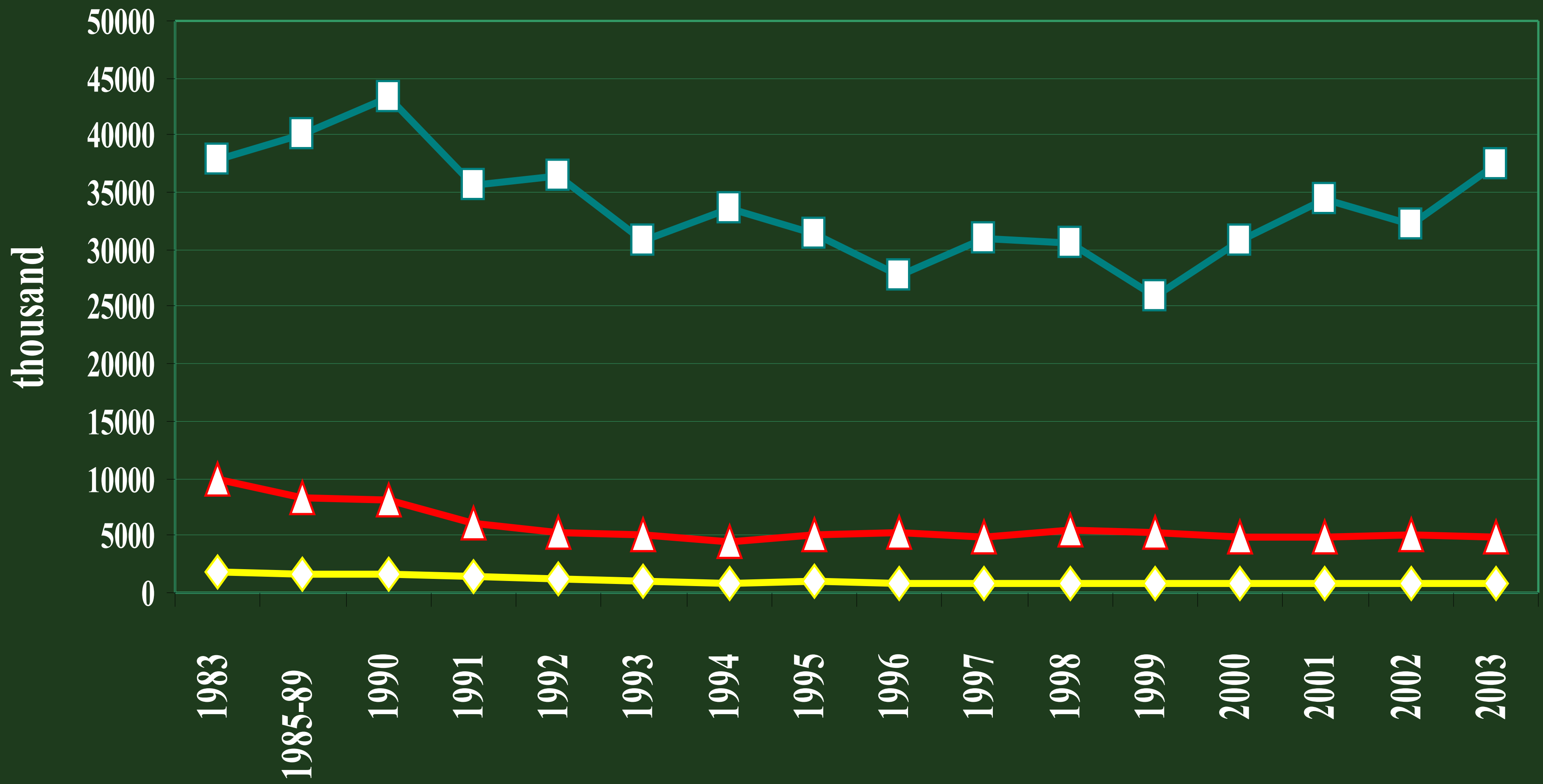
Changes in soil carbon are primarily effected by human activities (agriculture, forestry, etc.). The improper management practices open way for declines in soil organic carbon content, including one of the most important degradation processes, the water and wind erosion.

