Multifunctional Soil Management for Sustainable Development in Hungary

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Introduction

Sustainable development includes efficient agricultural production (using environment-friendly, energy- and material saving technologies and paying special attention to quality) and a socially acceptable rural development, simultaneously. Both represent a challenge for up-to-date soil science, for rational land use and soil management (BOUMA, 1997; DUMANSKI, 1997; HURNI, 1997). The given land resources (geological formations, relief, atmosphere, surface and subsurface water resources, soil, biota, vegetation) are used, managed and – hopefully – protected by society according to its requirements, depending on the given socio-economic conditions, modified by the historical background and formulated by the various level decision-makers (BOUMA, 1997; BOUMA et al., 1998; GREENLAND & SZABOLCS, 1993; VÁRALLYAY, 1997a).

In the decision-making „machinery" such questions have to be answered in an appropriate way, as:

– What are the potential land use alternatives under the given condition taking into consideration the requirements (biomass production for food, fodder, raw material for industry, energy; meaningful work for the local rural population; exploitation of mineral resources; place for building construction and infrastructure; drinking water supply; place for recreation, sports; pleasing landscape; conservation of biodiversity, etc.) and the natural conditions (elements of the ecological potential: climate-weather, relief, water resources, soil, biota, vegetation)?

– What are the potential and actual efficiencies of the various alternatives (based on a comprehensive and realistic cost/benefit analysis)?

– What are the predictable ecological and economical risks (risk analysis) and environmental consequences and potential side effects (impact analysis)?

Soil and Soil Functions

Soils represent a considerable part of the natural resources of Hungary. Consequently, rational land use and proper soil management are important elements of sustainable development, having particular significance both in the national economy and in environment protection (LÁNG et al., 1983; VÁRALLYAY, 1997a).

The main functions of soil in the biosphere are as follows (GREENLAND & SZABOLCS, 1993; VÁRALLYAY, 1997a):

a) Soils are the most significant – *conditionally renewable – natural resources.* During rational biomass production they do not change irreversibly, their quality does not decrease unavoidably and fundamentally. But their „renewal" based on soil resilience does not go on automatically: soil conservation, the maintenance and increase of soil fertility require permanent activities, such as: sustainable land use, agrotechnics, remediation and reclamation.

b) Soil is a *reactor* and *transformer* integrating the combined influences of other natural resources, such as solar radiation, atmosphere, surface and subsurface waters, deeper geological strata and biological resources. Their biogeochemical cycles develop „life-medium" for microbiological activities, as well as ecological environment (standort, landsite) for natural vegetation and cultivated crops.

c) Soil is the most important *medium for biomass production,* consequently, it is the primary food source of the biosphere. Water, air and available plant nutrients may occur simultaneously in soil, in this four-dimensional, three-phase, polydisperse system and soil may cover – to a certain extent – the main soil ecological requirements of plants.

d) Soil is a major *natural storage* of heat, water, plant nutrients and other elements, including wastes and (potentially) harmful elements or chemical compounds. The stored water and plant nutrients ensure the water and nutrient uptake of plants for shorter or longer periods – without continuous water or nutrient application.

e) Soil is an efficient *„natural filter"* and *detoxication system* that may prevent the deeper horizons and the subsurface waters from various pollutants deposited on the soil surface or put into the soil.

f) Soils represent a *high capacity buffer medium* of the biosphere, which – to a certain limit – may buffer and can moderate the various stresses caused by environmental factors (climatic droughts or too humid conditions, frost etc.) and/or human activities (high input, fully-mechanized and chemically controlled crop production; liquid manure of large-scale livestock farms; wastes and waste waters originating from industry, transport, urban and rural development; etc.) representing a sharply increasing ecological threat to the biosphere.

g) Soil is a significant *gene-reservoir* of the biosphere, an important element of biodiversity.

