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Soil degradation processes and extreme hydrological situations, as environmental problems in the Carpathian Basin

György VÁRALLYAY
email: g.varallyay@rissac.hu

Research Institute for Soil Science and Agricultural Chemistry
(RISSAC) of the Hungarian Academy of Sciences,
Budapest, Hungary

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Abstract. Rational and sustainable use of soils – the most important, conditionally renewable, natural resources in the Carpathian Basin – are priority tasks of biomass production and environment protection. Natural conditions in the Carpathian Basin are generally favourable for rainfed biomass production. These, however, show extremely high, irregular, hardly predictable spatial and temporal variability, often extremes, and sensitively react to various natural or human-induced stresses. The main constraints are: soil degradation processes; extreme moisture regime; unfavourable changes in biogeochemical cycles of elements. Soil processes can be controlled (to a certain extent) and their unfavourable consequences can be prevented or at least moderated.

Keywords: soil multifunctionality; soil fertility; soil resilience; soil moisture control; waterlogging hazard; drought sensitivity

1 Introduction

Soils are the most important – conditionally renewable – natural resources in the Carpathian Basin. Consequently, their rational and sustainable use, protection and conservation, maintaining their desirable multifunctionality, are priority tasks of biomass production and environment protection and are key elements of sustainable development.

2 Natural conditions

The natural conditions of the Carpathian Basin (particularly the lowlands and plains) are generally favourable for rainfed biomass production [1, 9]. These conditions, however, show high and irregular, consequently hardly predictable spatial and temporal variability, often extremes and sensitively react to various natural or human-induced stresses. The generally favourable agroecological potential is mainly limited by three soil factors:

(1) Soil degradation processes [2, 8].
(2) Extreme moisture regime: simultaneous hazard of flood, waterlogging, over-moistening and drought sensitivity [12, 13].
(3) Unfavourable changes in the biogeochemical cycles of elements, especially of plant nutrients and environmental pollutants.

The comprehensive assessment and efficient control of these phenomena are the primary tasks of multipurpose biomass production, environment protection and sustainable rural development.

3 Limiting factors of soil multifunctionality and soil degradation processes

The main limiting factors of soil multifunctionality/fertility/productivity in Hungary are shown in Figure 1 [6].

The most important soil degradation processes in the Carpathian Basin (similarly to Europe) are summarized in Figure 2.

In spite of the large and increasing extension of degraded lands in all continents, it can be stated that soil degradation is not an unavoidable consequence of intensive (but rational!) agricultural production and social development! Because of soil resilience most of these soil degradation processes can be prevented, eliminated or at least moderated. But it needs permanent control and widely adopted soil (and water) conservation technologies, as indispensable elements of sustainable site-specific precision soil management.

In the last years the revolutionary development of in situ and laboratory analytics, remote sensing, informatics, computer technology, GIS/GPS applications, etc. have given opportunity for the control of soil degradation processes on the basis of an up-to-date comprehensive environment/soil database [7]. This was the aim of the GLASOD (Global Assessment of Soil Degradation) and PHARE-MERA international projects; and this is in the focus of the European Soil Conservation Strategy [11]. In Hungary – based on all available soil information – the "environmental sensitivity/susceptibility/ vulnerability of soils to various soil degradation processes were comprehensively analysed, giving a good scientific basis for the development of the Hungarian Soil Conservation Strategy [3].