Through different degradation processes the native biologically productive soils became unproductive, can be characterized with slight humuous layer, low SOC, low soil quality, and low biomass productivity.

Soils represent a considerable part of the natural resources in the Central and Eastern European countries as well as in Hungary. Consequently, rational and sustainable land use and proper management practices ensuring normal soil functions have particular significance in national economy and soil conservation is an important element of environment protection.

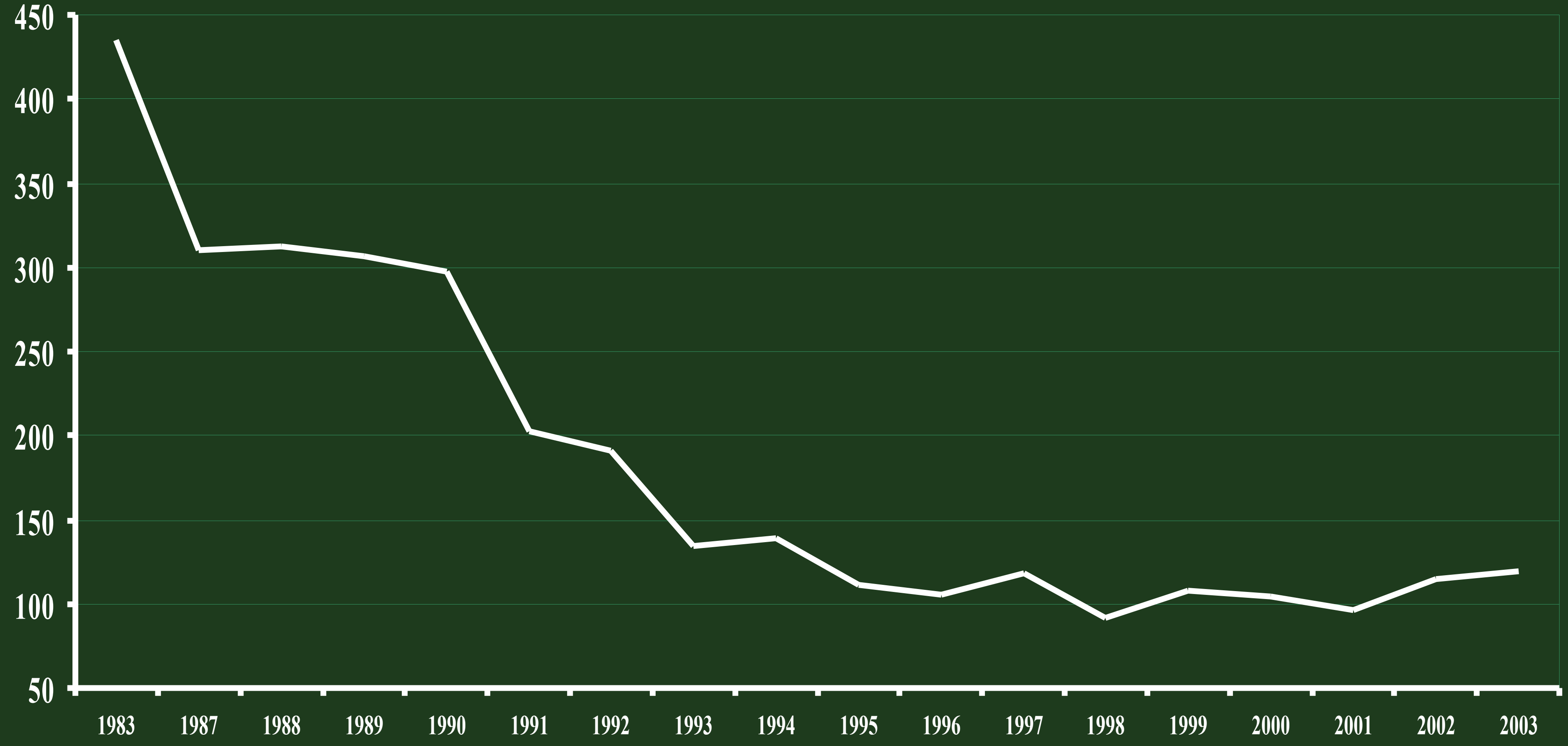
As a consequence of improving agricultural practice in Hungary, the increased use of fertilizers was characteristic of the early 1960's, and reached a rate as high as 250 kg $N+P_2O_5+K_2O$ /ha arable land units per year from the second half of the 1970's up to the late 1980's.

