Carbon Mining: the Story of Carbon Disappeared from the Agricultural Soils of Central and Eastern Europe

Tamás Németh

Hungarian Academy of Scineces

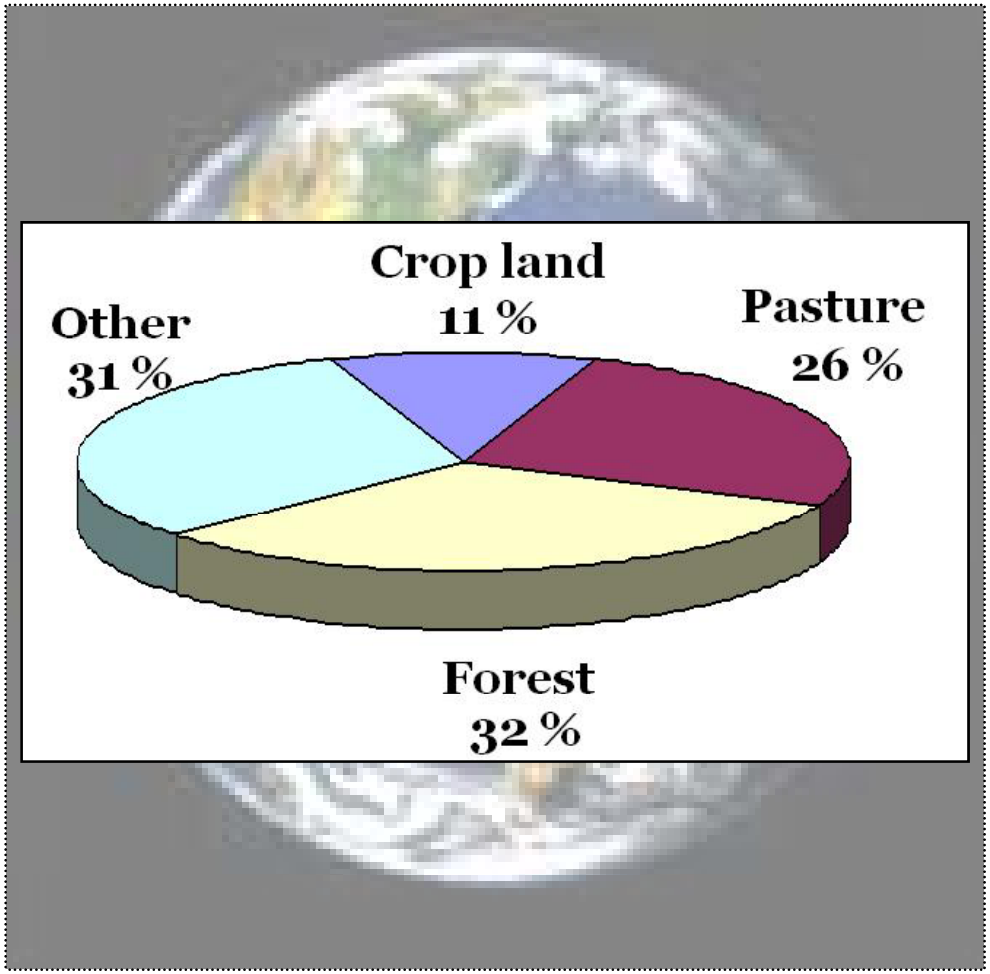
Tamás Németh– Carbon Mining ...

Tamás Németh– Carbon Mining ...

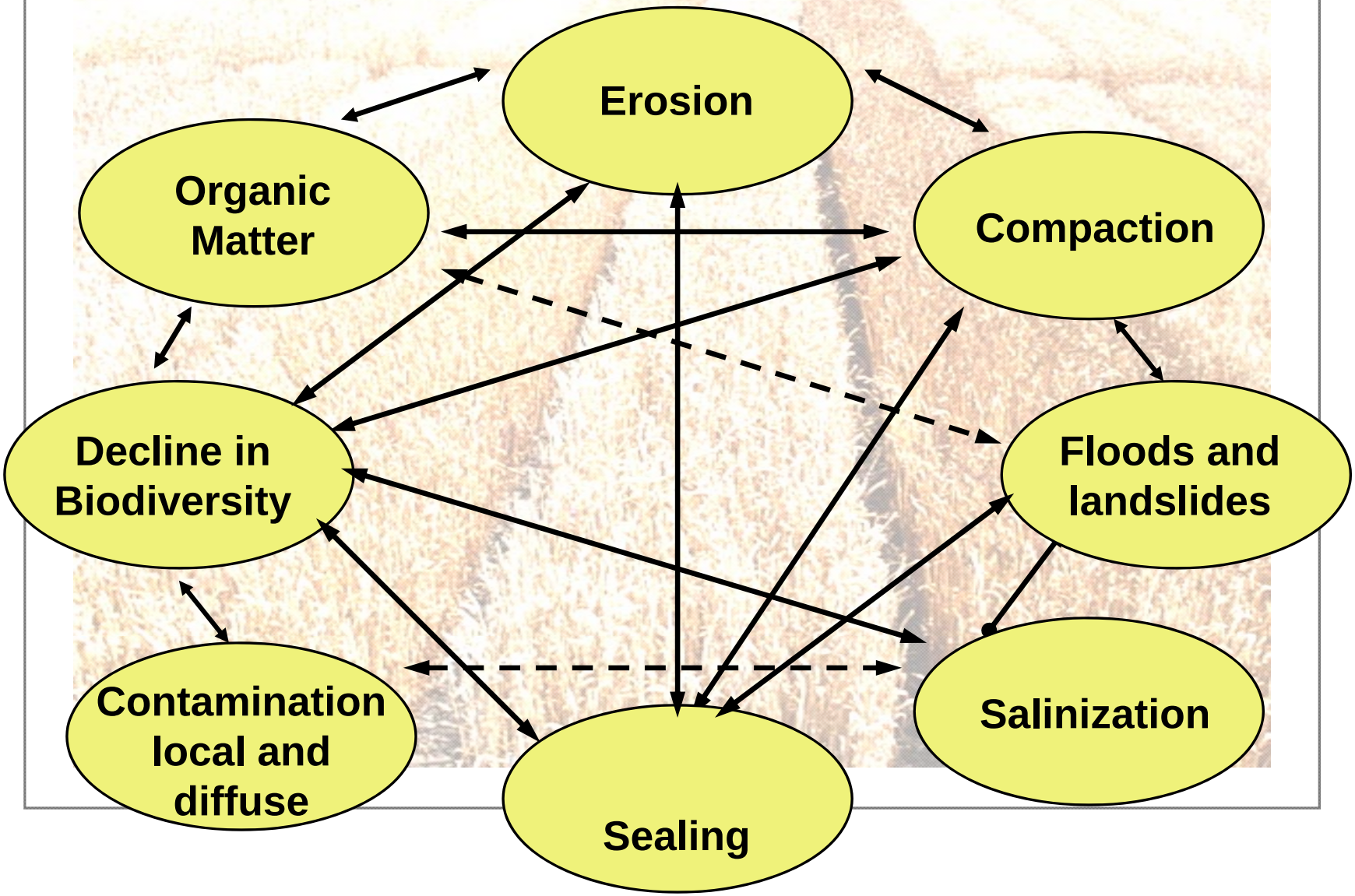
In respect of arable land territory per capita, Hungary is in an advantageous situation among the Eastern European countries, as well as in comparison with West-European countries or the world average. While the average arable land territory per capita is 0.26 ha in the developing countries, 0.23 ha 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 fullfill 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.

