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Soil Management and Environmental Relationships in Central and Eastern Europe

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Introduction

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

There are considerable differences among these countries (Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Yugoslavia and the European post-Soviet republics) in their physiographic conditions, soil resources, agro-ecological potential, socio-economic circumstances; in the role of agriculture in their national economy; rate, type and way of collectivization during the centrally-directed socialist period (Table 1); state, effectivity and efficiency of the economy restructuring, rate of (re)privatization during the last years and at present.

In spite of these differences there were many similarities in their land use policies and soil management practices during the last 60 years. The primary aim of agricultural production is to produce good-quality products with low costs and without any environmental side-effects: unfavourable changes in the given area and in its surroundings; at the present time or in the near- and far future. The relative importance of these partial objectives (high quantity, good quality, low costs, environmental impacts) varies and changes considerably in each of these countries, depending on their socio-economic conditions, historical traditions and political decisions.

The present paper is based mainly on Hungarian facts and impact analyses, taking into consideration the experiences of other countries in the region (without the post-Soviet republics), as well.

Table 1

Some statistical data on the importance of agriculture in the national economy of "East-European" countries

	Bulgaria	**Czechoslovakia**	**Hungary**	**Poland**	**Romania**	**Yugoslavia**
Part of population working in agriculture, %	13.2	10.0	11.8	22.2	22.1	23.6
Yearly increase of agricultural production, %						
1980-1988.	-0.1	2.9	1.4	1.5	2.2	0.5
1985-1991.	-2.1	0.8	1.0	0.7	-3.3	0.4
Average yield of main crops						
winter wheat	4.0	*5.2*	5.1	**3.7**	3.8	3.8
winter barley	*6.1*	4.3	4.4	3.3	5.1	**2.7**
maize (corn)	**3.5**	5.7	5.9	-	*6.2*	4.0
sugarbeet	**20.7**	35.3	*40.0*	33.6	25.4	37.8
sunflower	**1.1**	2.2	2.0	-	*2.5*	2.1
potatoes	9.2	*19.6*	17.4	18.8	16.8	**7.4**
Number of inhabitants per 100 hectare agricultural land	146	232	160	201	157	168
Fertilizer consumption (total), kg/ha agricultural land (without grasslands)						
1987	180	303	222	260	130	?
1988	222	314	245	268	133	?
1989	195	314	219	231	133	?
1990	173	255	104	127	107	?
Rate of collectivization*	f	f	f	p	f	m

* f = fully collective; p = fully private; m = mixed

Periods of Agricultural Development in Central and Eastern Europe

Four main periods can be distinguished in the last 60-year history of agricultural development, land use policy and soil management practices in these countries. The main characteristics of these periods are summarized below on the example of Hungary (VÁRALLYAY, 1991b, 1993b, 1994).

(1)

After World War II agriculture was in a destroyed and exhausted condition irrespective of its previous level, which was rather heterogeneous. The polarized pre-War ownership-structure (many small-holdings (1-2 hectares); few very large latifundiums (several thousand hectares) was almost equalized with the *"land reform";* most of the land was distributed among the agrarian proletars and small farmers. This period can be characterized by *small-scale private farming* (1-5 hectares) with low inputs, and low yields.

(2)

The *first* and radically pressed *collectivization* program was completed in the early 50's. However, most of the newly created co-operative farms did not survive the 1956 revolution and their lands (which were officially always owned by the members of the co-operative) were distributed again.

The *second collectivization* program was "voluntary" and it was pressed "only" by very strict economy regulations, giving a chance for efficient production practically only for co-operatives, without any other alternatives. It was completed in the early 60's. At that time about 25% of the land was owned and used by the state farms, 65% was used by the co-operatives (and still owned - theoretically - by the members of the co-operatives) and only less than 10% was owned and used privately.

10 years after full collectivization a *spectacular agricultural development* was witnessed. The centrally directed communist system wanted to prove that the large-scale collective ("social") sector can produce more than the small-scale private sector. The central directives and the economy regulations were elaborated and introduced accordingly:

- well-equipped soil laboratories were established (with the necessary or - in many cases - overestimated capacities for soil, water and plant analyses);
- in the newly established large state farms and co-operative farms well-educated agronomists represented the potential guarantee for the proper practical application of these soil information;
- in the new Land Law (and related documents) the duties and responsibilities of land owners, land users (farming units) had been listed and the necessary organization - coordination - control machinery for soil- and water conservation practices were financed practically fully from the central state budget;
- the economy regulations (high rate state subsidy on fertilizers and other chemicals, and on the main soil reclamation practices, such as amelioration of acid, salt-affected and sandy soils, erosion control, irrigation and drainage; long-term credits; price policy; etc.), as well as the evaluation of farming units and their agronomists on the basis of obtained yields or even on their fertilizer and pesticide consumption(!?) stimulated high yields and high inputs, irrespective of their efficiency, their impacts on quality and their environmental consequences.

Table 2

Average yields of the main crops in Hungary (tons/hectare)

Year	Wheat	Maize for corn	Sugar-beet	Sun-flower	Potatoes
1951-1955	1.46	2.06	18.69	1.07	8.77
1956-1960	1.50	2.31	21.20	1.10	10.46
1961-1965	1.86	2.61	24.64	0.96	7.91
1966-1970	2.43	3.23	32.52	1.11	10.45
1971-1975	3.32	4.17	33.00	1.24	11.74
1976-1980	4.06	4.85	33.64	1.61	14.16
1981-1985	4.63	6.11	38.90	1.98	18.23
1986-1990	4.88	5.63	38.40	2.03	17.74
1991	5.19	6.71	37.16	2.07	15.76