From the early 1990's, however, fertilizer use dropped dramatically down to the level of 30-40 kg ha^{-1} active ingredients (of which 90-95% was N). During the past years the same trend (decrease) was detectable in the farmyard manure application as well because of the dramatic decrease in the number of the breeding stock.



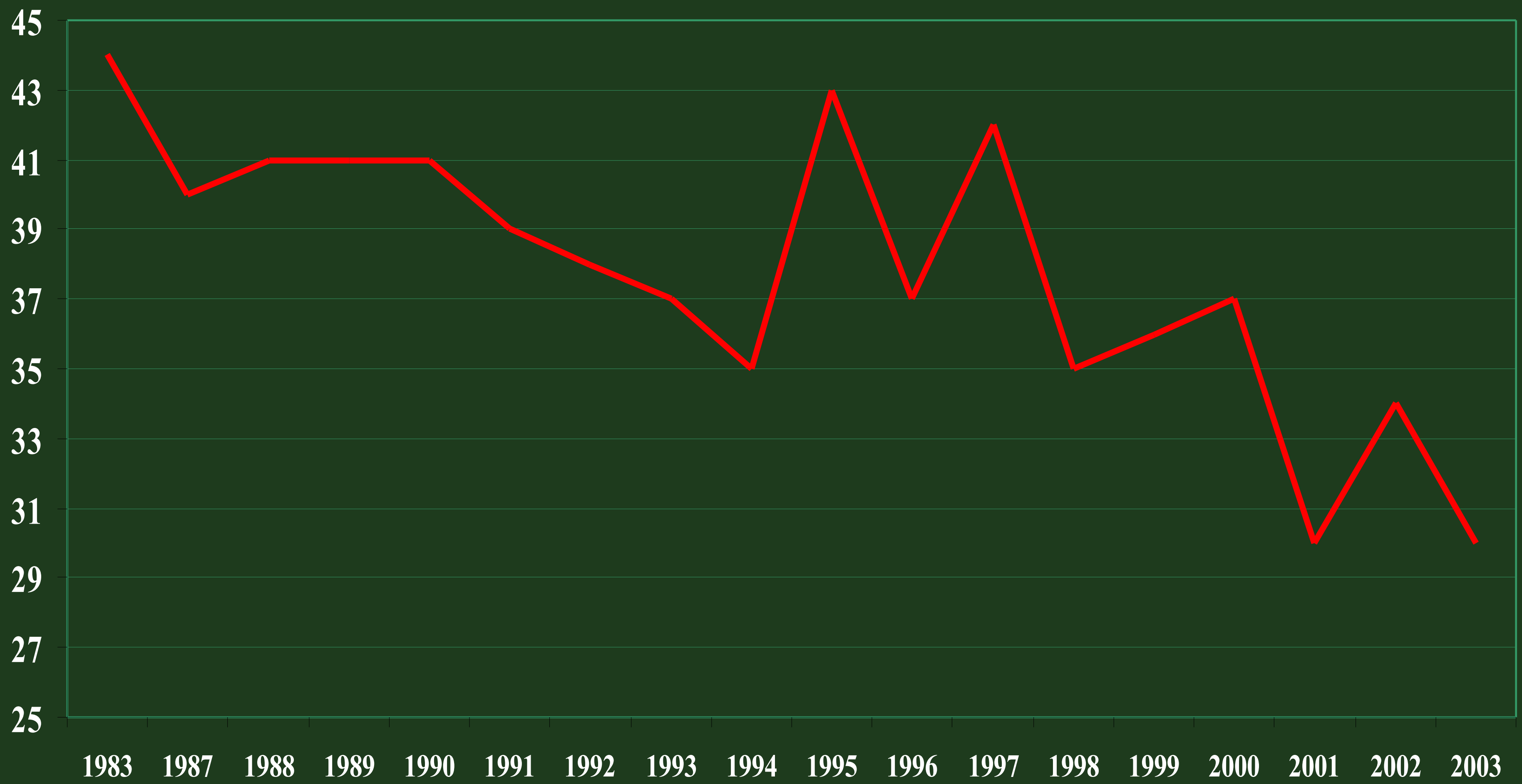
Poultry (22.4 million/2007), pig (3.7 million/2007) and bovine (0.7 million/2007) stock in Hungary

