Role of Soil Multifunctionality in Sustainable Development

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Abstract: Each society wishes to create favourable living conditions for its members. Life quality criteria are formulated in different ways by various societies or individuals, depending on the given geographical and socio-economic conditions, living standards; national, ethnical, and religious traditions; history, policy; age, sex, educational level, position in the social hierarchy; etc. Sustainable development is a global objective that includes efficient multifunctional agriculture: using environment-friendly, energy- and material-saving technologies and paying special attention to quality; and a socially acceptable rural development, simultaneously. The given land resources have to be used and managed in harmony with the production and protection.

Keywords: soil functions; soil resources; sustainable development

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– healthy, high quality food, and food security;
– clean water;
– pleasant environment.

All three are closely related to the sustainable management of the land resources, including the rational use of soil multifunctionality (Várallyay 1998, 2007, 2003).

Sustainable development

Sustainable development is a global objective: the management and conservation of the natural resource base, and the orientation of technological and institutional changes in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations (Láng *et al.* 1983; Greenland & Szabolcs 1993). Sustainable agricultural development conserves the land, water, plant, and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable (Várallyay 2003). Sustainable development includes efficient multifunctional agriculture: using environment-friendly, energy- and material-saving technologies and paying special attention to quality; and a socially acceptable rural development, simultaneously. The given land resources (geological formations, relief, atmosphere, surface and subsurface water resources, soil biota, vegetation) have to be used and managed in harmony with the production (satisfy the ever-growing demand of society) and protection (conservation, improvement) aspects (Figure 1) (Várallyay 1994, 2000, 2003).

Soil resources and soil functions

Land (the soil – water – near the surface atmosphere continuum, with its geology, relief and

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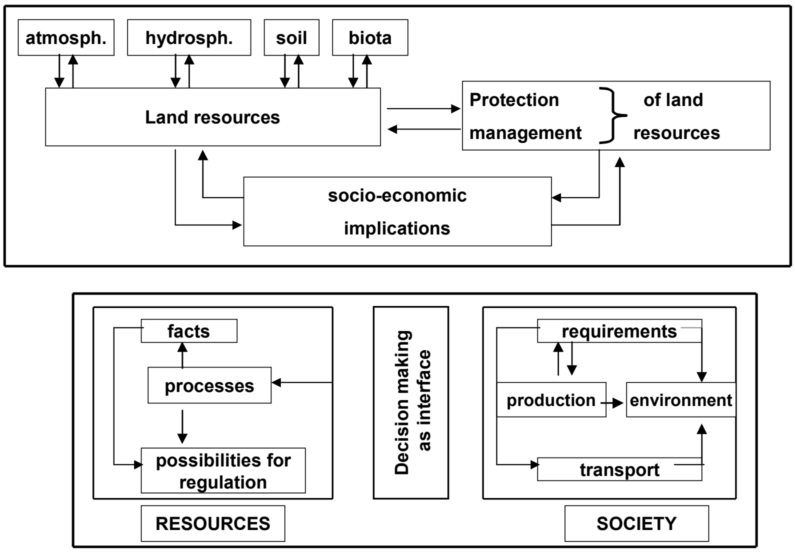

Figure 1. Relationships between the resources and society

biota) represents a considerable part of the nature. Consequently, rational land use and soil management – guaranteeing normal soil functions – is an important element of sustainable (agricultural) development, having special importance both in the national economy and in the environment protection (Csete & Várallyay 2004; Várallyay 1994, 1998).

The most important soil functions are as follows (Várallyay 2003, 2007):

(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 happen automatically. Soil conservation, the maintenance and increase of soil fertility requires permanent activities, such as rational land use, proper agrotechnique, and in some cases remediation, reclamation or amelioration (Greenland & Szabolcs 1993; Csete & Várallyay 2004).

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

(c) Soil is the most important medium for biomass production (food, fodder, industrial raw material, alternative energy). Soil, as a four-dimensional [spatial (horizontal and vertical) variability and temporal dynamism], three- (or four-) phase, polydisperse system can simultaneously satisfy – to a certain extent – the ecological requirements (air, water and nutrient supply) of living organisms, the natural vegetation and cultivated crops. This special ability is the unique soil property: soil fertility, which varies greatly and has changed considerably depending on natural factors and human activities. Soil is the primary food source of the biosphere, the starting point of the food chain (Várallyay 1994, 2000, 2003).

(d) Soil represents a major natural storage capacity of heat, water, plant nutrients and – in some special, well-controlled cases – wastes and other compounds. The stored water and plant nutrients ensure the continuous water and nutrient supply of plants (satisfying their uptake dynamics) for shorter or longer periods without any additional supply (rain, irrigation, nutrient application). This soil function is the basis of favourable soil moisture regime (preventing or moderating extreme hydrological situations as flood, water-logging, over-moistening vs. drought) and sustainable plant nutrition (Csete & Várallyay 2004; Várallyay 2006).