These functions are equally important, but society has been using them in different ways (rate, method, efficiency) throughout history, depending on the given natural conditions and socio-economic circumstances. In many cases the character (territorial and temporal variabilities, changeability-stability-controllability, boundary conditions, limitations) of a certain function was not (properly or adequately) taken into consideration during the utilization of soil resources. In such cases the misguided management resulted in over-exploitation, and – over a certain limit – in serious environmental deterioration (VÁRALLYAY, 1989a).

Soil Processes and Their Control

The multifunctionality of soil is determined by the combined influences of soil properties, which are the results of soil processes (mass and energy regimes, abiotic and biotic transport and transformation and their interactions) under the combined influences of soil forming factors. Any soil-related human activity influences the soil through these processes. Consequently, the *control of soil processes* is a great challenge and the main task of soil science and soil management.

In this respect four fundamental questions have to be answered:

Q1. Is it necessary to control soil processes?

Except some peculiar cases (e. g. strictly protected areas) a certain control is always necessary. Usually even the soils of protected ecosystems require an appropriate process control for the prevention of undesirable environmental side-effects (e.g. soil acidification due to atmospheric deposition). The abandoned (set-aside) land cannot find its way back to the „original" (?) condition without human help, or this regeneration process takes a – unacceptable – long time. For example, the set-aside arable land will never be the forest, species-rich grassland or wetland with high biodiversity which it was before deforestation, turning up or water regulation. Their restoration needs well-defined human measures and permanent „control activities".

Q2. What are the main purposes of the control of soil processes?

The general answer cannot be more specific than: „.... Ensure (guarantee) „normal" (≈ „desirable") soil functions." The definition of „normal" or „desirable" is purpose-specific and depends on the criteria of „priority functions", which are determined by the given conditions and requirements.

The most important objectives of soil process control can be as follows:

– maintenance (stabilization) of the present situation (it is not meaningful if the present state is not desirable);

– prevention of unfavourable changes; re-establishment of a previous („original", more natural?) situation (in that case the definition and the time criteria of „original" are rather questionable);

– modification of the present conditions to a positive direction (e.g. improvement of one or more soil properties, soil amelioration);

– recultivation of disturbed lands, remediation of polluted sites, or rehabilitation of degraded ecosystems (it is in many cases the re-establishment of a previous situation, but in many other cases it is only a certain soil improvement because the original deteriorations were fully irreversible and uncorrectable, consequently the original conditions cannot be re-established).

Q3. To what extent is soil process control necessary?

From the practically „0-control" (strictly protected areas) to „full control" (man-made and/or almost totally uncontrolled soils in flower pots or greenhouses) there is a great variety, wide spectra of control levels. The „optimum", „desirable", „required" or „tolerable" rate of soil process control is determined by the main objective, the costs, efficiency and the impacts (positive and negative economical and ecological consequences).

Q4. How can the various soil processes be controlled?

A conceptual model of the rational strategy for the control of soil processes was presented by VÁRALLYAY (1989a, b).

The scientifically based planning and implementation of sustainable land use and rational soil management require adequate *soil information*: exact, reliable, „detectable" (preferably measurable) and accurate, quantitative territorial data on well-defined soil and land properties, including the characterization of their spatial (vertical, horizontal) and temporal variabilities and pedo-transfer functions; on the soil processes and biogeochemical cycles, including their determining and influencing factors and their mechanisms.

In Hungary a large amount of information is available about the ecological conditions, including soils, as a result of long-term observations, and various soil survey, analytical and mapping activities on national (1:500,000), regional (1:100,000) farm (1:10,000-1:25,000) and field scales (1:5,000-1:10,000) conducted during the last 60 years (VÁRALLYAY, 1993, 1994b, 1997c; STEFANOVITS, 1968)

Soil Forming Factors, Soil Formation Processes and Soils of Hungary

Soil forming factors show high spatial and temporal variability in Hungary. The present soil cover of the country has developed mainly in the Quaternary (Pleistocene) and in the Holocene geological periods and a considerable part is of recent formation.