(after Marth & Karkalik, 2005; with permission)



Area fertilized with animal manure in Hungary (thousand hectares)

(after Marth & Karkalik, 2005; with permission)



Tons of organic manure for 1 hectare in Hungary

(after Marth & Karkalik, 2005; with permission)

Table 1. Farmyard manure and fertilizer use in Hungary, 1931-2001

(Statistical Yearbooks for Agriculture, Hungarian Statistical Bureau - KSH)

Year	*Farmyard Manure (million tons/year)*	*Fertilizer active ingredients, 1000 tons/ year*				*For arable lands,*
		N	*P_2O_5*	*K_2O*	Total	*kg ha^{-1} $year^{-1}$*
1931-1940	22.4	1	7	1	9	2
1951-1960	21.2	33	33	17	83	15
1961-1965	20.6	143	100	56	299	57
1966-1970	22.2	293	170	150	613	109
1971-1975	14.8	479	326	400	1,205	218
1976-1980	14.3	556	401	511	1,468	250
1981-1985	15.4	604	394	495	1,493	282
1986-1990	13.2	559	280	374	1,213	230
1991-1995	6.0	172	25	26	223	44
1996-2000	4.8	235	40	42	317	63

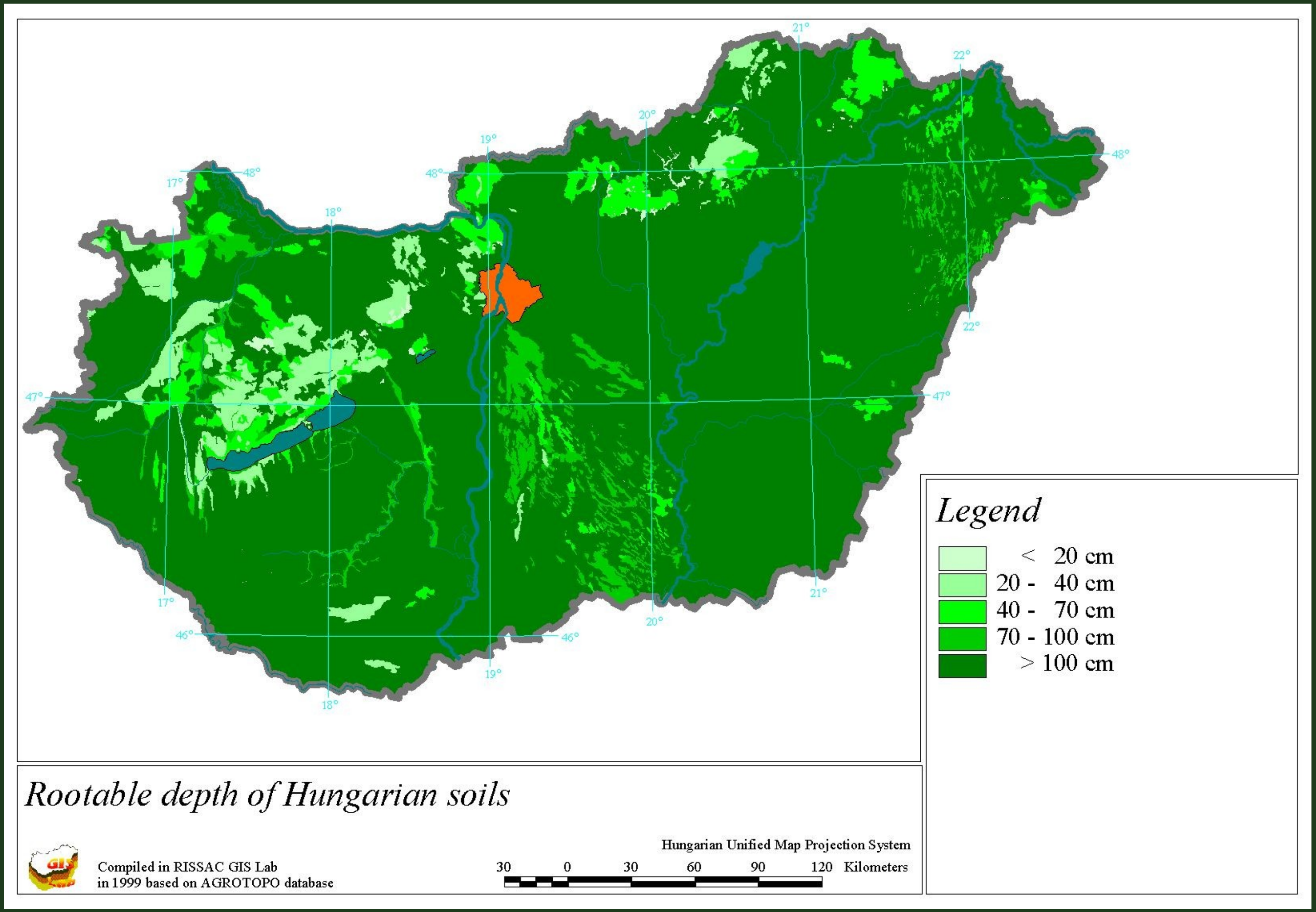
As a result of mineral fertilization, the proportion of nutrients given in farmyard manure diminished in the Hungarian plant nutrition system. On the other hand, with the increased application of mineral fertilizers, the average yields doubled or even tripled, resulting higher amounts of stubble and root remains in the soil, thus increasing the quantity of organic carbon.

[The yearly averaged primary biomass production in Hungary in 1980 was 24 970 tons (Láng, 1985)]

The previous intensive land use practice also had some unfavourable effects on soil carbon sequestration: large fields (100 ha or more) were formed for the efficient use of huge machineries. Rows of trees were cut for this reason, which caused an increase in erosion, deflation and soil carbon loss. The huge, overweighed machineries caused disadvantageous soil compaction, too.

Depth of the Hungarian Soils

The majority (86%) of Hungarian soils is more than 1.0 m deep. Soil depth is between 0.7 and 1.0 m in 4%, between 0.4 and 0.7 m in 5%, and between 0.2 and 0.4 m in 5% of Hungarian soils (Várallyay et al., 1980). Both soil depth and soil organic matter content can strongly determine the amount of organic matter resource in a given territorial unit. On the next the rootable depth of the Hungarian soils (1: 100 000) can be seen.