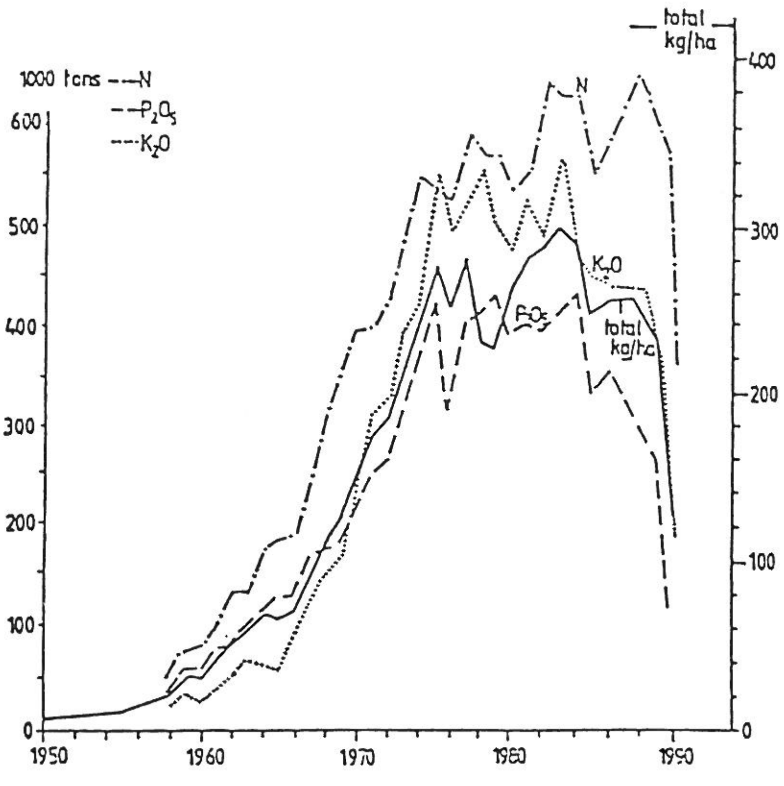

Figure 1
Mineral fertilizer application in Hungary

The efforts proved to be successful at the beginning. Yields of the main agricultural crops increased sharply, as it can be seen in Table 2. This was mainly due to four reasons:

- new, intensive, high yielding crop varieties;
- adequate nutrient supply of crops (sharply increasing rate of mineral fertilizer application: Fig. 1.)
- integrated pest management;
- full mechanization.

(3)

After the rather quick and spectacular agricultural development serious problems appeared and became increasingly threatening.

The over-emphasized, preferred and even pressed gianto-maniac *"global quantity" concept* of agricultural production (in which good or efficient is equal with big, large, high!) hide the problems arising in other aspects: quality, efficiency, economy and environmental side-effects. The quantity-oriented economy regulation system (credit, subsidy and price policy, etc.) did not stimulate neither for rational input reduction, nor for economic quality production without (or with minimum) environmental deteriorations. The concealed ownership-feeling lead to a harmful short-term thinking, to the exploitation of soil resources, decreasing care of soil quality and reduced attention to the prevention of soil degradation processes (FRENCH, 1991; VÁRALLYAY, 1994).

Some of the main problems were as follows:

- unfavourable changes in the land use and cropping pattern (the arable lands - including the large-scale corn monoculture - went up to and on sloping terrains to the detriment of forests and grasslands);
- too large farming units (several thousand hectares) → limited flexibility;
- too large agricultural fields (100-150 hectares) → increasing heterogeneity; even on hilly surfaces sacrificing the previous windbreakers, forest shelterbelts, soil conservation establishments → increasing hazard and rate of water- and wind erosion (STEFANOVITS & VÁRALLYAY, 1992; VÁRALLYAY, 1992a);
- overconcentrated livestock production, huge "livestock factories": evenly distributed farmyard manure → liquid manure problem (VÁRALLYAY, 1990a);
- heavy machinery, combined tillage operations, over-tillage → serious soil structure deterioration (compaction, surface sealing) (VÁRALLYAY & LESZTÁK, 1990);
- serious problems in fertilizer application (non-adequate distribution; polarization in fertilizer application → simultaneous hazard of underdosage and overdosage; environmental side-effects).

The possibilities and limitations of Hungarian agricultural production had been evaluated and thoroughly analysed in numerous scientific documents, e.g. in the final report of the national program for the assessment of the agro-ecological potential of Hungary. All these evaluations called attention to the above-mentioned problems and their conclusions and recommendations were formulated for and included in various laws, high-level Party and Government decisions, and related documents. However, these regulations were not controlled systematically, consequently, they were not followed seriously, especially if the written restrictions limited the "quantity production" plans. The economy regulations stimulated only for this and create, in many cases, "anti-interest" against quality, input reduction and environment protection (VÁRALLYAY, 1991b, 1993b, 1994).

(4)

Economy restructuring. After the favourable political changes in the region in the late 80's not only had the communist ideology and economy collapsed, but the quantity-oriented gianto-maniac concept of "industrialized" (high input) agricultural production changed radically, due to the following facts:

- the internal food markets became practically saturated and the forecasted intensive export growth failed (→ stabilized or even decreasing quantity requirements);
- sharply increasing quality requirements, reaching the European standards;
- radically increasing significance of efficiency and economy (→ necessity of input rationalization);
- increasing hazard of environmental side-effects: pollution of air, water and soil; increasing rate of soil degradation processes.

In the new concept - instead of the global quantity aspect - quality (exportability) efficiency (based on a real and exact cost-benefit evaluation) and environmental consequences became more and more important.

Environmental Aspects of Land Use and Cropping Pattern

Changes in Hungary's *land use* and cropping patterns between 1950 and 1988 are shown in Table 3 (LÁNG & CSETE, 1992; VÁRALLYAY, 1990b). As it can be seen, the following changes are evident:

a) The acreage of *uncultivated land* (e.g. settlements, roads, railways, open-pit mines, industrial enterprises, water ways, etc.) increased from 7.8% to 11.6%. This means the loss of about 335,000 ha of agricultural land, which area is equal to the size of a small Hungarian county (administrative region). The normal social development requires about 6,000-7,000 ha per year urban, rural and infrastructure which has to be concentrated to the places of lower productivity, if it is acceptable from other aspects as well.

b) The loss of *arable land* amounted to nearly 790,000 ha, dropping from 59.3% to 50.6%. *Vineyards* also decreased from 2.5% to 1.5% (with about