(e) Soil represents a high capacity buffer medium of the biosphere, which, within certain limits, may moderate the various stresses caused by environmental factors (extreme temperature; extreme hydrological events: floods, water-logging – droughts) and/or human activities (high input, fully-mechanised and chemically controlled crop production; liquid manure from large-scale livestock farms; wastes and waste waters originating from industry, transport, urban and rural development, etc.). Buffer systems have strict limits and boundary conditions. Sometimes this is forgotten by the users, which leads to serious environmental problems. To prevent and avoid unfavourable side-effects, the tolerance limits must be identified, precisely determined, quantified and evaluated. This requires comprehensive sensitivity (susceptibility, vulnerability) studies and impact analyses. Intensive international, regional, and national studies have been carried out to determine these tolerance limits and target conditions.Such evaluations are the scientific basis of documents such as the Soil Resolution of US (accepted by the 110th Congress); the Integrated European Soil Conservation Strategy; and national soil conservation strategies of various countries (Várallyay 2005b). In Hungary, comprehensive studies have identified and quantified the susceptibility/sensitivity/vulnerability of soils to wind and water erosion, acidification, salinisation/alkalisation/sodification, physical soil degradation (compaction, structure destruction, surface sealing) and chemical pollution (Csete & Várallyay 2004; Várallyay 1998).

(f) Soil is an efficient natural filter and detoxication system that may prevent the deeper horizons and the subsurface waters from becoming contaminated by various pollutants deposited on the soil surface or put into the soil.

(g) Soil is a significant gene reservoir for the biosphere and thus an important element of biodiversity. A considerable proportion of living organisms live in or on the soil or are closely related to (sometimes depending on) the soil.

(h) Soil is the conservator of natural and human heritages.

These functions are all equally important, but the society has used 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 utilisation of soil resources. In such cases the misguided management resulted in over-exploitation, decreasing the efficiency of one or more soil functions, and – above a certain limit – causing serious environmental deterioration (Várallyay 1994, 2000).

Limiting factors of soil multifunctionality

The major ecological constraints for multipurpose biomass production on the various subcontinents are summarised in Figure 2. Not an optimistic view, but a real fact (Várallyay 2000; Csete & Várallyay 2004).

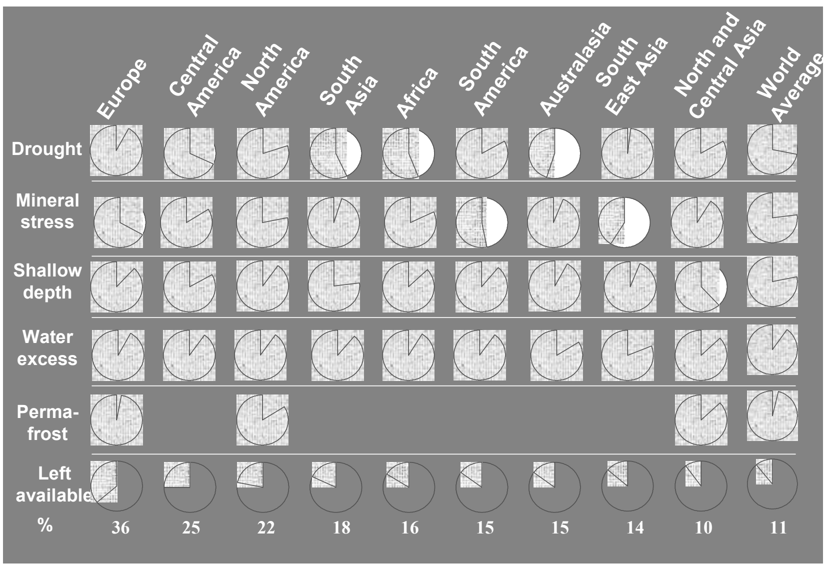

Figure 2. Major limitations of multipurpose biomass production on the subcontinents

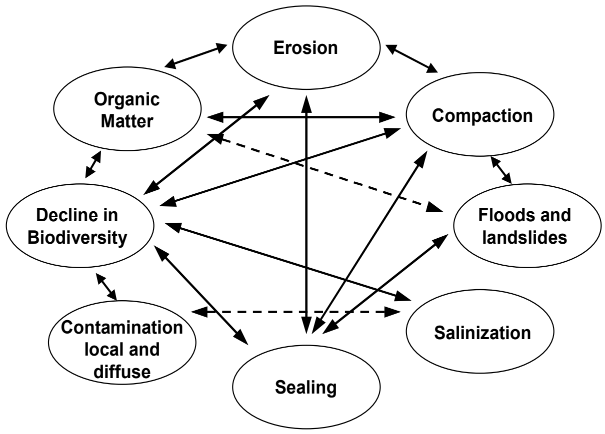

Figure 3. Land degradation problems in Europe

In the European Thematic Strategy of Soil Conservation, 8 main soil threats get priority attention: Figure 3 (Várallyay 2005b).