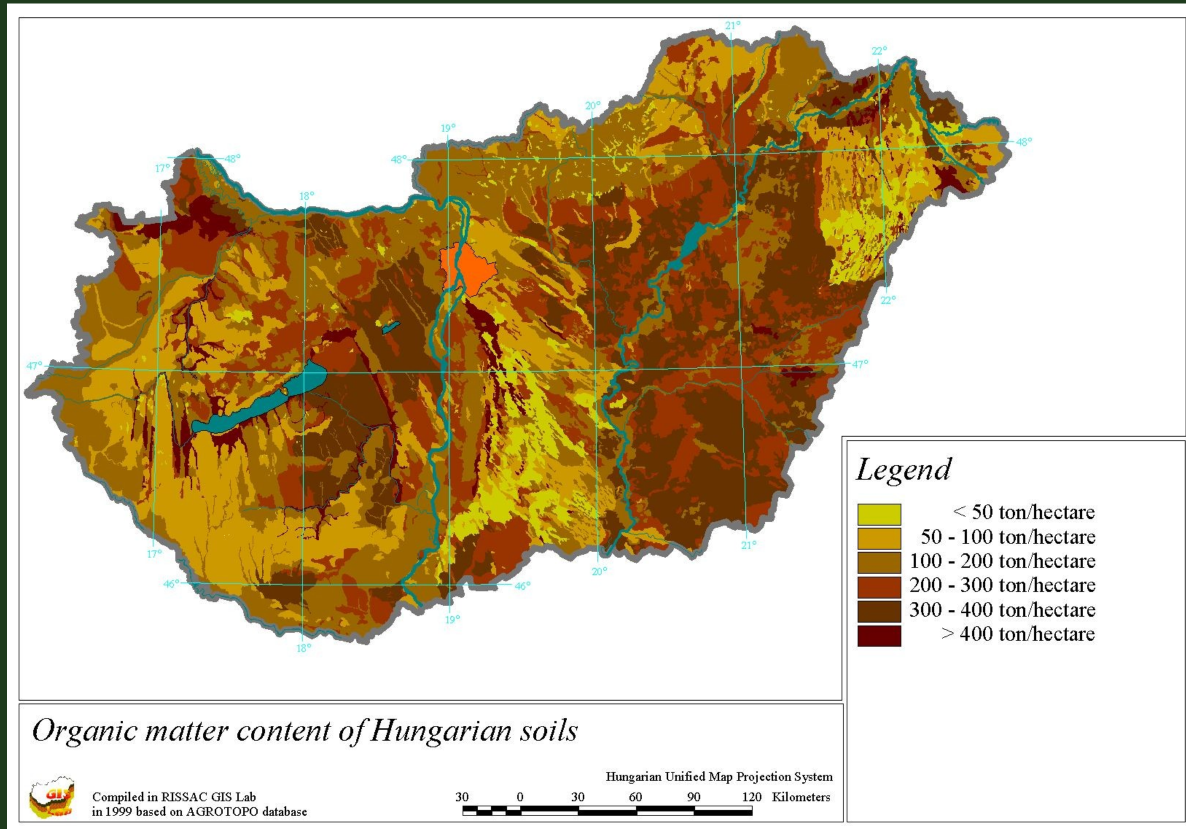


Rootable depth of Hungarian soils

Soil Organic Matter (OM) Content

From the distribution percentage of Hungarian soils according to their **organic matter content** can be seen that it is **between 1 and 3% in about 2/3 of Hungarian soils.** In sandy soils it is usually below 1% (15% of the area), while in clay loams between 3 and 4% (also 15% of the total area). It is over 4% on about 5% of the territory.

The territorial distribution shows that **sandy soils with low original organic matter contents** are situated in the south-western, in the central and in the eastern part of Hungary, while those with the highest OM contents are found in the south-eastern part, respectively.



Organic matter content of Hungarian soils

The distribution of Hungarian soils according to their soil organic matter resource groups is shown in this figure. In the majority of Hungarian soils soil organic matter resource is between 50 and 400 t/ha, and it is between 100 and 200 t/ha, resp. on about 30% of the total area.

Organic Matter and SOC Resource of Hungary

The estimation of the organic matter and soil organic carbon contents and pools was based on the calculation on territorial base with the thickness of the OM layer and the average SOC concentration in two layers (upper 20 cm and under) in the given soil. The **biggest OM as well as SOC pools can be found on chernozem, peat, and meadow soils,** 182 t/ha, 180 t/ha and 104 t/ha OM, respectively in the upper 0-40 and 0-60 cm (40 cm for meadow soil and 60 cm for chernozem and peat soils). The same calculation shows in average 105.6 t/ha SOC on chernozem soils, while 104.4 t/ha on peat soils and 60.3 t/ha on meadow soils, respectively.