Table 3

Land use and cropping patterns in Hungary

Land use	1950	1991	Main crops	1951-1960	1991
Arable land	59.3	50.6	Wheat and rye	32.2	27.0
Gardens	1.0	3.7	Barley	8.6	7.8
Orchards	0.6	1.0	Maize	23.4	24.0
Vineyards	2.5	1.5	Pulses	1.4	2.2
Grasslands	15.9	12.6	Sugarbeet	2.1	3.5
Forests	12.5	18.3	Sunflower	2.8	8.4
Reeds	0.3	0.4	Potatoes	4.3	1.0
Fishponds	0.1	0.3	Silage maize	1.7	5.3
Uncultivated areas	7.8	11.6	Alfalfa	4.6	6.6
	100.0	100.0	Vegetables	2.1	2.4
			Other crops	16.8	11.8
				100.0	100.0
Expressed as percentage of the total 93,032 km^2 surface of Hungary			Expressed as percentage of the total arable land		

90,000 ha), in spite of the efforts in the reconstruction programme of traditional vine producing areas.

c) *Grasslands* diminished from 15.9% to 12.9%, amounting to 240,000 ha. In Hungary the majority of grasslands is on land sites with low productivity (salt-affected, sandy and shallow soils, river floodplains, waterlogged areas, etc.) and in most of the cases represent an extensive land use with low animal carrying capacity (pastures) and low (1.0-1.5 t/ha) hay yield.

d) There has been a considerable increase in the amount of land used for gardens (1.0-3.7%), orchards (0.6-1.0%) and forests (12.5-18.3%).

- In the seventies large-scale *orchards* (mainly applied plantations) were established because of the existing and promising fruit export possibilities. Later on, this rapid increase proved to be irrational (due to the increasing costs of chemical pest control, high rate fertilization, harvest, storage and processing, and because of the decreasing export market for fruits - partly due to the quality and storage problems caused by high-rate fertilization) and large plantations were liquidated, even in the Nyírség region (NE Hungary) where the poor, acidic sandy soils with low fertility represent a low potential for arable crop production.
- *Afforestation* was implemented mostly for recreation, environment and landscape protection, as well as for soil conservation on hilly areas with complex slopes, on deteriorated lands (open mines, eroded slopes, floodplains, etc.) and on soils with a low agricultural potential (sand hills, shallow soils, etc.). Consequently, this tendency (in spite of the very low,

sometimes negligible wood production) can be evaluated as a positive change in the land use pattern.

- Considerable territories were divided into small holdings and used as *gardens*, especially near towns, main roads, recreation places along rivers and lakes.

e) The *cropping pattern* indicates stability (Table 3) with the exception of the radical reduction of potato production (from 4.3 to 1.0%) and a slight decrease of barley (8.6 - 7.8%) on the one hand, and the sharp increase of sunflower (2.8 - 8.4%) and silage maize (1.7 - 5.3%) production on the other hand.

A great part of the arable lands (14.5+81.0%), forests (68.9+30.6%), grasslands (17.8+77.7%), and even orchards (24.4+58.9%) and vineyards (14.7+ 54.5%) were owned by *state farms* and used by *cooperative farms,* respectively. Their large size (5,000 and 3,500 ha, as an average, resp.) and their large scale, high input agricultural production (irrationally large, consequently heterogeneous agricultural fields with a size of 50-70, sometimes 100-120 ha; irrational, non- or slightly flexible land use and cropping pattern; monocultures; mechanization with heavy machinery; high-rate application of chemicals, such as mineral fertilizers, pesticides, growth-regulators; etc.) and misguided soil management (improper tillage operations, fertilization and irrigation practices, etc.) in many cases result in environmental side-effects, such as: various soil degradation processes, soil toxicity, pollution of surface and sub-surface waters, etc.

In the smaller fields of the private sector, subsidiary farms or household farming plots in the co-operatives, more opportunity was provided for a more rational, microscale utilization of the land, with higher flexibility.

Realizing the high spatial and temporal yield variability of the main crops, a National Programme was initiated by the Hungarian Academy of Sciences in 1979 for the *"Assessment of the Agro-Ecological Potential of Hungary"* (LÁNG et al., 1983; LÁNG & CSETE, 1992). In spite of the fact that its results, conclusions and recommendations were presented to the policy-makers and the tasks were formulated in numerous official documents little initiative was taken for their implementation and the lack of flexibility in the state-controlled economy regulations (prices, subsidies, credits, taxes, etc.) does not stimulate rational land use practices. On the contrary, sometimes it prevents it. E.g. the economic "pressure" for corn production in the cooler and more humid NE hilly lands (→ low yield, high costs; → high risk of water erosion) instead of soil protective grassland farming.

Limiting Factors of Soil Fertility and Soil Degradation Processes

A large amount of soil information is available in Hungary, as a result of long-term observations, various soil survey, analyses and mapping activities on national (1:500,000), regional (1:100,000), farm (1:10,000-1:25,000) and field level (1:5,000-1:10,000) during the last sixty years. Thematic soil maps are available for the whole country in the scale of 1:25,000 and for 70% of the agricultural area in the scale of 1:10,000 (Hungarian National Atlas, 1989; KUMMERT et al., 1989; VÁRALLYAY, 1988b, 1989b, 1993a). The 1:100,000 scale map of the most important soil properties was prepared within the national programme on the "Assessment of the agro-ecological potential of Hungary in 1978-1981" (VÁRALLYAY, 1993a).

The necessity and rationality of the *reclamation of soils* with limited fertility depends on economical (cost-benefit analysis) and ecological considerations. The radical amelioration of salt-affected soils, sandy soils or peatlands requires expensive complex measures, therefore it is not economic. At the same time the saline lakes and soils, wetlands and sand regions are - in many cases - protected ecosystems, habitats of protected plants and animals, consequently, represent special environmental value. These areas must be kept in "original" condition, their reclamation is not advisable (although this was pressed sometimes in the last decades). On the contrary, the improvement of soils with moderate limitations (e.g. liming of acid soils, loosening of compacted soils, etc.) can be an efficient and economic tool for agricultural development.

In the Central and Eastern European countries the large extension of various undesirable soil degradation processes represents serious biomass production constraints and environmental problems both in the directly affected territories and in their surroundings. This is clearly shown on the UNEP/ISRIC GLASOD (Global Assessment of Human-induced Soil Degradation) Map.