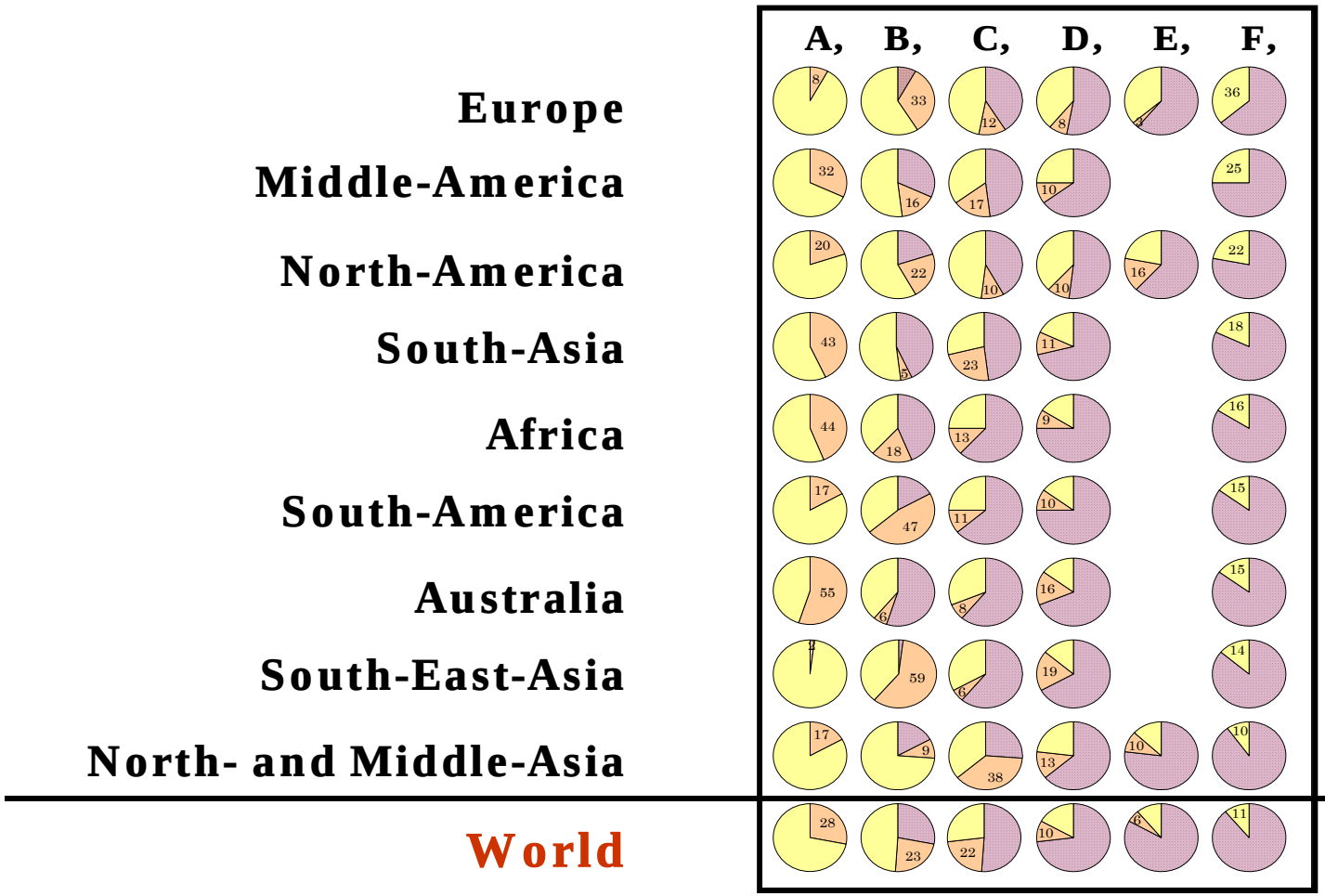
The formation of landuse in the World



Land degradation problems in Europe

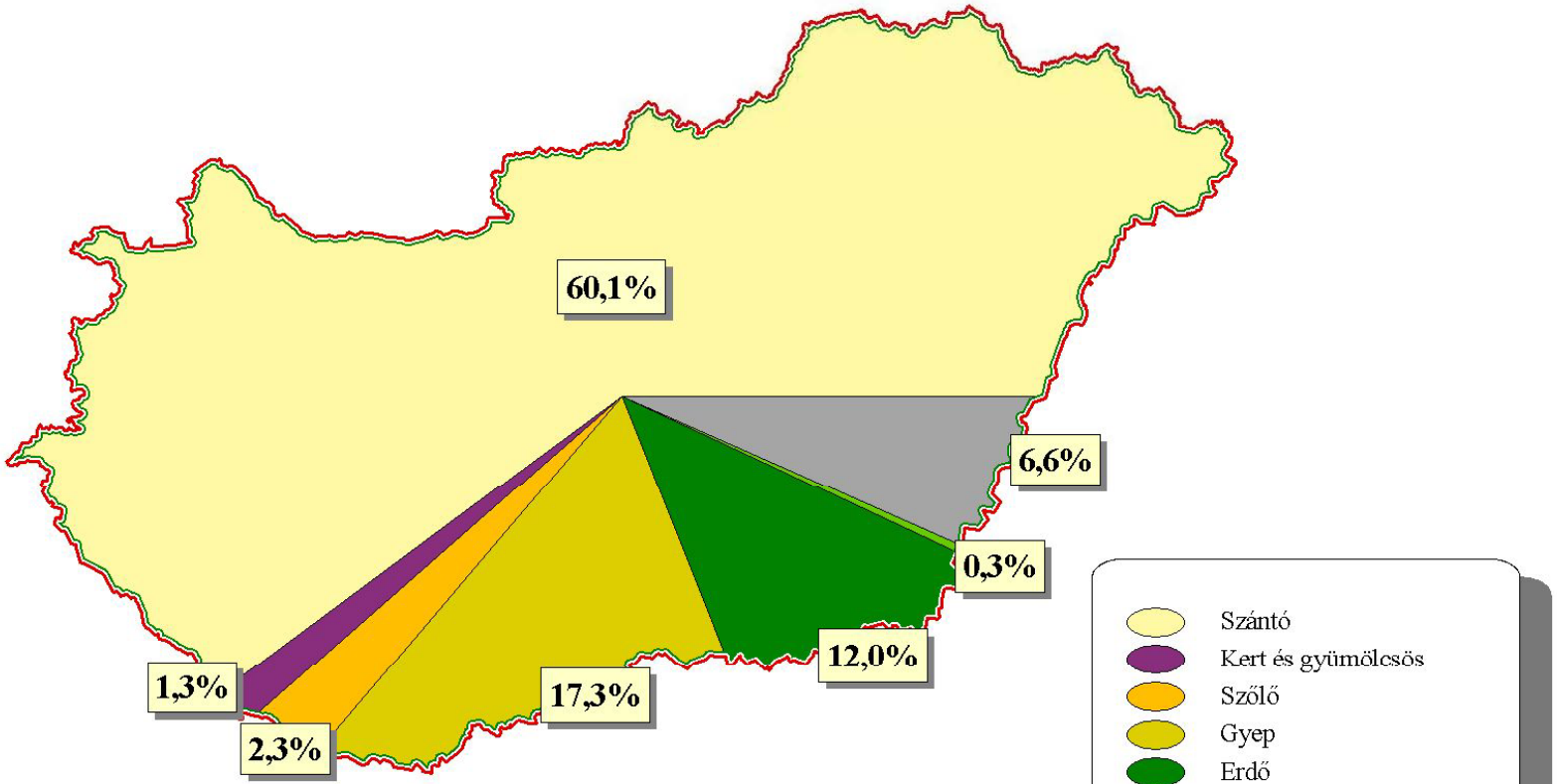


The main limitation factors of the World agricultural production (in the mainland percentage)