Altogether more than **1102 million tons OM** and more than **639 million tons SOC** are the **reserves** of the **Hungarian soils** in the given thickness. App. 53% of the OM and SOC can be found in the arable land (Tables 2 and 3).

Table 2. Distribution of organic carbon in soils of Hungary

Distribution of Organic Carbon in Soils of Hungary

Hungarian Classification	Soil Type: U.S. Soil Taxonomy	Soil Type: FAO	Area (ha)	Depth of Roots (cm)	OM % in Upper 20 cm	OM % in Below 20 cm	OM (t/ha)	OM in Total Area of Soil Type (t)	OC (t/ha)	OC in Total Area of Soil Type (t)
Skeleton soils	Entisols (Ustipsamments, Ustiorthents)	Regosols/Leptosols	763,750	10	0.5	0	6.5	4,964,375	3.8	2,879,338
Stony soils	Inceptisols (Ohrepts, Umbrepts)	Regosols/Leptosols	262,936	30	2	1	65	194,835,576	37.7	113,004,634
Forest soils	Alfisols (Ustalfs)	Luvisols	3,195,004	40	2	1	78	249,210,312	45.2	144,541,981
Chernozem soils	Mollisols (Ustolls)	Chernozems/Phaeozems	2,064,731	60	3	2	182	375,781,042	105.6	217,953,004
Salt-affected soils	Inceptisols (Halaquepts)/Vertisols (Salaquerts, Natraquerts)	Solonets/Solonchak	562,440	20	2.5	0	65	36,558,600	37.7	21,203,988
Meadow soils	Mollisols/Vertisols	Phaeozems/Vertisols	1,987,554	40	3	1	104	206,705,616	60.3	119,889,257
Peat soils	Histosols (Hemists, Saprists)	Histosols	132,983	60	30	30	180	23,936,940	104.4	13,883,425
Wetland forest soils	Inceptisols (Endoaquerts)	Gleysols	8,087	20	1	0	26	210,262	15.1	121,952
Floodplain soils & sediments	Entisols (Fluvents), Inceptisols	Fluvisols, Regosols	254,511	20	1.5	0	39	9,925,929	22.6	5,757,039
Total			9,231,996					1,102,128,652		639,234,618

Table 3. Distribution of organic carbon on arable land of Hungary

Distribution of Organic Carbon on Arable Land of Hungary

Soil Type FAO	Area (ha)	Depth of Roots (cm)	OM % in Upper 20 cm	OM % in Below 20 cm	OM (t/ha)	OM in Total Area of Soil Type (t)	OC (t/ha)	OC in Total Area of Soil Type (t)
Regosols/ Leptosols	255,392	10	0.5	0	6.5	1,660,048	3.8	962,828
Regosols/ Leptosols	25,961	30	2	1	65	1,687,465	37.7	978,730
Luvisols	1,425,147	40	2	1	78	111,161,466	45.2	64,473,650
Chernozems/ Phaeozems	1,682,508	60	3	2	182	306,216,456	105.6	177,605,544
Solonets/ Solonchak	262,096	20	2.5	0	65	17,036,240	37.7	9,881,019
Phaeozems/ Vertisols	1,280,565	40	3	1	104	133,178,760	60.3	77,243,681
Histosols	50,738	60	30	30	180	9,132,840	104.4	5,297,047
Gleysols	3,908	20	1	0	26	101,608	15.1	58,933
Fluvisols, Regosols	129,220	20	1.5	0	39	5,039,580	22.6	2,922,956
Total	5,115,535					585,214,463		339,424,389