Soil degradation is *not* an unavoidable consequence of intensive (but rational!) agricultural production and social development! Most of the degradation processes and their unfavourable consequences can be prevented, eliminated or at least moderated. But it needs permanent actions and widely adopted proper soil- (and water) conservation technologies. The key words in this system are: *prognosis* and *prevention*. This can be rationally based on a comprehensive:

- sensitivity analysis (evaluating the susceptibility/vulnerability of soils against various soil degradations) (VÁRALLYAY, 1991a);
- impact analysis (evaluating the "positive" and "negative" impacts of various human activities).

The main causes (natural factors and human activities) of various soil degradation processes in the Central and Eastern European region are summarized in Tables 4, 5, 6 and 7, including the main possibilities of their efficient control.

Table 4

Soil erosion

Main reasons		Possibilities for control
Natural factors	**Human activities**	
	a) water erosion	
Strong surface runoff - heavy rainfall - steep slope - uncovered surface (lack of permanent dense vegetation) - limited infiltration	- irrational land use, cropping pattern (deforestation, overgrazing, etc.) - too large farming plots - inadequate agriculture	Reduction of surface runoff - reduction of slopes (levelling; terracing: contour ploughing) - establishment of permanent and dense plant cover (rational land use, cropping pattern) - help infiltration (deep-loosening) - surface drainage
Erodability of soil		Reduction of soil erodability (mulching; chemical reclamation; soil conditioning)
		Proper infrastructure (layout of roads, canals; optimum-size plots)
	b) wind erosion	
- strong wind - lack of permanent dense vegetation cover - dry and loose (non-stable) soil surface - lack of good soil structure	- as in part (a) - lack of wind-breaks	- forest shelter belts (wind-breaks) - establishment of permanent and dense plant cover (rational land use, cropping pattern, crop rotation) - stable soil surface (surface stabilization; irrigation; soil conditioning)

Table 5

Development of extreme soil reaction

Main reasons		Possibilities for control
Natural factors	**Human activities**	
	a) acidification	
- acidic (non-calcareous) parent material - decomposition of plant residues (leading to CO_2, acidic substances - leaching (high precipitation + low water retention)	- acidic depositions, air pollution (urban, industrial, etc.) - improper fertilizer application (form, dosage)	- rational (adequate) fertilization system (form; dosage; Ca fertilizers) - chemical amendments (lime; alkaline substances) - air pollution control
	b) salinization/alkalization	
- salt accumulation from local weathering surface } waters subsurface } waters seepage } waters - improper drainage vertical horizontal - migration of soil solution	- salt accumulation from: irrigation water groundwater with rising water table due to human activities (unlined canals and reservoirs; poor irrigation practice; improper drainage) applied chemicals (fertilizers, amendments) - alkalization due to applied chemicals	- prevention of salt accumulation good quality irrigation water (on the field) groundwater control (horizontal drainage) - lowering of } groundwater table - prevention of rise of } groundwater table saline seep control - amelioration reduction of alkalinity (amendments) $Na^+ \rightarrow Ca^{2+}$ ion exchange - Ca-containing amendments (solubility) - mobilization of soil-Ca acids, acidic materials) leaching (leaching requirements + vertical drainage /deep ploughing horizontal drainage

Table 6

Physical degradation of soils

Main reasons		Possibilities for control
Natural factors	Human activities	
	a) structural damage, compaction	
- lack of structure-forming and stabilizing agents: - inorganic and organic colloids - cementing agents - biological components (roots; microbial and earthworm activity) - natural structure destruction - heavy raining - surface runoff, flood, water-logging - chemical properties (e.g. alkalinity, etc.)	- mechanization (heavy machinery; combined operations; overtillage - tillage in improper moisture conditions - poor moisture-control practice - irrigation (intensity; method) - drainage -unfavourable changes in organic matter regime (chemical soil properties; biological degradation; improper recycling; lack of organic fertilizers)	- proper agrotechnics - tillage (time; moisture content; accuracy, "quality" and number of operations) ← technical background - cropping pattern, crop rotation - organic matter recycling - irrigation (moisture regime control) - chemical amelioration (improvement of acid- and salt-affected soils, sands, etc.) - soil conditioning
	b) extreme moisture regime	
- extreme climate - too high or too low precipitation - uneven territorial and time distribution - extreme soil texture - poor soil structure - shallow depth (solid rock; pans; cemented or compacted layers on or near to the soil surface) - heavy surface runoff from the area → drought to the area → overmoistening, waterlogging	- inadequate - land use - watershed management - improper agrotechnics structural damage (a) surface crust plough pan	Soil moisture control: improvement of water-use efficiency - amelioration - control of water (4a) and wind (4b) erosion - soil reclamation (acidic, salt-affected and sandy soils, etc.) - deep loosening - improvement and stabilization of soil structure (6a) - irrigation - drainage (surface and subsurface)

Table 7

Other soil degradation processes

Main reasons	Consequences	Possibilities for Control
	a) biological degradation	
- See Tables 4, 5, 6 - intensive use of chemicals - fertilizers - pesticides - growth-regulators - other chemicals - soil pollution	- undesirable changes in microbial populations total number; species spectra; activity, etc.) - undesirable changes in earthworm activities - desirable → undesirable changes in the biological transformation processes	- see Tables 4, 5, 6 → better environment for the desirable soil biological processes - rational system for plant nutrition - prevention of soil pollution environment protecting agriculture - inoculation
	b) unfavourable changes in the nutrient regime	
- See Tables 4, 5, 6, 7a - non-adequate system for plant nutrition (fertilization)	- limitations in the optimum nutrient supply of crops (leaching; surface runoff; immobilization) - undesirable ion antagonisms (as a result of 5 and 7a) - nutrient "pollution" of surface and/or subsurface waters	- See Tables 4, 5, 6, 7a: increase nutrient use efficiency - rational nutrient regime control fertilizer application mobilization of the nutrient resources of soil recycling of organic residues
	c) decrease of buffering capacity (→ pollution, toxicity)	
- unfavourable changes in abiotic and biotic soil processes - overdosage of chemicals (overdosage; uneven distribution) - pollution from other sectors - agriculture (liquid manure) - industry; - mining - urban development sewage waters, wastes, by-products of various origin and chemical composition	- limitations in crop growth and metabolism - biological degradation - toxicity	- no overdosage! - prevention of permanent and periodical stresses - increase the buffer capacity of soil - agrotechnics - amelioration