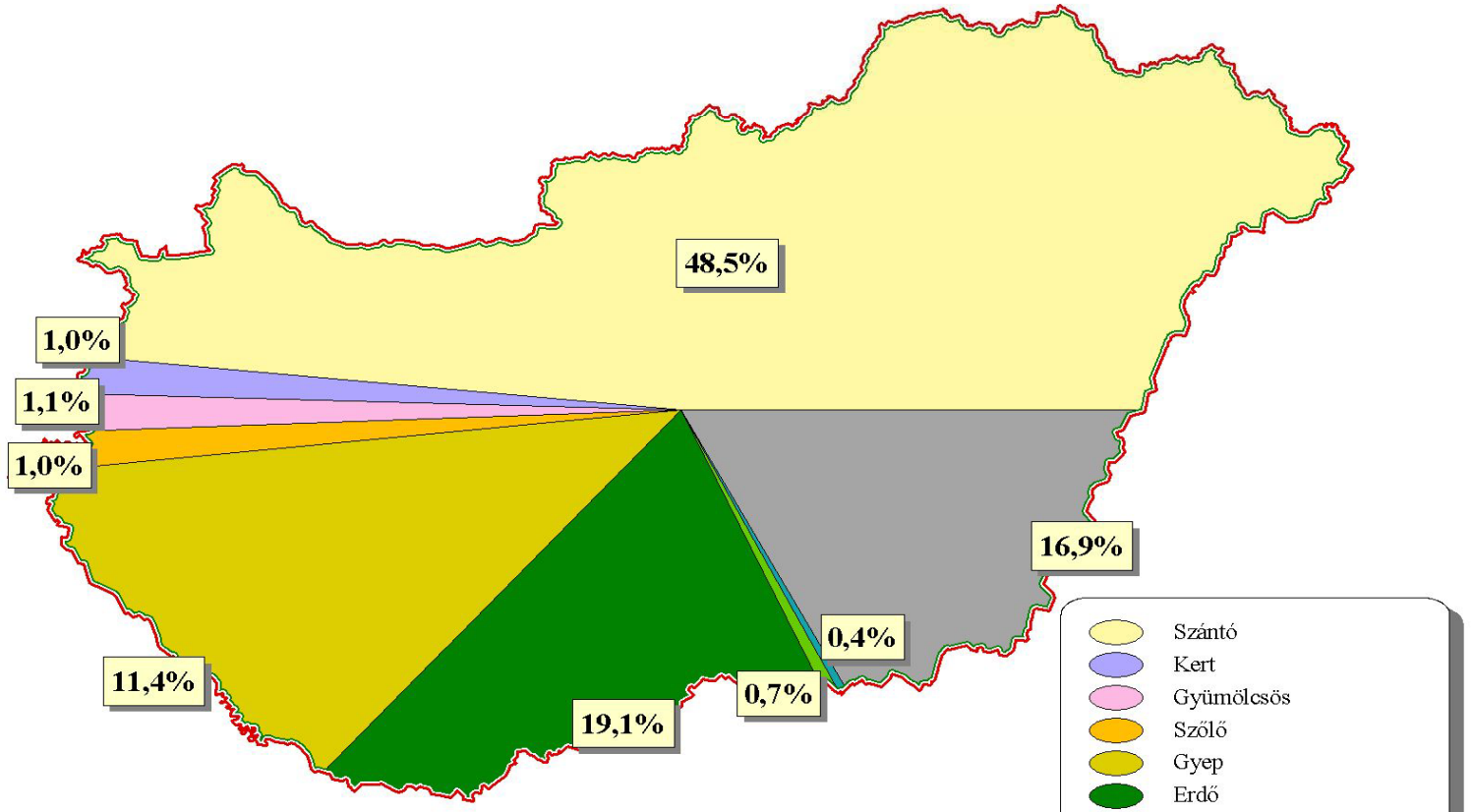


A, drought. B, nutrient stress. C, shallow arable layer.
D, extreme precipitation. E, permafrost. F, arable soil

The Landuse of Hungary
between 1931 and 1950 (in average)



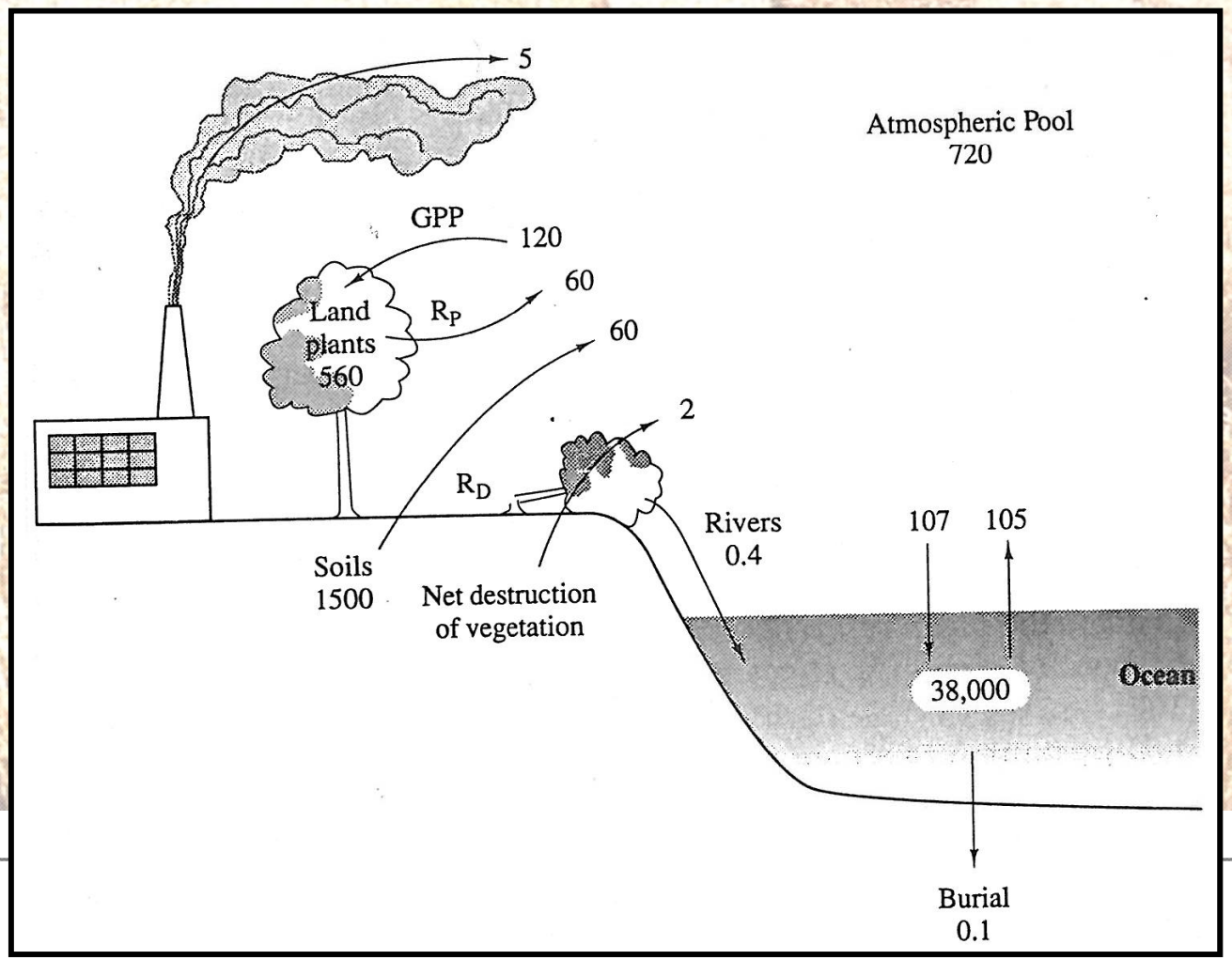
The Landuse of Hungary
in the year of 2003