In the Carpathian Basin (especially on the Carpathian plains) the natural conditions are relatively favourable for rainfed biomass production. In spite of this fact, a considerable part of the soils are subject to various ecological constraints and unfavourable soil processes (Láng *et al.* 1983; Csete & Várallyay 2004; Várallyay 2006):

– Soil degradation processes: the main soil degradation processes are: soil erosion by water or wind; soil acidification; salinisation and/or alkalisation; physical degradation (structure destruction, compaction); biological degradation; decrease in natural buffering capacity (Várallyay 1989).
– Extreme moisture regime: the simultaneous hazard of waterlogging or over-moistening and drought sensitivity on large areas, sometimes in the same places within a short period of time (Várallyay 2006).
– Nutrient stresses: the deficiency or accumulation and/or toxicity of one or more elements in the biogeochemical cycle.
– Environmental pollution: the accumulation or mobilisation of various, potentially harmful (or even toxic) elements (or compounds) in the soil – water – plants – animals – human beings food chain (Várallyay 2000).

Control of soil functions

The multifunctionality of soil is determined by the combined influences of the soil properties, which are the results of the soil processes: mass and energy regimes, abiotic and biotic transport and transformation, and their interactions. The control of the soil processes is a great challenge and the main task of the soil science and soil management (Várallyay 1998).

The control of the soil functions requires adequate soil information: exact, reliable, detectable (preferably measurable) and accurate, quantitative territorial data on well-defined soil and land properties, including the characterisation of their spatial (vertical, horizontal) and temporal variabilities and pedotransfer functions; on the soil processes and biogeochemical cycles, including their determining and influencing factors and their mechanisms, and on the actual and/or potential impacts of human activities. The schematic model of the strategy of the soil process control is shown in Figure 4.

In Hungary, a large amount of such information is available as a result of long-term observations, and various soil surveys, analytical and mapping activities conducted at the national (1:500 000), regional (1:100 000), farm (1:10 000–1:25 000) and field levels (1:5 000–1:10 000) over the past 60 years. A considerable part of these data were organised into a GIS database giving opportunities for an efficient control of the soil processes and soil functions (Várallyay 2005a; Várallyay *et al.* 1985).

Efficient, economically viable, socially acceptable, and environmentally sound sustainable, multifunctional soil management includes the following main elements (Várallyay 2003, 2007):

(1) Territorial coordination of the agroecological conditions (land-site characteristics) and the agro-ecological requirements of the cultivated crops: site-specific land use and cropping pattern; selection and breeding of varieties and genotypes for the given conditions; improvement of (soil) ecological conditions.
(2) Rationalisation of the structure of agricultural fields: optimisation of the field size; development of proper infrastructure.
(3) Reduction (minimalisation) of production wastes*:* plant residues; animal excrements, wastes from yield and food processing, with their most efficient recycling without any harmful environmental side-effects.
(4) Control (prevention, elimination or at least moderation) of undesirable soil degradation processes: Priority must be given to the efficient preventive measures, based on comprehensive prognoses, sensitivity, and impact analyses.