The main characteristics of the basic soil forming factors in Hungary are briefly summarized in the following (STEFANOVITS, 1968; VÁRALLYAY, 1994b):

– The surface (or near to surface) *geological deposits* (parent material) vary widely in origin, mineral and chemical composition, particle size and weathering resistance: aeolian sand and various alluvial (← fluviatile activity) and colluvial (← lateral erosion) deposits (37.7%); Quaternary loess (deposited partly to dry surfaces, partly into water or waterlogged areas during the Pleistocene interglacial periods (48.0%); Tertiary or older sediments (including the heavy-textured and saline deposits of the Pannonian sea) (7.5%); and various sedimentary, igneous and volcanic rocks and their weathering products (6.8%).

– The *weather* is under the combined and changing influences of the Atlantic, Continental and Mediterranean climates and shows particularly wide spatial and temporal variability. The average annual temperature is 10.5 °C (the monthly average in January is -2.5 °C, while it is 25.0 °C in August). The average annual precipitation is 550-700 mm, ranging between the 450-500 mm annual value in the driest part of the Hungarian Plain and 800-900 mm in the Western Prealpine Region.

– Both *surface and subsurface hydrology* of the country are determined by the fact that Hungary is situated in the deepest part of the hydrologically (the only drainage outlet is the Danube) and hydrogeologically (practically no subsurface outflow) closed Carpathian Basin. The majority (85-90%) of the rivers are flowing from and flowing to the neighbouring countries. The water balance of the Hungarian Plain is negative (potential evapotranspiration, ET is higher than precipitation, P) and this deficit is equilibrated by horizontal inflow: surface runoff, R; seepage in the unsaturated zone, S; and groundwater flow, G. It means equilibrium for water, but results in the accumulation of soluble materials.

– The *natural vegetation* (determined by climatic factors, relief and moisture regime/wetting conditions) was forest steppe and various wetland ecosystems in the Carpathian Basin.

– Its role was considerably modified by the *activities of man* both directly (deforestation; grazing; flood control; intensive agricultural use, including chemization, mechanization, amelioration, irrigation and drainage, etc.) and indirectly (human-induced stresses, soil degradation and soil pollution, landscape deterioration, etc.).

The combined influences of these soil forming factors with high spatial and temporal variability create extremely heterogeneous physico-geographical environment for soil formation processes, which results in the mosaic-like variability of soils and their properties in Hungary.

The soil formation processes and the occurrence and geographical distribution of various soils can be illustrated well by the development of the following soil sequences:

1. *Chrono-sequence.* – If the changing factor is time (duration of pedogenesis) the result is a sequence from unaltered parent material (alluvium, aeolian deposits, colluvium, weathered rocks, etc.) to well-developed soils with differentiated soil profiles.

2. *Topo-sequence (Catena).* – Catena is a sequence of soils of about the same age, derived from similar parent material, and occurring under similar climatic conditions, but having different characteristics due to the variation in relief, in drainage conditions and in moisture regime (intensity of wetting).

Another type of topo-sequence is the *erosion sequence*, according to the rate of water erosion and sedimentation on the various parts of slopes in an undulating - hilly landscape.

3. *Leaching sequence.* – In this case the different rates of downward flow (due to high atmospheric precipitation and/or surface seep-in) results in the different intensity of leaching of soluble compounds or clay minerals and various rates of profile differentiation.

4. *Salinity-alkalinity sequence.* – If the changing factor is the salinity-alkalinity status, then, a well-defined sequence can be distinguished according to the water soluble salt content and its profile distribution; the rate of profile differentiation; the depth and ESP of the „solonetz" B-horizon; and the hydromorphic character of the soil.

The soil cover of Hungary shows a „super matrix" of these sequences with their numerous combinations and transitional formations. Within the national programme on the „Assessment of the Agro-ecological Potential of Hungary" (1978-1981) (LÁNG et al., 1983) an updated evaluation of soil resources was made by the author's team – on the basis of all available soil information (VÁRALLYAY et al., 1985). Later, all these information were organized into a computerized GIS database – AGROTOPO – in RISSAC (VÁRALLYAY, 1993, 1994a, 1997c; VÁRALLYAY et al., 1997).