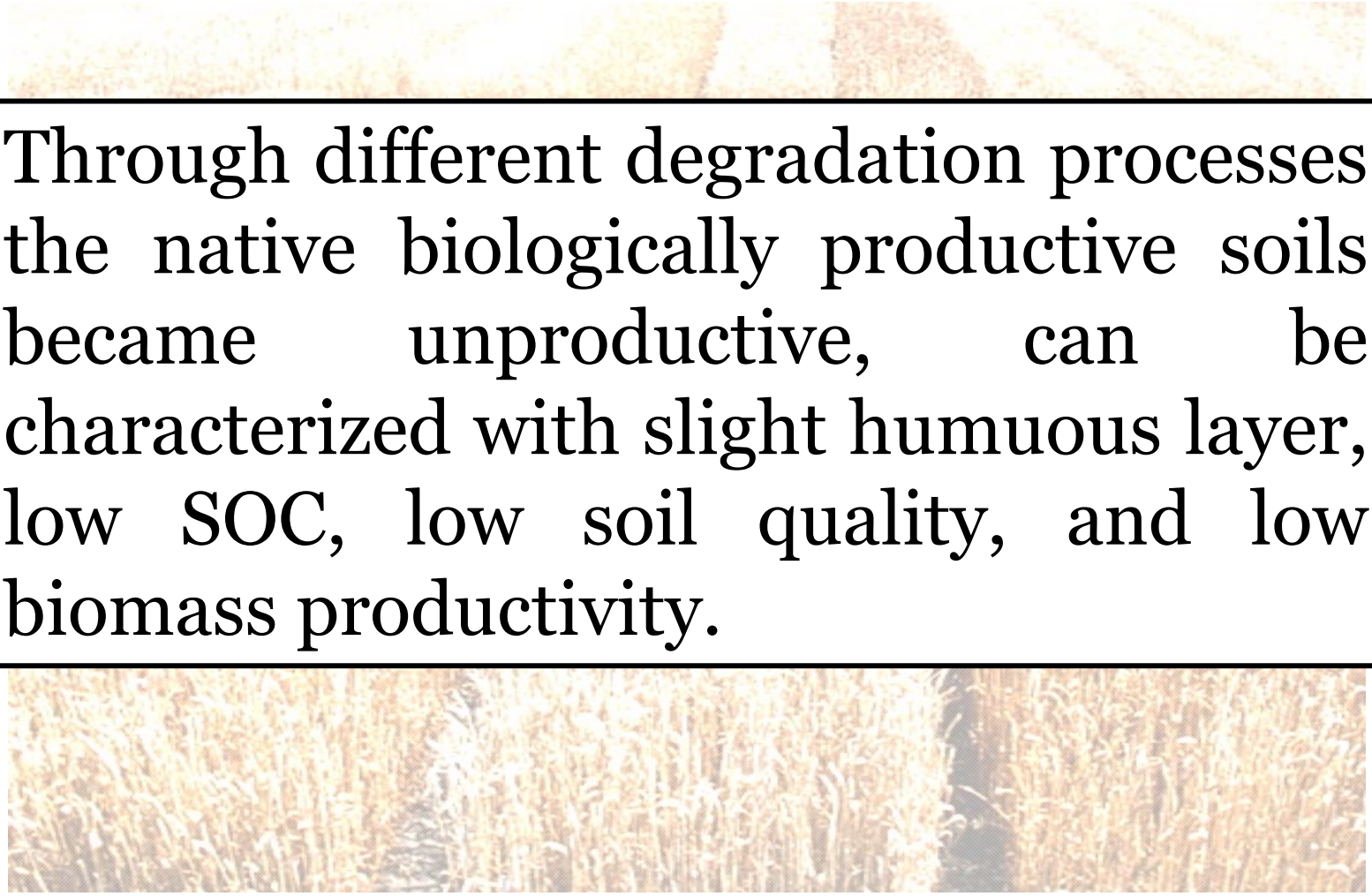
Changes in soil carbon are primarily effected by human activities (agriculture, forestry, etc.). The unproper management practices open way for declines in soil organic carbon content, including one of the most important degradation processes, the water and wind erosion.

The global Carbon cycle

All pools are expressed in units of 10^{15} gC and all annual fluxes in units of 10^{15} g C/yr

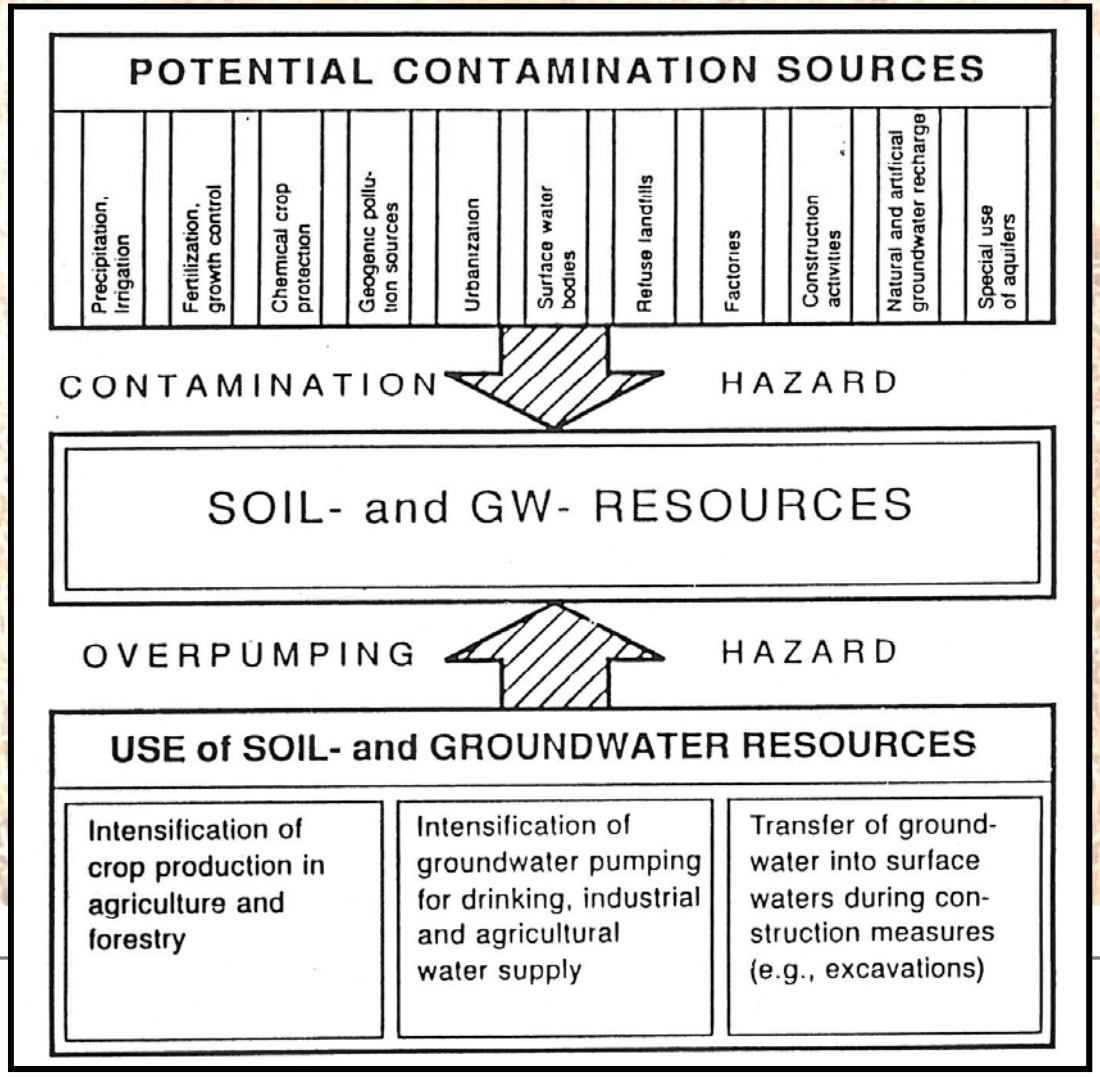


Through different degradation processes the native biologically productive soils became unproductive, can be characterized with slight humuous layer, low SOC, low soil quality, and low biomass productivity.