Between 1960 and 1970 considerable efforts were taken in most of the "former-Eastern-block" countries to prevent soil degradation processes (VÁRALLYAY, 1992a, 1994). Based on the results of comprehensive soil survey - soil test and soil analysis - large scale soil mapping programmes huge (sometimes oversized) amelioration plans were elaborated and implemented. All of these activities were financed from the central state budget. There was a high-rate state subsidy on the main soil reclamation practices and soil degradation control measures. They were apparently cheap and highly efficient, because the politically dictated, complicated and artifically manipulated economy regulators (e.g. credits, subsidies, prices, etc.) prohibited any real cost-benefit analyses of these actions. Later (in the '70's) these well-coordinated activities decreased dramatically (in spite of the political and economical pressure) and were not able to balance the further extension of soil degradation processes due to improper land use, cropping pattern, soil management and agrotechnics.

Environmental Aspects of Soil-Water Problems

The *soil moisture regime* has particular significance in soil fertility. It determines the water supply of plants, influences the air- and heat regimes, biological activity and plant nutrient status of the soil. In most of the Central and Eastern European countries soil moisture regime strongly influences (sometimes determines) the ecological potential and agricultural productivity of a given area, the biomass production of various natural and agro-ecosystems, and the hazard of "nutrient pollution" of surface and subsurface waters (Proceedings of the Hungarian-Polish Seminar on Soil Water Problems, 1989).

E.g. in Hungary the 620 mm yearly average precipitation may cover the water requirement of the main crops even at high yield levels. But the average shows extremely high territorial and temporal variability - even in micro-scale. Under such conditions a considerable part of precipitation is lost by surface runoff, downward filtration and evaporation. The non-uniform rainfall distribution is one reason of the extreme moisture regime: the simultaneous hazard of waterlogging or over-moistening and drought-sensitivity in extensive areas, sometimes on the same places within a short period (VÁRALLYAY, 1988a, 1989a).

The other two reasons of the extreme moisture regime are:

- the relief (in addition to the undulating surfaces the microrelief of the "flat" Hungarian Plain);
- the unfavourable hydrophysical properties of soils (VÁRALLYAY & LESZTÁK, 1990).

The hydrophysical properties of soils are closely related to (are reasons or consequences of) the limiting factors of soil fertility and soil degradation processes. This is shown by Figure 2, where the main soil reasons of non-

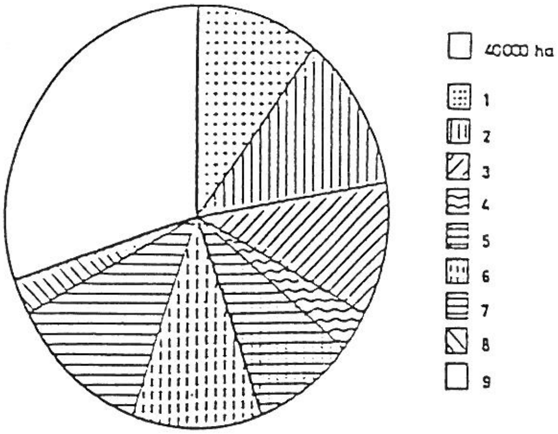

Figure 2
Distribution of soils with good and unfavourable hydrophysical properties in the counties (administrative districts) of Hungary. 1-6: Soils with unfavourable hydrophysical properties: (1) due to coarse texture; (2) due to heavy texture; (3) due to clay accumulation in the B horizon; (4) due to salinity/alkalinity; (5) due to peat formation; (6) due to shallow depth. 7. Soils with good hydrophysical properties.

favourable and moderately unfavourable moisture regimes are illustrated (VÁRALLYAY, 1988a, 1989a).

The highly variable moisture regimes would necessitate a special *"double-faced" soil moisture control* in Hungary:

- ensuring (or making possible) the drainage of excess water
- giving the necessary additional water

{ when and where it is necessary,

sometimes simultaneously.

Both actions are costly and faced with serious limitations:

a) *drainage:* poor permeability of soil; limited capacity of drainage canals and drainwater reservoirs; salinity problems);

b) *irrigation:* relief; limited and still decreasing water available for crop production as a result of limited surface and subsurface water resources and the increasing water demand of other sectors.

Consequently, all efforts have to be taken to *improve* agricultural *water use efficiency* by proper soil management:

- to help infiltration to the soil;
- to increase the water storage capacity of soil;
- to improve the water availability for plants.

All actions ensuring normal soil functions are related to the regulation of the substance regime of soil, which is - in most of the cases - closely connected with soil moisture control in Hungary. On the other hand, most of the measures for soil moisture control are - at the same time - the elements of environment control, as it is shown in Table 8 (VÁRALLYAY, 1990b).

In the last years a comprehensive soil survey-analysis-categorization-mapping-monitoring system was developed for the exact characterization of hydrophysical properties, modelling and forecast of water and solute regimes of soils. The system may serve as a scientific basis for soil moisture control and it was efficiently used for practical soil water management both for crop production and environment protection (VÁRALLYAY, 1988a, 1989a).

Environmental Aspects of Fertilizer Application

Before World War II the plant *nutrient status* of Hungarian soils was rather poor, due to the negative nutrient balance: more nutrients were taken up by the cultivated crops and were taken away from a given territory as yield (or biomass) than was being put back in the form of organic and green manures or fertilizers (VÁRALLYAY, 1990b; VÁRALLYAY et al., 1992).

From 1955 there was a rapid increase in *fertilizer consumption* (Figure 1). This tendency was one of the reasons of the substantial yield increase during the same period (Table 2). Another consequence was that - due to the positive nutrient balance - the nutrient status of Hungarian soils was significantly improved. In the early seventies well-equipped agrochemical laboratories were established in each county, a regular soil test system (with 3-year cycles) was introduced and a national advisory service was organized, including 19 regional soil testing and plant analysis laboratories (VÁRALLYAY, 1991b).