Main Elements of Rational Land Use and Soil Management For Sustainable Agricultural Development

1. Territorial coordination of the agroecological conditions (land-site characteristics) and the agro-ecological requirements of the cultivated crops, taking into consideration both production and environmental aspects in short-, mid- and long-term scales:

– *rational land use and optimization of cropping pattern* according to the given (and hardly controllable) natural conditions (LÁNG et al., 1983; VÁRALLYAY, 1997c);

– *selection of proper crops* (crop rotations), cultivars according to the given natural circumstances (selection and breeding of varieties or even genotypes tolerant to certain ecological constraints, such as frost, soil acidity, salinity/alkalinity, drought, moisture surplus, extreme soil texture, soil compaction, etc.);

– *improvement of (soil) ecological conditions* according to the crop requirements (amelioration of land, reclamation/improvement of soil, soil conservation, irrigation and drainage, proper agrotechnics).

2. *Rationalization of the structure of agricultural fields* (under the new ownership structure):

– *optimization of field size* according to the given physiographic conditions (development of more homogeneous fields for uniform agrotechnical measures, taking into consideration the rational level of biodiversity);

– *development of proper infrastructure* (rational territorial arrangement of fields, roads, canals, buildings, forest shelter belts, etc., taking into consideration landscape preservation requirements, as well).

3. *Reduction* (minimalization) *of production wastes* (plant residues, animal excrements, such as organic manure and liquid manure, wastes of yield and food processing, etc.) with their most efficient recycling without any harmful environmental side-effect.

4. *Improvement of* the existing *agro-ecological conditions* (amelioration, reclamation) *and the prevention* (or at least moderation) *of undesirable soil degradation processes*. The main *limiting factors of soil fertility* in Hungary are as follows (SZABOLCS & VÁRALLYAY, 1978):

– extremely coarse texture (low amount of inorganic and organic colloids);
– acidity (and its undesirable consequences);
– salinity/alkalinity (and their unfavourable consequences);
– salinity/alkalinity in the deeper layers;
– extremely heavy texture (high amount of clay and swelling clay minerals);
– waterlogging (or regular over-moistening);
– water and wind erosion (soil loss);
– shallow depth.

The simplified map of the main limiting factors of soil fertility are presented in Figure 1. Their territorial extension and the most important soil degradation processes are summarized in Table 1 (SZABOLCS & VÁRALLYAY, 1978).

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 uneconomical. At the same time 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 increasing biomass production for food, fodder, raw material for industry, energy or for other purposes.

In Hungary the large extension of various undesirable *soil degradation processes* represents serious crop production and environmental problems both in the directly affected territories and in their surroundings. These processes are summarized in Table 1.