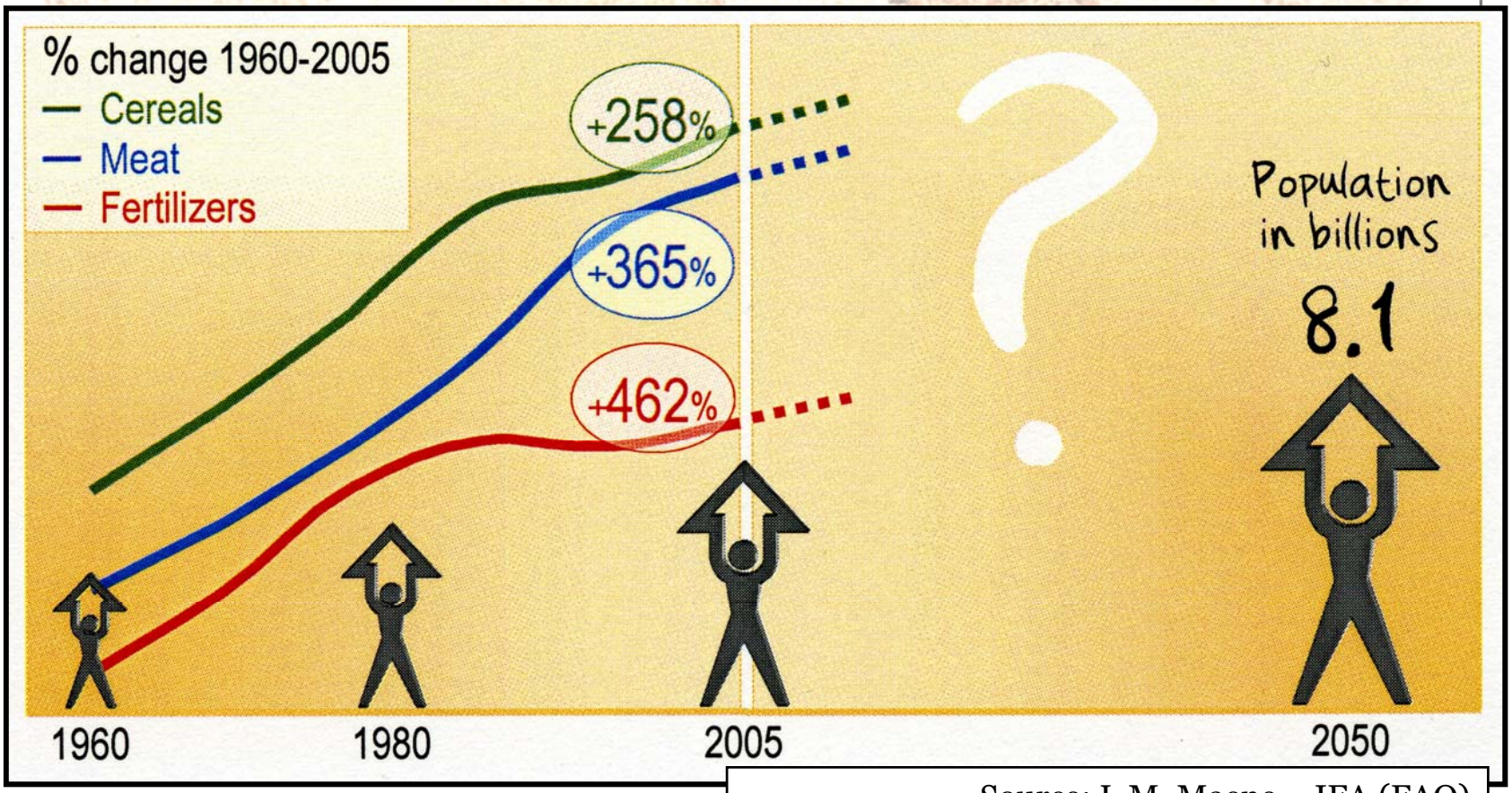


Soils represent a considerable part of the natural resources in the Central and Eastern European countries as well as in Hungary. Consequently, rational and sustainable land use and proper management practices ensuring normal soil functions have particular significance in national economy and soil conservation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

Pressure on soil- and groundwater resources caused by potential contamination sources and overuse



Feeding a Growing Population



Source: L.M. Maene – IFA (FAQ)

The evolution of yields in Europe
between the XIII and XIX century

Area	period	average yield (discarded cores compared)
England	1200-1249	3,7
France	1200 előtt	3,0
England	1250-1499	4,7
France	1300-1499	4,5
Germany, South-Skandinavia	1500-1699	4,2
East-Midle- and East-Europe	1550-1820	4,1

Source: Slicher van Bath (1963)

The Changes of Cultivated Lands of the World between 1850-1980 (1850 = 100 %)

South Asia	296%
South-East Asia	770%
Europe	96%
North America	409%
China	179%
Latin America	777%
Soviet Union	247%
Tropical Africa	388%
Total	279%

IIED-WRI, 1987

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.

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 t (Mg) (Láng, 1985)]

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. The animal unit dropped from 3 million down to 1.5 million in the past 10 years.

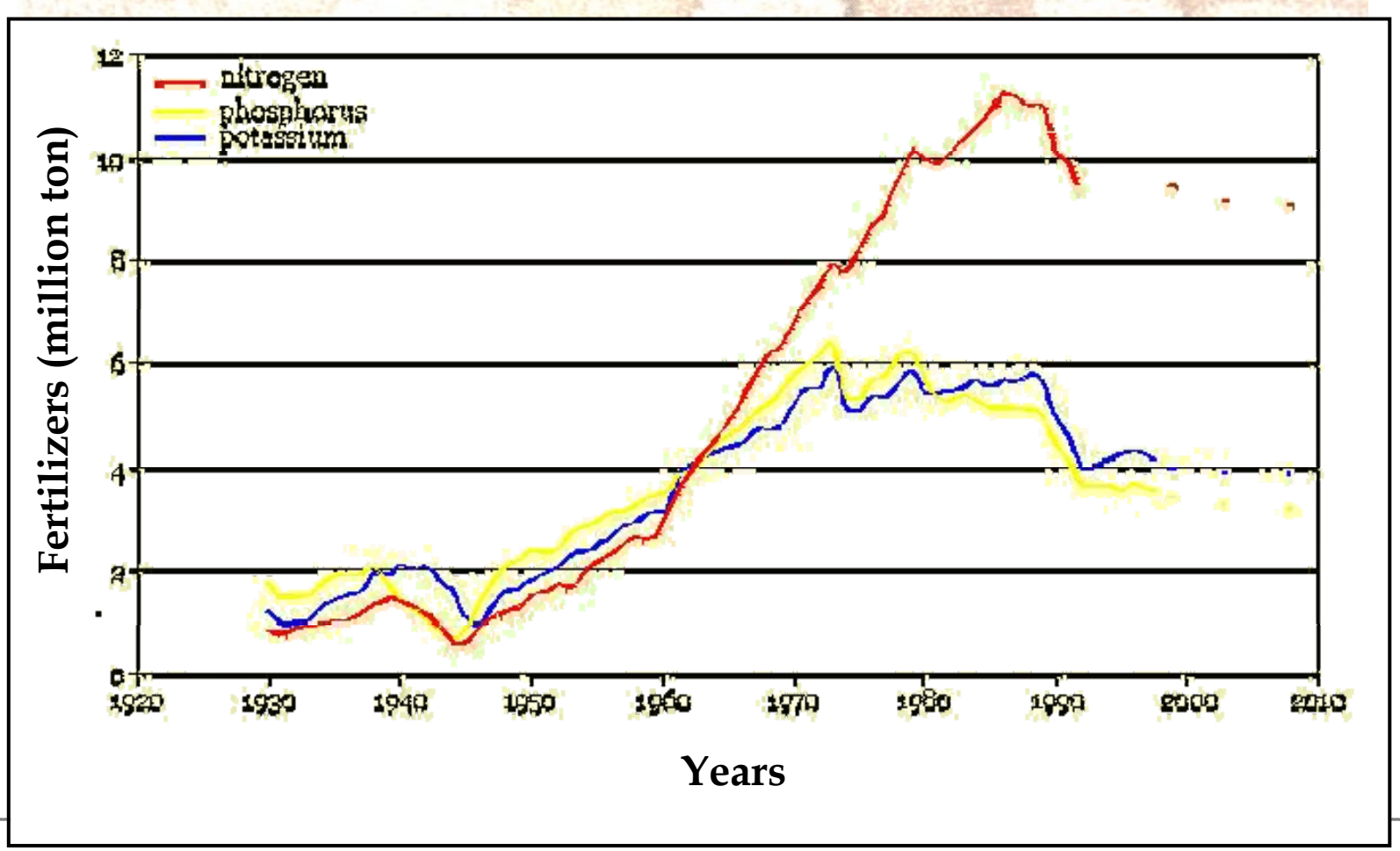
Use of mineral fertilizers in EU member states in 1998
Agricultural land area (kg ha^{-1} active ingredients)

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	**Total**
Austria	33	16	19	68
Belgium/Luxemburg	117	35	61	213
Denmark	107	19	37	163
Finland	81	26	36	143
France	83	37	47	167
Greece	59	26	13	98
Hollandia	188	34	33	255
Ireland	87	28	34	149
Great Britan	79	25	28	132
Germany	103	24	38	165
Italy	55	31	24	110
Portugal	29	13	12	54
Spain	35	18	16	69
Sweden	66	16	17	99
EU 15	**70**	**26**	**30**	**126**