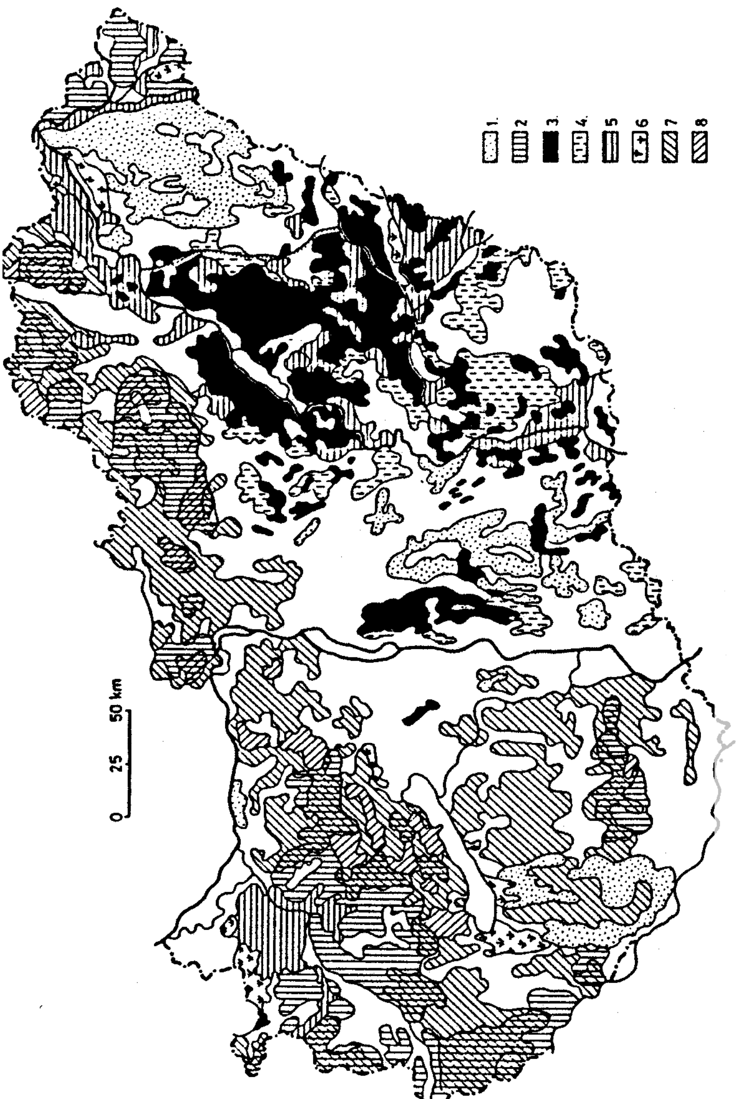

Figure 1: Map of the limiting factors of soil fertility in Hungary.
1. Extremely coarse texture (8% of the total area of Hungary). 2. Acidity (12.8%). 3. Salinity and/or sodicity (8.1%). 4. Salinity and/or sodicity in the deeper layers (2.6%). 5. Extremely heavy texture (6.8%). 6. Peat formation (1.7%). 7. Erosion (15.6%). 8. Shallow depth (2.3%).

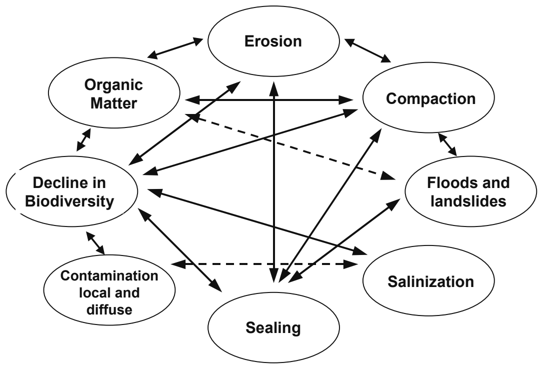

Figure 2: The main soil degradation processes in the Carpathian Basin

4 Extreme moisture regime

It can be predicted with high probability that in future water will be the determining (hopefully not limiting) factor of food security and environmental safety in the Carpathian Basin [4, 5]. Consequently, the risk reduction of extreme hydrological events and soil moisture regimes, and the increase of water use efficiency will be the key issues of soil and water management, biomass production.

Limited water resources

The water resources are limited and an increasing water demand must be satisfied from these limited resources [5].

The average 500-600 mm annual precipitation in the Pannonian Plains shows extremely high territorial and temporal (Figure 3) variability – even at micro-scale. Under such conditions a considerable part of the precipitation is lost by surface runoff, downward filtration and evaporation. Precipitation will not be more in the future. On the contrary, it might be less and its spatial and time variability is expected to increase. It results in increasing risk (frequency, intensity) of extreme weather events (high intensity rains, droughts etc.) with their hydrological (flood, waterlogging, over-moistening), ecological (droughts, crop damages, yield reduction) and environmental (erosion-sedimentation, infrastructure damages, landscape destruction) consequences.

The available quantity of surface waters (rivers) will not increase, particularly not in the critical low-water periods.

A considerable part of the subsurface waters (especially in the poorly drained lowlands) is of poor quality (high salinity, alkalinity, sodicity), threatening with harmful salinisation/sodification processes. The over-exploitation of groundwater may result in serious environmental deterioration: "desertification symptoms" appear.