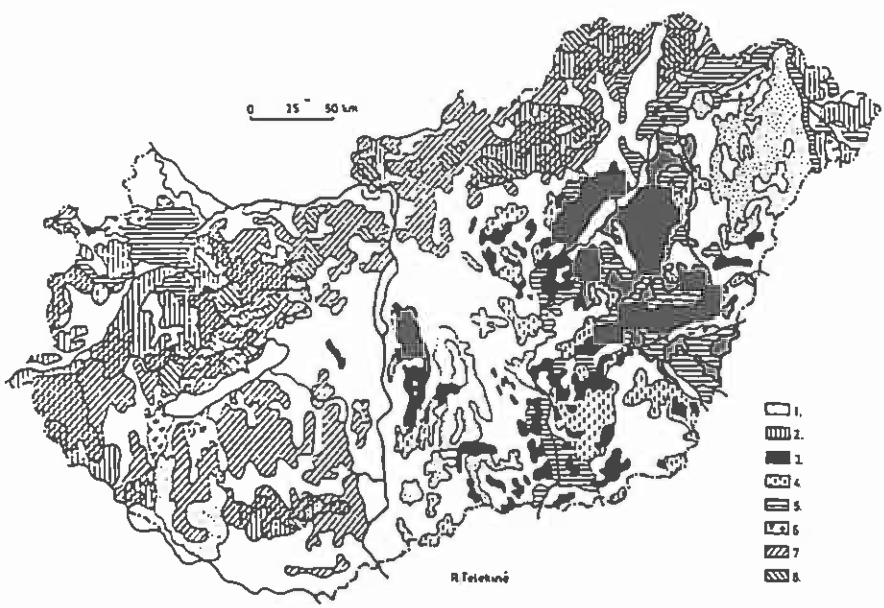

Figure 1

Map of the limiting factors of soil fertility in Hungary (original scale: 1:500,000).
1. Extremely coarse texture. 2. Acidity. 3. Salinity and/or alkalinity. 4. Salinity and/or alkalinity in the deeper layers. 5. Extremely heavy texture. 6. Waterlogging. 7. Erosion. 8. Shallow depth.

Soil degradation is *not* an unavoidable consequence of intensive (but rational!) agricultural production and social development! Because most soils are resilient to a certain extent, most of the degradation processes and their unfavourable consequences can be efficiently prevented, eliminated or at least moderated. But it needs permanent actions and widely adopted proper soil- and water conservation practices. The key word in the system is *prevention* (VÁRALLYAY, 1989a, 1993).

For successful *prevention* satisfactory *prognosis* is necessary. It can be rationally based on a comprehensive

– sensitivity analysis: evaluating the susceptibility of soils against various soil degradation processes, as water and wind erosion, acidification, salinization/alkalization, structure destruction or compaction, hazard of nitrate leaching; vulnerability of terrain to various chemical pollutants;

– impact analysis: evaluation of the „positive" and „negative" impacts of various human activities.

In the last years extended research programmes have been carried out in Hungary for the exact definition, characterization and quantification of sensitivity/susceptibility/vulnerability of soils/lands against various environmental and human-induced stresses and for the evaluation of their ecological/economical/ social impacts.

Table 1

Limiting factors of soil fertility and soil degradation processes in Hungary

No	Limiting factor of soil fertility	Area, 1000 ha	%	No	Soil degradation processes
1.	Extremely coarse texture	746	8.0	1.	Soil erosion: - by water - by wind
2.	Soil acidity - combined with erosion	1200 (348)	12.8 (3.7)	2.	Soil acidification
	- combined with shallow depth	(67)	(0.7)	3.	Salinization/alkalization
3.	Salinity/alkalinity	757	8.1	4.	Physical soil degradation - structure destruction - compaction - surface sealing
4.	Salinity/alkalinity in the deeper layers	245	2.6		
5.	Extremely heavy texture	630	6.8		
6.	Peat formation (waterlogging)	161	1.7	5.	Extreme moisture regime - overmoistening, waterlogging - drought sensitivity
7.	Soil erosion - combined with acidity	1455 (348)	15.6 (3.7)		
8.	Shallow depth - combined with acidity	217 (67)	2.3 (0.7)	6.	Biological degradation - decrease of organic matter - deterioration of soil biota
				7.	Unfavourable changes in the nutrient regime - leaching - biotic and abiotic immobilization
				8.	Decrease of the buffering capacity, soil pollution, „toxicity"

5. Improvement of the efficiency of agricultural water management and soil moisture control. In Hungary 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 hazards of „nutrient pollution" of surface and subsurface waters (VÁRALLYAY, 1989b, 1997b).

The average 600 mm annual 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 rain distribution is one reason of the *extreme moisture regime:* the simultaneous hazard of waterlogging or overmoistening and drought-sensitivity in extensive areas, sometimes on the same places within a short period. The other two reasons of extreme moisture regime are:

– the relief (undulating surfaces and the heterogeneous microrelief of the „flat" Hungarian Plain);

– the unfavourable hydrophysical properties of some soils (VÁRALLYAY, 1997b).