In spite of these developments there were serious problems and inadequacies in the fertilizer application technology (improper N-P-K ratio; lack of Ca, Mg and micronutrient supply; limited variety of fertilizers; problems with their storage, time of application, way of distribution; etc.). The main problem, however, was an unfavourable "polarization" tendency in fertilizer application (BARANYAI et al., 1987):

a) better soil → rich farm → higher rate of fertilizer application (in spite of the lower requirements → better nutrient status of soils) → overdosage;

b) poor soils → poor farms → lower rate of fertilizer application (in spite of the higher requirements → lower nutrient supply of soils) → underdosage.

The over-generalization and the imperative "maximum-concept" led to false conclusions, decreased the effectivity and efficiency of mineral fertilization, and resulted in *environmental side-effects*, like:

- soil acidification (due to non-adequate type of fertilizer, lack of simultaneous lime application) and its consequences: mobilization of toxic elements ("chemical time bomb effect"), fixation of some of the nutritive

Table 8

Elements and methods of soil moisture control with their environmental impacts

Elements		Methods	Environmental impacts	
			Favourable	Unfavourable
Surface runoff	Moderation of these elements	Increase of the duration of infiltration (moderation of slopes; terracing, contour ploughing; establishment of permanent and dense vegetation cover; tillage); improvement of infiltration; soil conservation farming system	1, 1a, 5a, 8	-
Evaporation		Help infiltration (tillage, deep loosening); prevention of runoff and seepage, water accumulation	2, 4	-
Feeding of groundwater by filtration losses		Increase of the water storage capacity of soil; moderation of cracking (soil reclamation); surface and subsurface water regulation	5b, 7	-
Rise of the water table		Minimalization of filtration losses (↑); groundwater regulation (horizontal drainage)	2, 3, 5b, 5c	-
Infiltration	Increase of	Minimalization of surface runoff (tillage practices, deep loosening) (↑)	1, 4, 5a, 7	-
Storage in the soil in available form		Increase of the water retention of soil; adequate cropping pattern (crop selection)	4, 5b, 6, 7	-
Irrigation		Irrigation; groundwater table regulation	4, 5c, 7	9, 10
Surface Subsurface } drainage		Surface Subsurface } drainage	1, 2, 3, 5c, 6, 7	11

Environmental impacts

Favourable				Unfavourable	
Prevention, elimination, limitation or moderation of the following phenomena					
1	Water erosion	5a	Surface runoff (surface waters - eutrophication) of plant nutrients	9	Overmoistening; waterlogging; peat and swamp formation; secondary salinization/alkalization;
1a	Sedimentation				
2	Secondary salinization, alkalization	5b	Leaching (subsurface waters) of plant nutr.		
3	Peat formation, waterlogging, overmoistening	5c	Immobilization of plant nutrients	10	Leaching of plant nutrients
		6	Formation of phytotoxic compounds	11	Drought sensitivity
4	Drought sensitivity, cracking	7	"Biological degradation"		
		8	Flood hazard		

elements, etc. (Proceedings of the Polish-Hungarian Seminar, 1985; VÁRALLYAY et al., 1989, 1993);

- load of surface waters by P compounds (mainly due to surface runoff, lateral erosion and sediment transport);
- contamination of subsurface drinking water resources by nitrates (leaching);
- accumulation of harmful toxic elements in the various stages of the "food chain": in soils, plants, animals and human organs, according to their solubility, mobility and availability (KÁDÁR, 1991; MOLNÁR et al., 1992).

(Most of) these side-effects - however - are not inevitable and uncontrollable consequences of fertilizer application: they can be prevented, or at least reduced, efficiently by precision nutrient management, based on the nutrient requirements and nutrient uptake dynamism of cultivated crops (the specific requirements of species, variety or even genotype); the nutrient status and other properties of soils; the characteristics of agroclimate and hydrology conditions of the given landsite.

All of these factors were taken into consideration in the development of our new plant nutrition advisory system which was efficiently used on several hundred hectares year by year (SARKADI & VÁRALLYAY, 1989; VÁRALLYAY, 1994; VÁRALLYAY et al., 1992).

Influence of Land Use and Nutrient Management on Water Resources

The impacts of crop production on surface and subsurface water resources can be summarized, as follows (Studies on the State of the Environment, 1989; VÁRALLYAY, 1990a):

a) *Soil erosion* by water results in considerable soil losses in the undulating hilly regions and sedimentation (silting up of waterways, canals and reservoirs → limitations in their functions, necessity of their more frequent cleaning → increasing costs, increasing hazards of waterlogging and floods) in the lower parts of the watershed (Proceedings of the US-Central and Eastern European Workshop, 1992; STEFANOVITS & VÁRALLYAY, 1992; VÁRALLYAY, 1992a).

b) *P fertilization.* Because most of the P compounds have low water solubility their liquid transport and leaching is negligible (is limited to some centimetre distances). But adsorbed (fixed) P, insoluble P compounds and sometimes P fertilizer particles can be transported by surface runoff directly to surface waters. Their high P concentration may result in increasing eutrophication and its undesirable consequences:

- rapid silting up of canals and reservoirs (see above);

- unfavourable changes in the aquatic ecosystems of shallow lakes (e.g. the Lake Balaton, particularly the Keszthely Bay: recreation problems, fish disease, etc.).

c) *K fertilization.* Most of the potassium fertilizers are highly soluble and can be leached from the profile of light-textured soils. In heavy soils the greater part of soil-K is fixed not only on the clay surfaces but within the lattice structure of the swelling clay minerals.

d) *N fertilization.* The nitrate pollution of subsurface waters is one of the most important environmental problems in many countries. In Hungary more than 600 villages are supplied with bottled water because the nitrate concentration of the drinking water supplies exceeds the permissible limit. The potential sources of these high N concentrations can be the following factors:

1. Liquid manure from large, concentrated livestock farms. The annual 9 million m^3 of liquid manure is distributed on 70,000 ha of agricultural fields (approx. 7 M m^3) and 5,000 ha of special "filter fields" (approx. 2 M m^3), resulting sometimes in considerable point source N pollution of subsurface waters (VÁRALLYAY, 1990a).