EUROSTAT/FAO, 2000

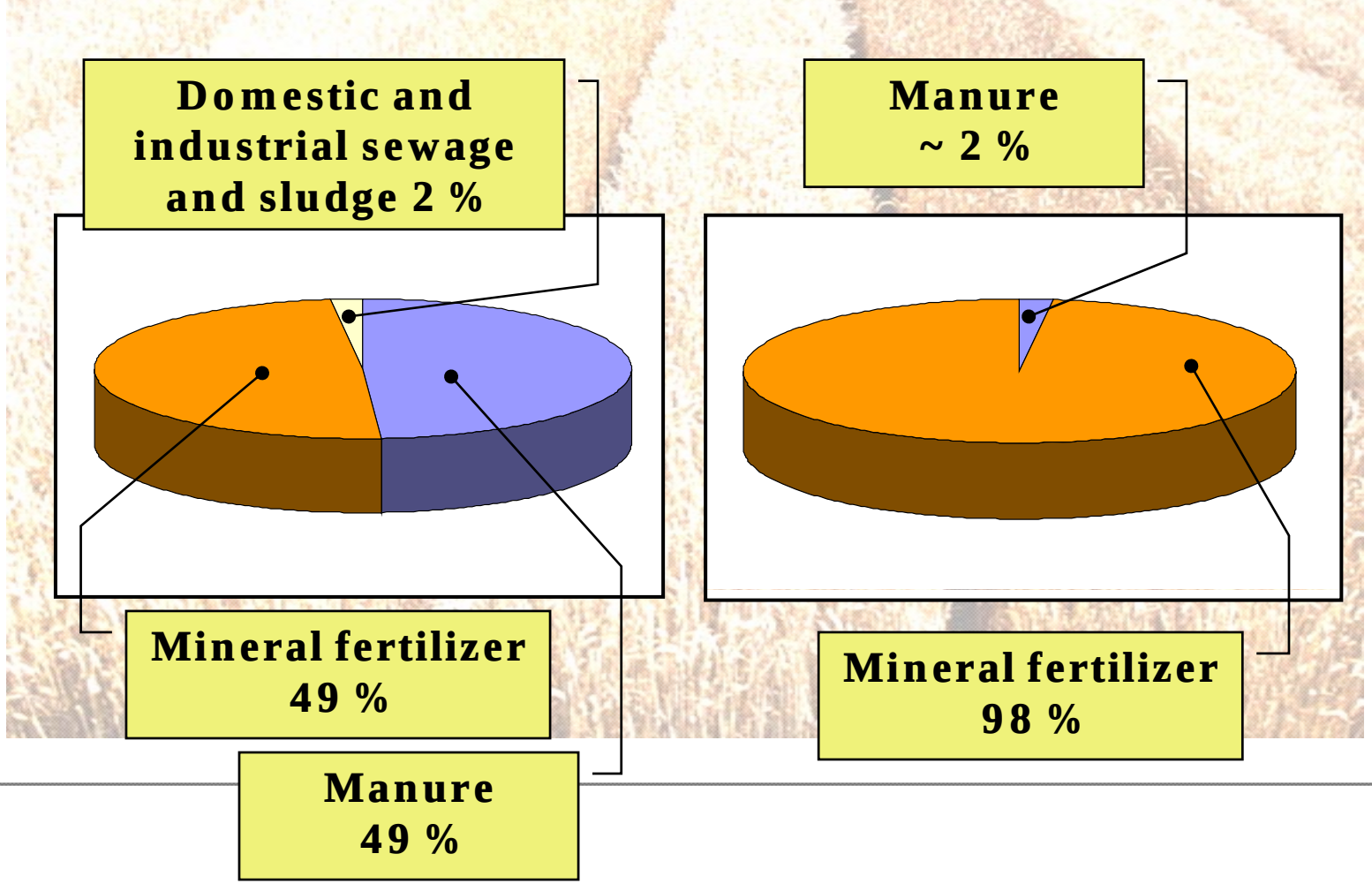
Fertilizer use in the European Union

European Fertilizer Manufacturers Association (EFMA)



The application of fertilizers in the EU countries and in Hungary

European Fertilizer Manufacturers Association (EFMA)



Development of the ratios of cultivation types from the total land area (%)

Based on Agricultural Statistical Almanac, 1991

Land use	Hungary	EU-15	OECD	World
Arable land, vegetable garden and fruit plantation	54.5	27.9	13.3	11.1
Grass	12.4	18.6	25.3	26
Agricultural area	66.9	46.5	38.6	37.1
Forestry	19.1	36.3	33.5	31.7
Area (1000 ha)	9 303	313 025	3 352 529	13 045 423

Forecast for mineral fertilizer application in the EU for the period 1999-2009

European Fertilizer Manufacturers Association (EFMA)

It is desirable to decrease:

N utilization	by 7%
P utilization	by 10%
K utilization	by 4%

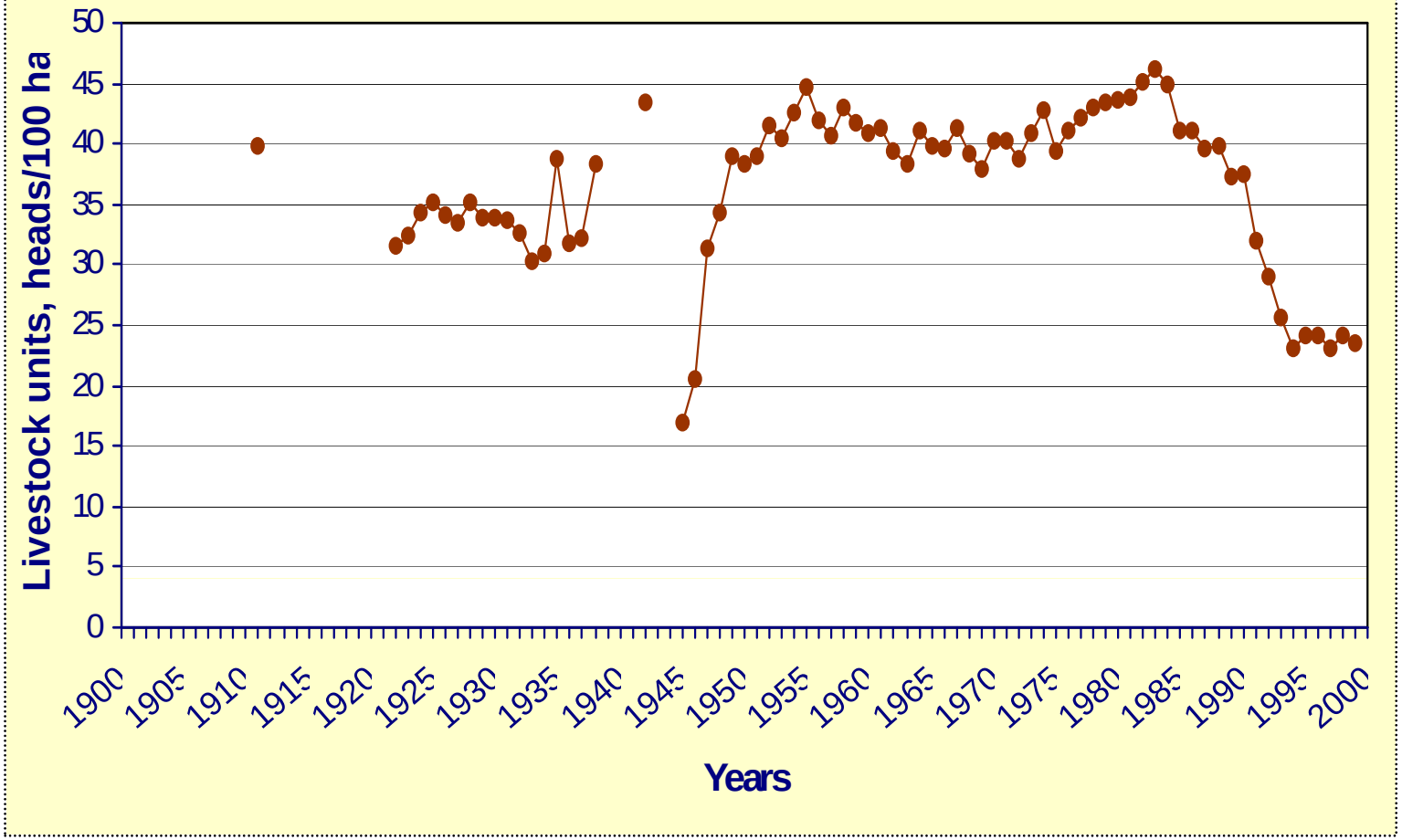
During the same period, however the wheat yields are intended to be increased from 5.8 t to 6.2 t/ha