The highly variable moisture regimes of soils 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 and natural darainage conditions of extensive areas; 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:*

– to increase the water storage within the soil in plant available form without any unfavourable environmental consequences: to help infiltration into the soil; increase the water storage capacity; reduce the immobile and not plant-available moisture content;

– to reduce evaporation, surface runoff and filtration losses of water (atmospheric precipitation and irrigation water);

– to improve the vertical and horizontal drainage condition of the soil profile or the given area (prevention of over-saturation and waterlogging).

Most of these measures are – at the same time – the elements of environment protection (VÁRALLYAY, 1989b, 1997b).

In the last years a comprehensive soil survey – analysis – categorization – mapping – monitoring system was developed for the exact characterization of hydrophysical properties, modelling and forecasting of water and solute regimes of soils. The system may serve as a scientific basis for soil moisture control and it is efficiently used for practical soil water management both for crop production and environmental protection (VÁRALLYAY, 1989b, 1997b).

6. *Precision plant nutrient management:*

– *rational use of fertilizers* according to crop requirements (dynamics of their nutrient uptake), soil conditions and agroclimate;

– *efficient recycling* of crop residues and production wastes (including organic manures);

– *utilization of* other *wastes* with utilizable plant nutrient content and without potentially harmful chemical compounds.

Before World War II the plant nutrient status of Hungarian soils was rather poor, due to the negative nutrient balance. From 1955 there was a rapid increase in *fertilizer application*. This tendency was one of the reasons of the substantial yield increase during the same period and the nutrient status of Hungarian soils was significantly improved.

After the political and economical changes from 1990 the high-rate state subsidy for fertilizers was withdrawn and this resulted in a dramatic decrease in fertilizer application: 300 kg/ha in 1985 → < 10 kg/ha in 1992. A certain increase in fertilizer application (→ 30-50 kg/ha) was recorded again only from 1994-1995 (KÁDÁR, 1992; VÁRALLYAY, 1997a).

In spite of the existing up-to-date plant nutrition advisory service 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.). These inadequacies decreased the effectivity and efficiency of mineral fertilization, and resulted in *environmental side-effects*:

– soil acidification (due to inadequate 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 elements, etc.;

– „contamination" of subsurface drinking water resources by nitrates, load of surface waters by P compounds;

– accumulation of harmful toxic elements in the various stages of the „food chain".

(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. Consequently, *rational* fertilizer application is not harmful for the environment.

For the exact characterization of nutrient status of soils three factors have to be known:

– the total quantity of a certain element („pool": potential source);

– the potential rate of mobilization (or immobilization);

– the „available" quantity of a certain element for a certain plant at a given moment.

Their exact and quantitative determination is the main task of agrochemistry researches. Based on all available information all of these factors have been evaluated and were taken into consideration in the development of our new site-specific precision nutrition advisory system (KÁDÁR, 1992; VÁRALLYAY, 1994a, VÁRALLYAY et al., 1992).

7. Control of soil pollution.

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.