2. Sewage waters, sewage sludges and solid wastes as a result of industrial, urban and rural development. In many settlements drinking water supply was introduced without the simultaneous establishment of canalization. This resulted in rising water table ("groundwater hills" below these villages) and an increasing hazard of N contamination of the groundwaters.

3. Recreation and tourism, without appropriate waste water management.

4. Illegal local sources (e.g. use of "old" wells for waste disposal, etc.).

5. Irrational N fertilizer application.

Rational N fertilization cannot cause a significant N pollution, because, if we use the necessary amount of N - according to the crop's requirement - N losses (sources of N pollution) can be efficiently reduced to a minimum level. What are the main possibilities of the N pollution of groundwaters due to N fertilization?:

- leaching of N through preferential pathways, such as cracks and biological channels (roots, earthworm channels);
- uncontrolled N application in "hobby gardens";
- improper fertilizer application, non-adequately selected for the crop requirement (nutrient uptake), soil properties and weather conditions; problems in uniform distribution, or differential distribution according to the N status of the soil; time of application; etc.

Any improvement in the technology of N fertilizer application will result in the reduction of losses (→ higher efficiency) and environmental hazards.

e) *Water soluble salts.* Leaching of Na salts from the soil profile is favourable for the given soil (→ decreasing salinity), but increases the salt concentration in the drainage water. Consequently, this water cannot be used for irrigation again, and can be drained to international waterways only up to a certain quality limit prescribed by international agreements. In addition to other facts (high clay and swelling clay content, Na_2CO_3-$NaHCO_3$-type salinity → high alkalinity → high ESP → very low permeability of the soil; lack of frost-free period after the growing season; lack of good quality water) this is the main reason why we cannot use the traditional leaching-drainage concept for salinity-alkalinity control and the only way for that is a well-functioning prediction → prevention system (SZABOLCS, 1974, 1989).

f) *Pesticides and other organic chemicals.* Hungary takes part in various international programmes on these subjects ("Mapping of critical loads"; "Chemical Time Bomb"; "Vulnerability of soils to organic pollutants"; etc.) and these researches are in the focus of our future scientific activities.

Soil Pollution and Its Management

Most of the elements occurring on Earth can be found in the soil. Their quantity, quality, solubility, mobility; availability for microorganisms, plants, animals and human-beings show an extremely wide spectra. Most of these elements are essential for the living organisms, but - over a certain "threshold concentration" - a great part of the same elements can be harmful, or even "toxic" for the same organisms (MOLNÁR et al., 1992; VÁRALLYAY, 1990a).

The occurrence and accumulation of these elements (e.g. heavy metals and other - potentially toxic - elements such as Al, As, F, etc.; organic pollutants; water soluble salts; nitrates, P and S compounds; etc.) can be due to natural sources, as:

- air (NO_X, SO_X, etc.) via wet and dry atmospheric deposition;
- water (B, Na, N, etc.) via irrigation water or groundwater;
- soil and geological deposits (P, K, Ca, Mg, Na, Fe, Al, Mn, As, Co, Cu, Ni, Se, Zn, etc.) via local weathering and soil formation processes;

or it can be the consequence of various human activities (industry, energy production and energy used, agriculture, urban and rural development, transport, domestic, commercial and military activities producing or using irrigation water, organic manure, liquid manure, mineral fertilizers, amendments for soil reclamation; sewage waters, sewage sludges, solid wastes; etc.). In addition to the increasing quantity (accumulation) of these elements the sudden - sometimes surprising - mobilization of the - temporarily - immobile pollutants as a consequence of changes in soil properties (e.g. soil acidification, salinization/ alkalization, destruction of soil structure and clay minerals, decrease of organic matter content and buffer capacity, limitations in the "filter function" of the soil, etc.) is even more harmful. This non-linear, time-delayed effect of potentially harmful chemical compounds is the typical "chemical time bomb" (CTB) problem.

Both accumulation and mobilization of these elements and compounds represent a serious environmental problem in many parts of Central and Eastern Europe.

The main potential possibilities of *soil pollution control* are schematically illustrated by Figure 3.

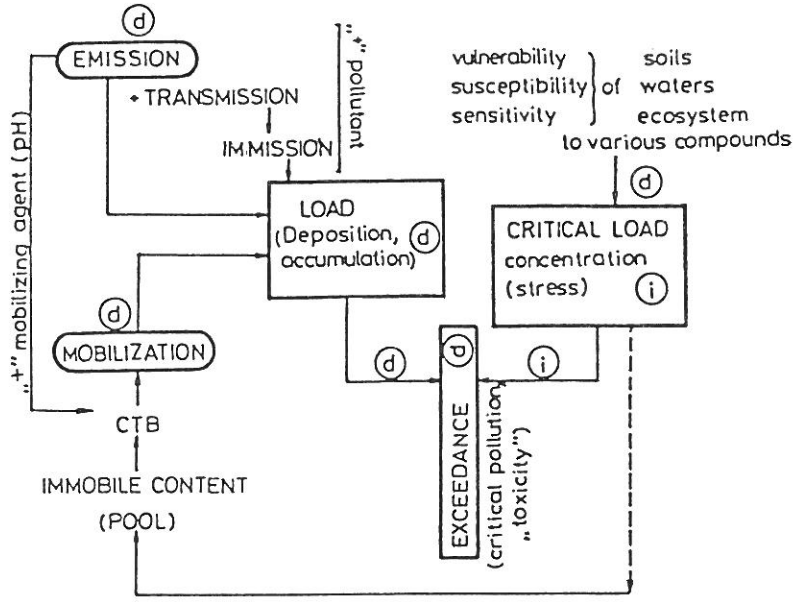

Figure 3

Strategy for pollution control (i: increase; d: decrease)

Its main elements are:

- emission/imission reduction (preventing or reducing the quantity of pollutants deposited or transported to the soil surface or into the soil);
- prevention of the mobilization of potentially harmful chemical compounds or elements which are already present in the soil but in - temporarily - immobile form;
- decrease of the susceptibility/vulnerability of soil against various pollutants (with the increase of the buffering capacity of soils) which tolerate a higher critical load of pollutants, consequently reduce the "exceedance-risk" and the unfavourable ecological consequences (VÁRALLYAY, 1991a).