Predicted Change in the Land Use System in Hungary

Nearly 4% from the Hungary's existing agricultural land (closely 230 000 ha) can be turned into protection zone, more than 35% (~ 2.2 million ha) can be classed as extensive production, while more than 60% (~3.7 million ha) left for intensive agricultural production. Regarding to the arable land the same scenario showed that 111 300 ha can be moved from the existing arable land (4 714 000 ha) to protection zone, 1 408 900 ha to extensive agricultural production, while more than 67% of it (3 193 800 ha) can remain in the intensive agricultural production zone. The following conversions can be suggested:

- **533 000 ha of grassland into forest,**
- **229 000 ha of arable land into forest,**
- **788 000 ha of arable land into grassland, and**
- **503 000 ha of intensive arable land into extensive arable land.**

Table 4. Scenario of land-use change of arable land for next 25 years

Scenario of Land-Use Change of Arable Land for Next 25 Years

Soil Type FAO	Currently Arable Land Area (ha)	Expected Partial Land-Use Change	Change to Area (ha)	Remaining Arable Land Area (ha)
Regosols/Leptosols	255,392	Grassland	74,722	180,670
Regosols/Leptosols	25,961	Grassland	5,324	20,637
Luvisols	1,425,147	Forest	824,501	600,646
Chernozems/Phaeozems	1,682,508	Grassland	1,658,345	24,163
Solonets/Solonchak	262,096	Grassland	171,537	90,559
Phaeozems/Vertisols	1,280,565	Grassland	1,109,887	170,678
Histosols	50,738	Wetland	36,101	14,637
Gleysols	3,908	Wetland forest	1	3,907
Fluvisols, Regosols	129,220	Grassland/forest	64,087	65,132
Total	5,115,535		3,944,505	1,171,029

The predicted change in the land use system give a possibility for calculating the OM and SOC according to the new distribution (Tables 4 and 5). Table 4 showed that how this change will effects the distribution of the soils in different land use categories, while Table 5 give a scenario for the SOC balance in the next 25 years. This change is only a suggestion from soil suitability point of view, taking into account that the less valuable arable land would be changed. It contains more than 50% of the Regosols/Leptosols, app. 40% of the Luvisols, Solonets/Solonchak and Histosols, and almost all the Gleysols, while includes only few percents from Chernozems/Phaeozems and Phaeozems/Vertisols.

Table 5. Scenario for organic carbon due to land-use change and erosion after 25 years

Scenario for Organic C Content Due to Land-Use Change and Erosion after 25 Years

Soil Type FAO	Current OC Status (t)	Expected Increase of OC (t) Due to Land-Use Change	Expected Loss of OC Due to Erosion (t)		Summa Change	Expected OC Status (t) after 25 Years
			On Remaining Arable	On "Changed"		
Regosols/ Leptosols	962,828	3,406	56,340	58,718	–111,652	851,176
Regosols/ Leptosols	978,730	6,224	32,114	53,656	–79,546	899,184
Luvisols	64,473,650	181,155	2,486,695	1,561,680	–3,867,220	60,606,431
Chernozems/ Phaeozems	177,605,544	10,931	3,751,176	37,694	–3,777,939	173,827,606
Solonets/ Solonchak	9,881,019	51,211	646,694	294,317	–889,800	8,991,220
Phaeozems/ Vertisols	77,243,681	77,215	5,021,129	665,644	–5,609,558	71,634,122
Histosols	5,297,047	0	0	0	0	5,297,047
Gleysols	58,933	295	0	0	295	59,227
Fluvisols, Regosols	2,922,956	7,366	289,930	508,030	805,326	3,728,282
Total	339,424,389				–13,530,094	325,894,294

CONCLUSIONS

- **Soil depth** (mostly in arable lands located in plains) is enough to store sufficient amount of carbon in Hungary
- **Humus content** of Hungarian soils is relatively good
- Utilization of **farmyard manure** decreased dramatically in Hungary (direct re-supplement of C is low, biowaste utilization? biomass burning?)
- **Change in land use** can slow down the carbon loss of Hungarian soils

Thank you very much

for

your attention