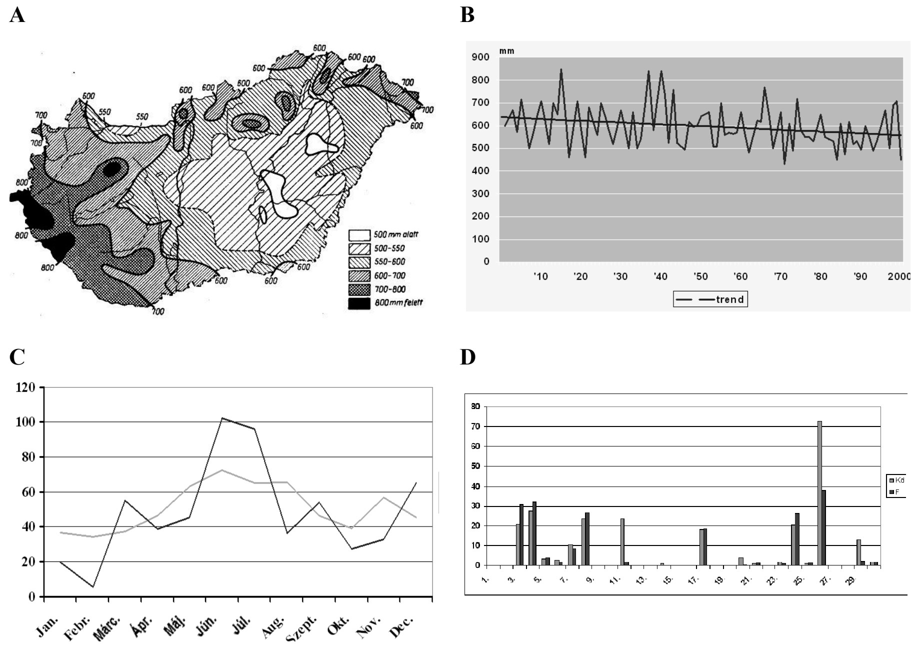

Figure 3: Territorial and time distribution of atmospheric precipitation in Hungary. A. Geographical distribution of the 100-year average annual precipitation. B. Average annual precipitation in Hungary in the 20^{th} century. C. Monthly distribution of the long-term average and 2008 annual precipitation. D. Daily distribution of monthly precipitation (May 2008) at two nearby meteorological stations

(Hydro)Physical properties of soils

There are two additional reasons of extreme soil moisture regime:

- the heterogeneous microrelief of the "flat" lowland;
- the highly variable, sometimes mosaic-like soil cover and the unfavourable physical and hydrophysical properties of some soils [10, 13].

According to our comprehensive assessment 43% of Hungarian soils can be characterized by unfavourable, 26% by moderately (un)favourable and 31% by favourable moisture regime, as illustrated by Figure 4, indicating the main reasons of various moisture conditions.

In the last years a comprehensive soil survey-analysis-categorization-mapping-monitoring system was developed in Hungary for the exact characterization of hydrophysical properties, modelling and forecast of water and solute regimes of soils. The system was used efficiently in the planning, implementation, operation, maintenance and control of land use and agricultural water management activities [10, 14].

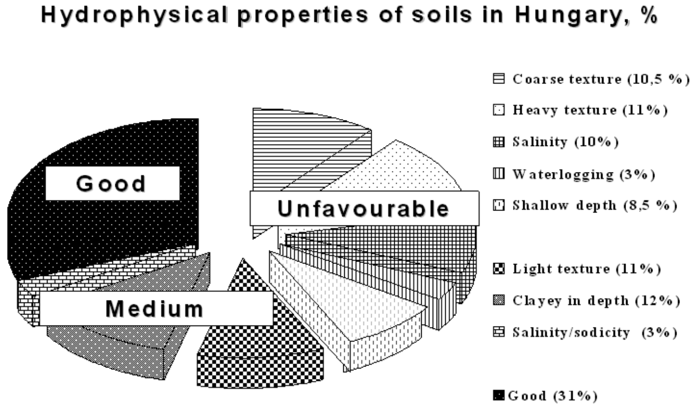

Figure 4: Moisture regimes of soils in Hungary and their reasons

The schematic map of these – quantitatively characterized – soil hydrophysical categories is presented in Figure 5.

5 Soil as water reservoir – extreme hydrological events

Under the given natural conditions it is an important fact that soil is the largest potential natural water reservoir (water storage capacity) in the Carpathian Basin. The 0-100 cm soil layer may store about half of the average annual precipitation and about 50% of it is “available moisture content”. In many cases, however, this huge potential water storage capacity is not utilized because of:

- limited infiltration due to water saturated pore volume: frozen topsoil; nearly impermeable soil surface or near surface soil horizon;
- poor water retention.

As a consequence of these limitations the risk/hazard of extreme hydrological/soil moisture events (as flood, waterlogging, over-moistening vs. droughts) are characteristic features in the Carpathian Basin and occur with increasing frequency and intensity, often in the same year on the same area.