For the comprehensive assessment of the status and regime of these elements in the soil and for the evaluation of their ecological impacts and environmental hazards

- the character of the contaminants (their total, soluble, mobile, plant-, animal-, and human-available and toxic quantities);
- their sources and pathways (atmospheric wet and dry deposition; vertical movement within the soil; horizontal transport, such as surface runoff, seepage in the unsaturated zone, groundwater flow; abiotic and biotic transformation, etc.)

has to be identified and quantified.

In the last years great efforts have been made in most of the Central and Eastern European countries for such assessments. It is a fact that many of these failed because of financial difficulties and even the operated programmes were stopped or radically reduced. In Hungary, i.e., a national programme started in 1987-1988 for the monitoring of micronutrients and potential pollutants. According to the plan the 0-30, 30-60 and 60-90 cm layers of 6,000 soil profiles (representing 5 million hectares of agricultural fields) would have had to be sampled in 3-year cycles, and 1,000 "representative" soil samples have had to be analyzed for 20 elements in 5 various soil extracts. The huge Programme stopped during the 2nd cycle.

At the same time thematic maps have been prepared on the susceptibility/vulnerability of soils against various pollutants, their critical loads were calculated and efficiently used as guidelines for non-harmful waste, waste-water and sewage sludge disposal.

New Trends, Further Developments

At the end of the 80's considerable changes took place in the political and economical circumstances in the "post-Eastern-block" Central and Eastern European countries. Not only the communist ideology, the inefficient, politically dictated and manipulated economy collapsed, but the "gianto-maniac" concept of "industrialized", strongly-controlled, high-input agricultural production, as well.

These changes were rather different in the various countries of the region and the following facts are valid directly for Hungary, but similar tendencies can be observed in Slovakia, in the Czech Republic, and in Poland, as well.

In the last years the primary objectives of agricultural development and biomass production changed considerably. Instead of the global quantity aspect quality (exportability, efficiency and economy (based on a real and exact cost-benefit analysis), and environmental impacts became more and more important. The planned economy restructuring can be characterized by the following tendencies in agricultural production:

a) *Privatization* of agricultural land to a rational extent:

- mixed ownership: co-existence and cooperation of private, co-operative and state sectors;

- decreasing size of farming units and agricultural fields → more flexibility and better possibility for rational land use, cropping pattern and agrotechnics according to the given ecological circumstances;
- ownership feeling → more care for maintaining soil fertility and for stabilizing environmental sustainability.

b) *Market-oriented production* with special regard to efficiency (input reduction) and sustainability (prevention, or at least minimalization of harmful environmental side-effects).

c) Steps toward an European integration, with special attention to *quality standards and environmental aspects.*

The new tendencies result in two - contradictory - consequences for the environment:

- the re-establishment of the lost ownership feeling will help the farmer to maintain soil fertility in his holdings because it is his interest (better yield; higher land price, etc.);
- the short-term market-oriented production of a land-user may lead to serious environmental deterioration, because of the lackage of the necessary (but sometimes costly) preventive measures, especially in cases when the harmful side-effect is detectable one-two years later or appears in the surroundings (off-site effects: e.g. secondary salinization of soil, or nitrate pollution of groundwaters in the low-lying areas as a result of irrigation, or overdosage of N fertilizers in the surrounding higher territories).

The rational privatization of land and the market-oriented production give potential possibilities for the establishment of a flexible sustainable agriculture. It will be based on various production systems with special roles of "intensive" (not equal to "big", "high", "large", "much"), low input and organic (biological-ecological) farming systems.

The new circumstances formulate the main tasks of a productive, efficient (economically viable), socially acceptable and environmentally sound sustainable agricultural development, land use and soil management including the following elements:

1. Territorial coordination of the agro-ecological conditions and the ecological requirements of cultivated crops, taking into consideration both the production and the environmental aspects in short-, mid- and long-term time scales: *rational land use.*

2. Rationalization of the structure of agricultural fields by the *optimization of field size* according to the given physiography conditions, resulting more homogeneous fields for the uniform agrotechnical measures.

3. Elaboration, adoption and implementation of *scientifically-based crop production technologies,* including 5 fundamental elements:

- adequate cropping pattern and crop rotation;
- reduction (minimalization) of "production wastes" with their recycling;
- improvement of agricultural water-use efficiency;

- precision nutrient management, including rational fertilizer application;
- integrated pest management with minimum use of chemicals.

The rate, direction and technologies of crop production are economy driven. In contrast, the maintenance of soil functionality, the quality of surface and subsurface water resources, and the protection of the natural environment (the biosphere) are not economy-dependent, but imperative tasks. Only their efficient and most economic methods can be selected on the basis of cost/benefit analysis.

For the above-mentioned purposes:

- the criteria of sustainable agricultural development and crop production have to be defined and quantified;
- the necessary economical regulations have to be elaborated (such as: tax, price, credit, subsidy regulations, etc.) guaranteeing the fulfilment of these criteria;
- the defined and quantified criteria and the economy regulations have to be formulated in various legal documents (laws and related official documents);
- the potential possibilities and efficient ways (methods) of sustainable crop production have to be elaborated, adopted, published and demonstrated, which needs the establishment of appropriate mechanisms for research, training and education, demonstration, extension and advisory service;
- the necessary mechanisms for continuous control have to be built up.

The main tasks of the scientist - extensionist - farmer - environmentalist community in the future will be:

- ensuring the above-mentioned preconditions;
- broadcasting the present knowledge and providing the necessary help (education, extension and advisory service, technical assistance, etc.) to the land user;
- establishment of proper society control mechanisms (legislation, financial policy and other economy regulations) to stimulate (or even press - when and where it is necessary) the land users for sustainable land use, including precision nutrient management.

The effective realization of these tasks must be jointly guaranteed by the State, by the land-owner and by the land-user for the benefit of efficient, rationally privatized, market-oriented, sustainable agricultural production harmonized with successful environment protection, ensuring a pleasant environment and a promising future.

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