Farmyard manure and fertilizer use in Hungary 1931-2001

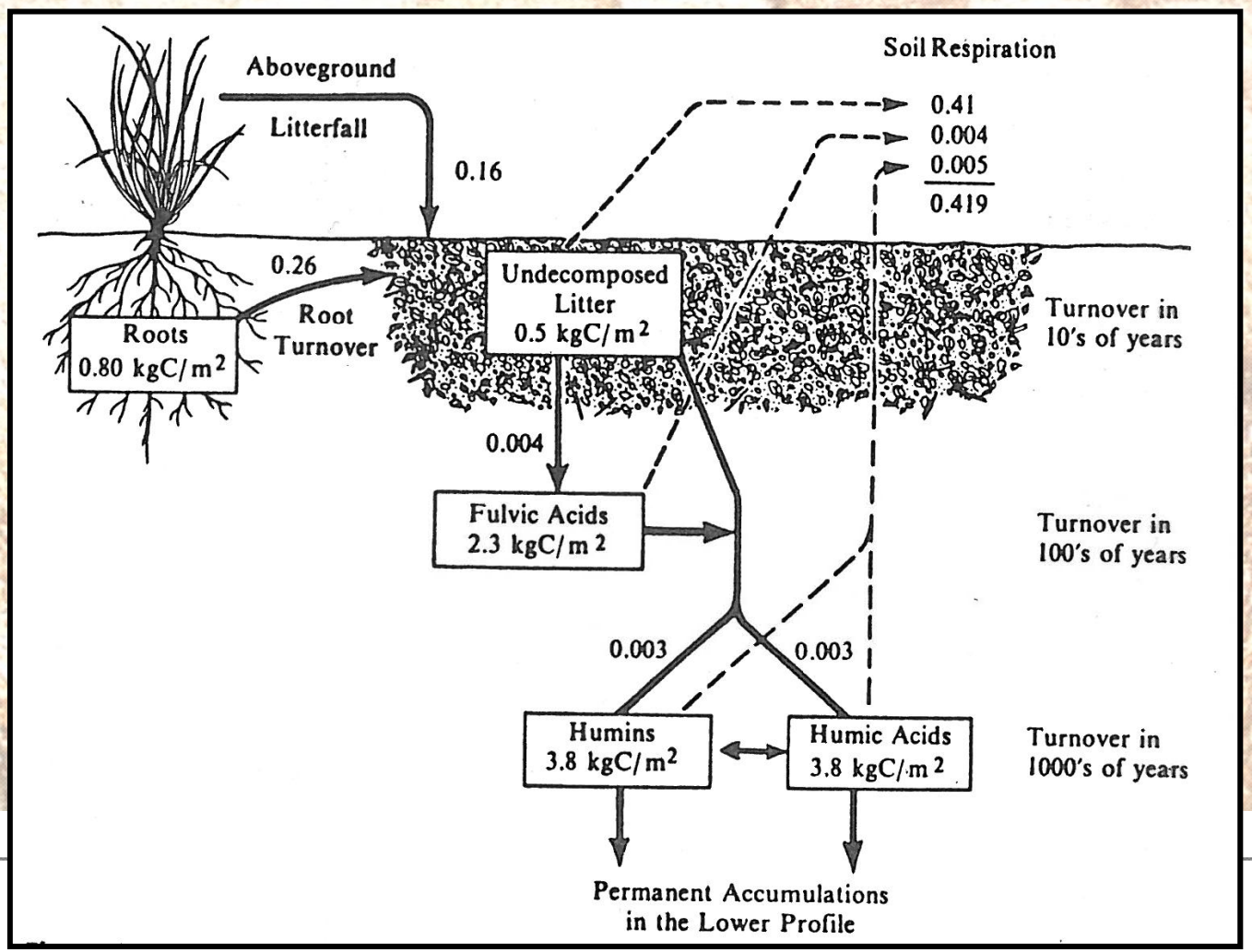
(Statistical Yearbooks for Agriculture, KSH)

Year	*Farmyard Manure, Million Mg year^{-1}*	*Fertilizer active ingredients, 1000 Mg year^{-1}*				*For arable lands, kg ha^{-1} year^{-1}*
		N	*P_2O_5*	*K_2O*	Total	
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

Volume of livestock production in Hungary 1901-2000



Turnower of litter and soil organic matter fractions in a grassland soil – Schlesinger, 1977



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, over weighted machineries caused disadvantageous soil compaction, too.

Analysing the possibilities of the land use change summarized that Hungary can achieve advantages if the special conditions of the different measures to be taken are precisely determined i.e. a land use zone system can be formed. The zonality characterizes both nature conservation and agriculture and can be grouped as follows:

- *Basic nature conservation zones – nature reserves, strictly protected areas,*
- *Buffer zone of nature conservation and protection zones for water reservoirs – limited land use, areas with priority for protection,*
- *Mixed zones (ecological and other extensive type farming systems) – land use limitations for protective purposes,*
- *Zones for agricultural production – best agro-ecological conditions for intensive land use,*
- *Non-cultivated land.*

Along this lines the available nature and land information were collected by Institute for Environmental and Landscape Management of the Gödöllő Agricultural University (IELM-GAU) and Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC-HAS). The databases were put into four groups (Ángyán et al., 1998a, b; Németh et al., 1998b):

Variables and databases used

•for evaluation and qualification of the suitability for agricultural production i.e. (i) terrain and soil databases, and (ii) climatic parameters,

•for evaluation of environmental sensitivity i.e. (i) flora and fauna, (ii) soil, and (iii) water,

•database of land use and land cover i.e. (i) CORINE land cover, and (ii) forest areas,

National Ecological Network (NECONET).

The position of Hungary's areas on a scale of environmental sensitivity and agricultural suitability (%)

Standard categories	*Total*	*Agricultural land*
< 60	0.42	0.04
61 – 70	1.09	0.10
71 – 80	2.06	0.56
81 – 90	5.84	2.53
91 – 100	11.78	7.96
101 – 110	18.99	16.76
111 – 120	18.33	19.44
121 – 130	15.08	17.91
131 – 140	12.33	15.62
141 – 150	10.18	13.65
151 – 160	3.88	5.42
> 160	0.01	0.01
Total:	*100.00*	*100.00*

Altogether 28 environmental datasets were classified and weighted according to their role in the determination of agricultural production and environmental sensitivity (the priority standards were given also by certain experts and institutes that developed the databases). The area of the observation unit (cell) was 1 hectare (100x100 m grids).

The values of environmental sensitivity (VES) and agricultural suitability (VAS) varied between 0 and 99, respectively. During the calculation the VES were subtracted from VAS in each cells, then 100 were added to the difference, i.e. (VAS-VES)+100. Using this formula the values varied between 0 and 198, where the values under 100 reflect to the determinant role of environmental sensitivity, the values above 100 of agricultural suitability. At the two extremes of this scale the well-determined areas (agricultural and environmental) can be found, while in the middle of the scale the mixed areas (areas with extensive production limited by environmental features) are situated.

Using the values of this estimation three scenarios (the differences were set up between the extensive and intensive agricultural zone, according to the extensive rank between 100 and 120, 100 and 125, and 100 and 130) were worked out in order to develop a land use zone system, the medium of them was calculating whit the following categories:

- **areas with a value less than 100 were ranked into the protection zone,**
- **areas with a value between 100 and 125 were ranked into the extensive agricultural zone, and**
- **areas with a value more than 125 were ranked into intensive agricultural zone.**

Suggestion for the development of a land-use zone system in three categories
(Second scenario)