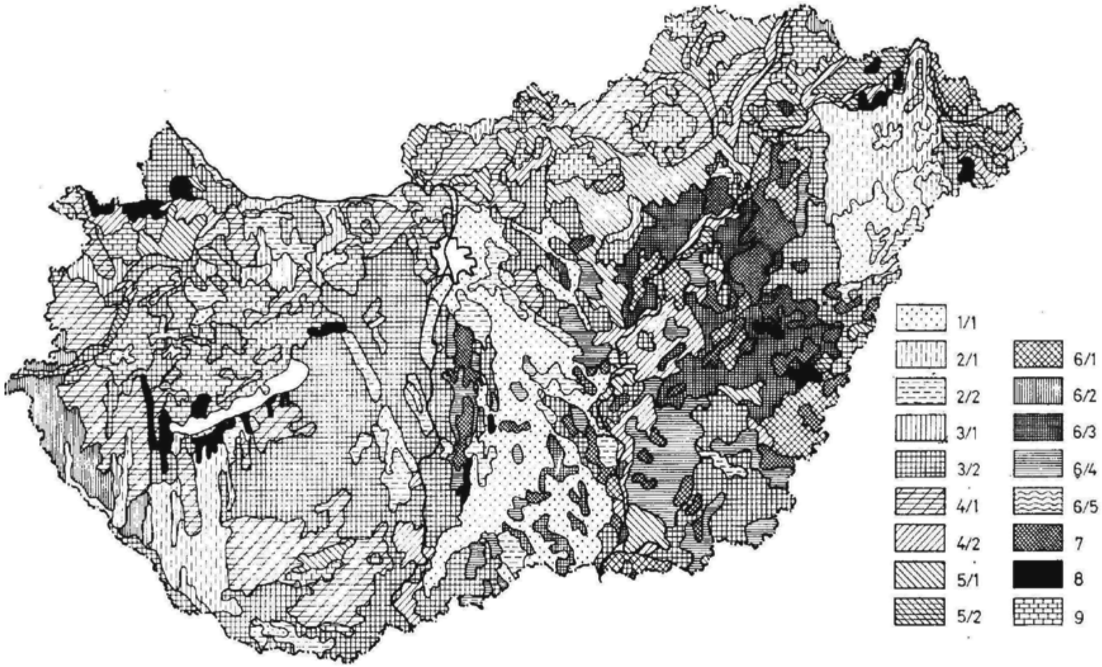

Figure 5: Hydrophysical characteristics of soils in Hungary

1.Soils with very high IR, P and K; low FC; very poor WR. 2. Soils with high IR, P and K; medium PC; and poor WR. 3. Soils with good IR, P and K; good FC; and good WR. 4. Soils with moderate IR, P and K; high FC; and good WR. 5. Soils with moderate IR, poor P and K; high PC and high WR. 6. Soils with unfavourable water management: very low IR and K. 7. Soils with extremely unfavourable water management due to high salinity/sodicity: extremely low AMR, IR and K. 8. Soils with good IR, P and K; and very high FC (organic soils). 9. Soils with extreme moisture regime due to shallow depth. *The main profile variants:* (1) texture becomes lighter with depth (soils formed on relatively light-textured parent material): 2/1, 3/1. (2) uniform texture within the profile: 1/1, 2/2, 3/2, 4/2, 5/2. (3) relative clay accumulation in the horizon B: 4/1, 5/1. Profile variants of category 6: 6/1: highly compacted, heavy-textured soils with poor structure; 6/2: pseudogleys; 6/3. deep meadow solonetzes and solonetzic meadow soils; 6/4: soils with salinity/sodicity in the deeper horizons; 6/5: peaty meadow soils

6 Unfavourable changes in the biogeochemical cycles of elements

Soil moisture regime has distinguished significance in soil productivity. It determines the water supply of plants, influences the air- and heat regimes, biological activity and plant nutrient status of soil. In most of the cases it determines the agro-ecological potential; the biomass production of various natural and agro-ecosystems; environmental sensitivity and the hazard of soil and water pollution. Extreme hydrological situations and soil moisture regime result in unfavourable changes in the biogeochemical cycles of elements (plant nutrients, pollutants) [13, 14].

7 Control of extreme moisture regime

The control of extreme field water cycle requires a special "two-way" ("double faced") soil moisture control in the Carpathian lowlands. Because the "active" water management actions, such as irrigation and drainage are faced with serious economical and environmental limitations [12] all efforts have to be taken

- to reduce evaporation, surface runoff and filtration losses;
- to increase the available moisture content of the soil: to help infiltration; increase the water storage capacity; reduce the immobile moisture content;
- 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 "moisture management actions" are – at the same time – efficient environment control measures [12, 13].

8 Conclusion

Sustainable and rational land use, soil and water management, including the risk reduction of extreme hydrological events and soil moisture regime requires continuous actions. This permanent control may prevent, eliminate or at least reduce undesirable soil processes and their harmful economical/ecological/ environmental/social consequences; and may satisfy the conditions for the "quality maintenance" of this "conditionally renewable" natural resource.

Control – with priorities of preventive actions – can be efficient only on the basis of comprehensive database, risk assessment, impact analysis and prognosis.

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