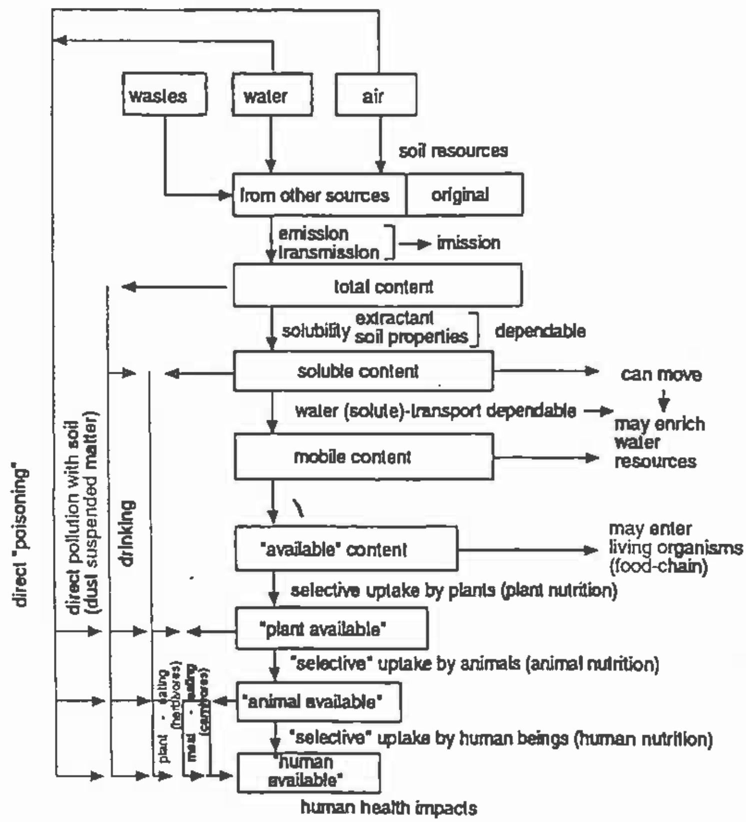

Figure 2
Sources and pathways of soil pollution

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 use, 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. (KÁDÁR, 1995; VÁRALLYAY, 1996).

In addition to the increasing quantity (accumulation) of these elements the time-delayed effect of potentially harmful chemical compounds („chemical time bomb" – CTB problem) can be even more threatening.

For the comprehensive assessment of the status and regime of pollutants in 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) (Figure 2); and

– 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.) have to be identified and quantified.

The main elements of an efficient *soil pollution control* are as follows (Figure 3) (VÁRALLYAY, 1996):

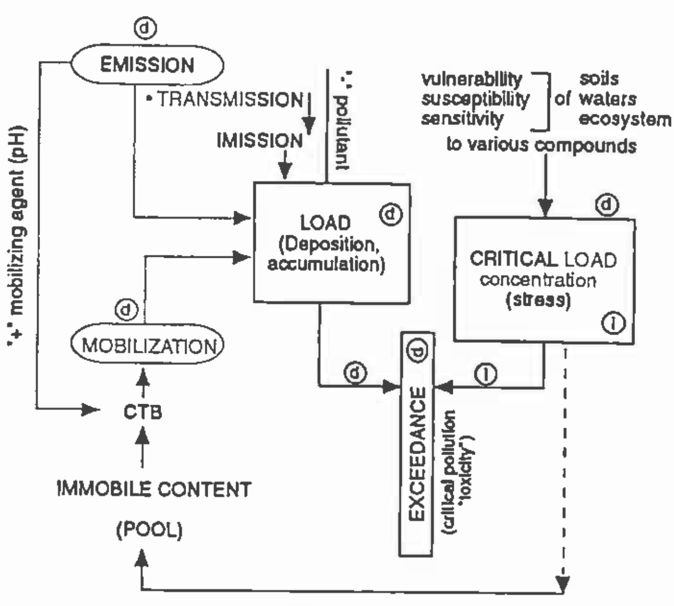

Figure 3
Strategy for pollution control (i: increase; d: decrease)

– 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.

In the last years considerable efforts have been made in Hungary for such assessments. The comprehensive micronutrient and pollutant monitoring programme failed, but a new soil monitoring programme (TIM) has started in 1992.

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.

Summary

Efficient, economically viable, socially acceptable and environmentally sound sustainable land management includes the following main elements:

1. Territorial co-ordination of the agro-ecological conditions (land-site characteristics) and the agro-ecological requirements of the cultivated crops, taking into consideration both the production and the environmental aspects in short-, mid- and long-term scales.

2. Rationalization of the structure of agricultural fields (under the new ownership structure).

3. Reduction (minimalization) of production wastes with their most efficient re-cycling without any harmful environmental side-effects.

4. Prevention of unfavourable soil degradation processes.

5. Improvement of the efficiency of agricultural water management and *soil moisture control.* Increase of the water storage within the soil in plant available form without any unfavourable environmental consequences.

6. Precision plant nutrient management.

7. Prevention and control of soil pollution.

These actions are joint tasks of the state, decision makers on various levels, land owners, land users, and – to a certain extent – of each member of the society. Only their joint efforts can be efficient towards a sustainable agricultural development harmonized with successful environment protection, ensuring pleasant environment and promising future.

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