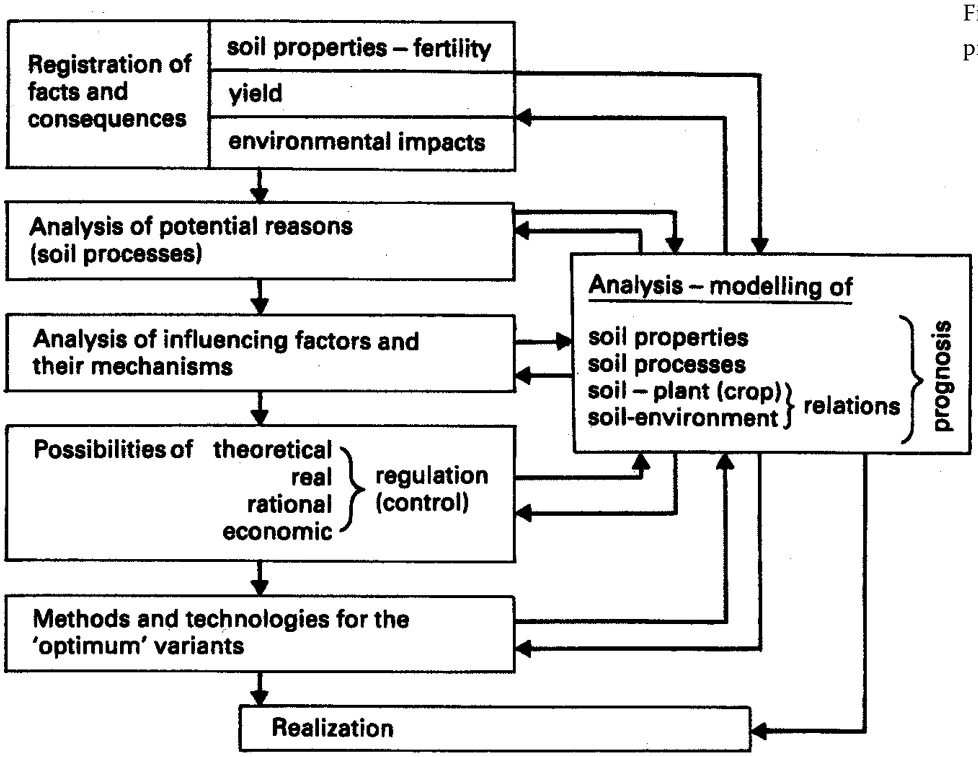

Figure 4. Control of soil processes

(5) Improvement of the efficiency of agricultural water management and soil moisture control:
  - increase the water storage within the soil in plant-available form without any unfavourable environmental consequences: help infiltration into the soil; increase the water storage capacity; reduce the immobile and not plant-available moisture content;
  - reduce evaporation, surface runoff and filtration losses;
  - improve the vertical and horizontal drainage conditions.

(6) Precision plant nutrient management:
  - rational use of fertilisers based on crop requirements (dynamics of their nutrient uptake), soil conditions and agroclimate;
  - efficient recycling of crop residues;
  - utilisation of wastes with utilisable plant nutrient content and without potentially harmful chemical compounds.

(7) Soil pollution control:
  - emission/imission reduction;
  - prevention of the mobilisation of potentially harmful chemical compounds;
  - reduction of the vulnerability of soil to various pollutants.

References

Greenland D.J., Szabolcs I. (eds) (1993): Soil Resilience and Sustainable Land Use. CAB International, Wallingford.

Csete L., Várallyay Gy. (eds) (2004): Agroecology, Environmental Relations of Agro-ecosystems and Possibilities of their Control. AGRO-21 Füzetek, No. 37. (in Hungarian)

Láng I., Csete L., Harnos Zs. (1983): The Agro-ecological Potential of Hungarian Agriculture in 2000. Mezőgazd, Kiadó, Budapest. (in Hungarian)

Várallyay Gy. (1989): Soil degradation processes and their control in Hungary. Land Degradation and Rehabilitation, **1**: 171–188.

Várallyay Gy. (1994): Soil management and environmental relationships in Central and Eastern Europe. Agrokémia és Talajtan, **43**: 41–66.

Várallyay Gy. (1998): Multifunctional soil management for sustainable development in Hungary. Agrokémia és Talajtan, **47**: 7–22.

Várallyay Gy. (2000): Soil quality in relation to the concepts of multifunctionality and sustainable development. In: Wilson M.J., Maliszewska-Kordybach B.: Soil Quality, Sustainable Agriculture and Environmental Security in Central and Eastern Europe. NATO Science Series 2. Environmental Security, Vol. 69, Kluwer Academic Publishers, Dordrecht – Boston – London. 17–33.

Várallyay Gy. (2003): Role of soil multifunctionality in future sustainable agricultural development. Acta Agronomica Academiae Scientiarum Hungaricae, **51**: 109–124.

Várallyay Gy. (2005a): Soil survey and soil monitoring in Hungary. In: Jones R.J.A., Housková B., Bullock P., Montanarella L. (eds): Soil Resources of Europe. ESB Research Report No. 9, 2nd Ed., JRC, Ispra, 169–179.

Várallyay Gy. (2005b): Soil conservation strategy in an extended Europe and in Hungary. In.: Sobocka J. (ed.): 4th Slovakian Pedological Days, Cingov, June 14–16, 2005, 372–379. (CD ROM)

Várallyay Gy. (2006): Soil degradation processes and extreme soil moisture regime as environmental problems in the Carpathian Basin. Agrokémia és Talajtan, **55**: 9–18.

Várallyay Gy. (2007): Soil multifunctionality in sustainable development. Tessedik Sámuel Főiskola Közlemények, **7**: 309–315.

Várallyay Gy. *et al.* (1985): Soil factors determining the agroecological potential of Hungary. Agrokémia és Talajtan, **34** (Supplement): 90–94.

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