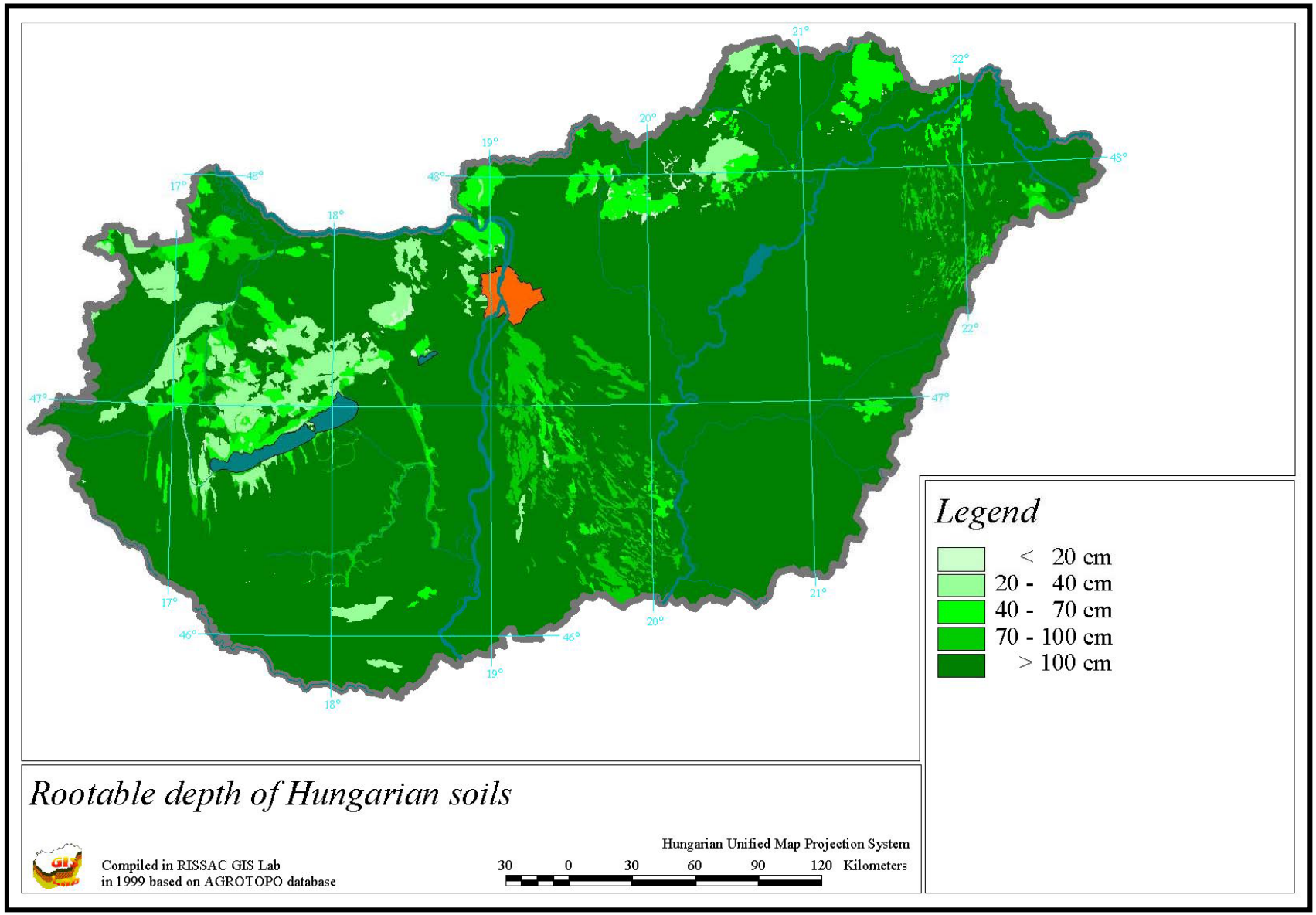
Land-use zone	*Total*	*Agricultural land*
	In percentage	
Protection zones (%)	10.38	3.74
Zones for extensive agricultural production (%)	41.15	35.88
Zones for intensive agricultural production (%)	48.47	60.37
Total:	*100.00*	*100.00*
	In hectare	
Protection zones (ha)	966 095	229 257
Zones for extensive agricultural production (ha)	3 827 954	2 196 834
Zones for intensive agricultural production (ha)	4 508 952	3 695 909
Total:	*9 303 000*	*6 122 000*

According to this scenario it can be stated that 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.

Depth of the Soil

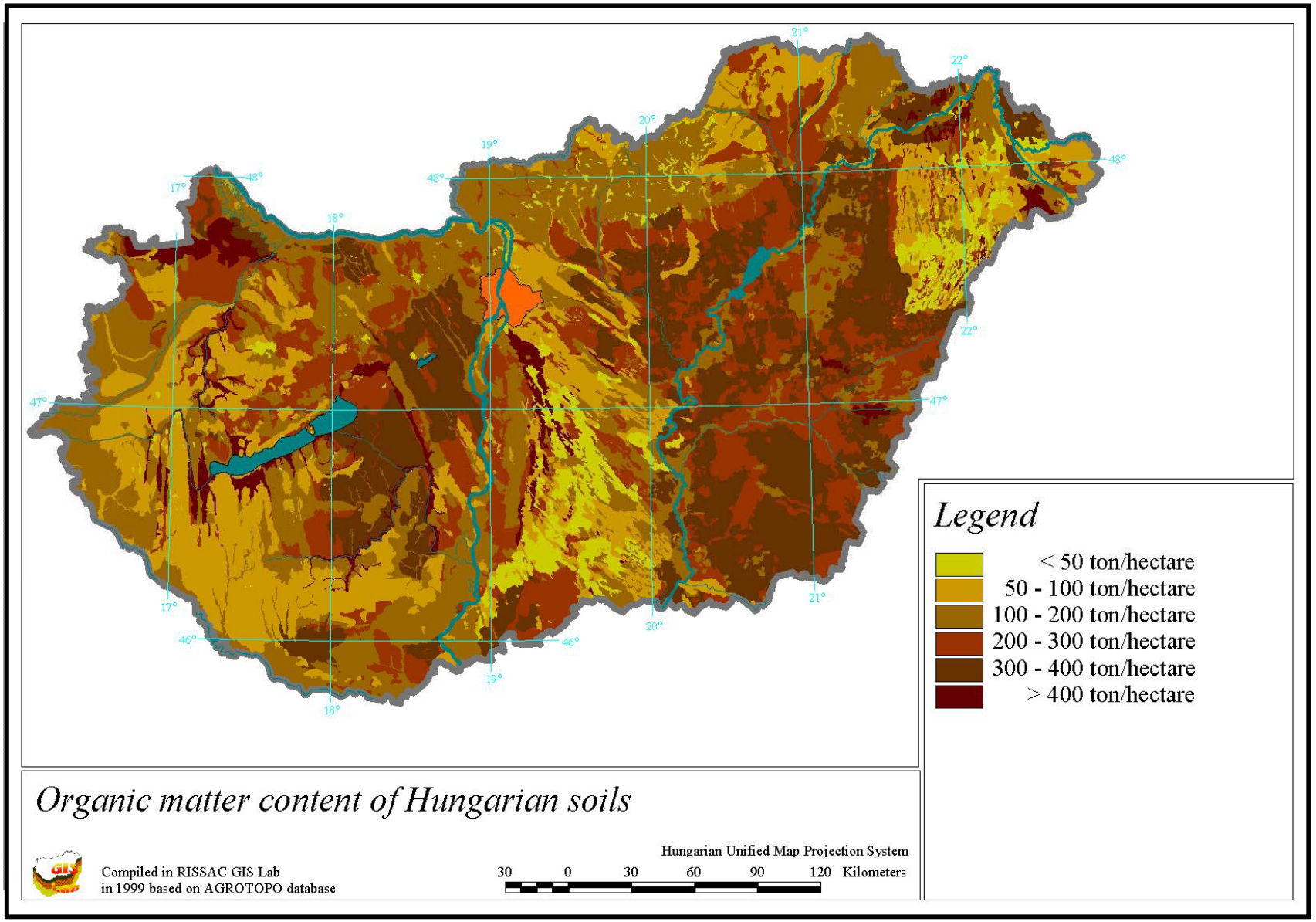
The majority (86%) of Hungarian soils is more than 1.0 m deep. Soil depth is between 0.7 and 1.0 m in 4%, between 0.4 and 0.7 m in 5%, and between 0.2 and 0.4 m in 5% of Hungarian soils (Várallyay et al., 1980). Both soil depth and soil organic matter content can strongly determine the amount of organic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


Legend
< 20 cm
20 - 40 cm
40 - 70 cm
70 - 100 cm
> 100 cm
Rootable depth of Hungarian soils
Compiled in RISSAC GIS Lab
in 1999 based on AGROTOPO database
Hungarian Unified Map Projection System
30 0 30 60 90 120 Kilometers

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, resp.


Legend
< 50 ton/hectare
50 - 100 ton/hectare
100 - 200 ton/hectare
200 - 300 ton/hectare
300 - 400 ton/hectare
> 400 ton/hectare
Organic matter content of Hungarian soils
Compiled in RISSAC GIS Lab
in 1999 based on AGROTOPO database
Hungarian Unified Map Projection System
30 0 30 60 90 120 Kilometers

Organic Matter and SOC Resource of Hungary

The distribution of Hungarian soils according to their soil organic matter resource groups is shown in Figure 2. 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.

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 t (Mg) OM and more than 639 million t (Mg) SOC is the reserves of the Hungarian soils in the given thickness. App. 53% of the OM and SOC can be found in the arable land.

Distribution of Organic Carbon in Soils of Hungary

Table 4 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	36,556,600	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

Distribution of Organic Carbon on Arable Land of Hungary

Table 5 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

The predicted change in the land use system give a possibility for calculating the OM and SOC according to the new distribution. Next slide shows that how this change will effects the distribution of the soils in different land use categories, while Table 7 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.

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

Table 6 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

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

Table 7 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

Tamás Németh– Carbon Mining ...

Thank you for your attention!