Soil Mapping in Hungary

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Soils represent a considerable part of the natural resources of Hungary, consequently, their rational utilization has particular importance in the national economy /especially in agricultural development/; and their conservation has particular significance among the tasks of environment protection.

The main functions of soils in the biosphere can be summarized, as follows /VÁRALLYAY, 1988/:

a/ Soil as reactor, is the transformator and integrator of the combined influences of various natural resources, as solar radiation, atmosphere, surface and subsurface waters and biological resources. Soil represents the "life media" for microbiological activities and the ecological environment /standort, landsite/ for natural vegetation and cultivated crops.

b/ Soils are the most important means of production in agriculture, the most important media for crop production.

c/ Soils are the most significant - conditionally renewable - natural resources. During crop production they do not change irreversibly, their quality does not decrease necessarily, radically and fundamentally. This renewal does not go on automatically: the maintenance and increase of soil fertility requires permanent activities. In most cases this is the aim of agrotechnics and amelioration.

d/ Soils represent a high capacity buffer media of the biosphere, which - to a certain limit - may buffer and can moderate the various stresses caused by:
  - environmental factors, as climatic droughts, or too humid conditions, air pollution, frost, etc. and/or
  - human influences, as intensive, fully-mechanized and chemically controlled crop production; liquid manure of large-scale animal husbandry farms; wastes and waste waters originating from industry, transport, civilization, urbanization, recreation; pollution from various sources, etc.

Unfortunately, the human-induced stresses gradually increase in their probability, intensity, frequency and territorial occurrence, and their consequences are becoming more and more threatening.

The most important, unique and complex characteristic of soil is fertility /or productivity/: the specific feature that water, air and available plant nutrients may occur simultaneously in this four-dimensional, four-phase, polydisperse system and may cover - to a certain extent - the main soil ecological requirements of natural vegetation or cultivated crops. Soil fertility depends on the integrated influences of various soil characteristics and properties, which are the result of soil processes, the mass and energy regimes, abiotic and biotic transport and transformation processes of soils, or more exactly, the geological strata - soil - water - plant- - near-surface atmosphere system.

Consequently, any soil-related activity, as land use, crop production, agrotechnics, amelioration, waste disposal, etc. influences land qualities, landsite characteristics, soil characteristics and properties through these processes. The final aim is to control these processes in such a way, which simultaneously guarantees:

- normal soil functions;
- the renewal of soil as natural resource
  - maintenance or increase of soil fertility,
  - prevention of harmful soil degradation processes;
- the satisfaction of soil ecological requirements of various crops, as well as soil technological requirements of various agrotechnical operations;
- the prevention of undesirable environmental consequences, e.g. pollution of surface and subsurface waters; landscape deteriorations, etc.

To ensure the effectivity, rationality and efficiency of any soil-related action, for the establishment of an exact scientific basis for rational land use, and for the various measures guaranteeing normal soil functions, ensuring the soil ecological requirements of plants as well as the maintenance and increase of soil fertility /e.g. agrotechnics: soil cultivation, tillage operations, plant nutrient supply, etc.; amelioration: soil reclamation and chemical improvement, soil conservation, irrigation-drainage, levelling, etc./ adequate *soil information* are required. These are exact and quantitative territorial data on well-defined soil and land characteristics and properties, as well as on single and compound land qualities, including pedotransfer functions; with statistical characteristics on their spatial /vertical, horizontal/ and time variabilities. Soil information are required on global, regional, national, micro-regional, farm and field levels, and in different phases of these actions: necessity evaluation → selection of necessary elements → planning → implementation → maintenance → utilization.

Hungarian soil science and soil survey - soil analysis practices have always paid special attention to fulfill these requirements, and continuously give a particularly significant help in the development, planning and organization of agricultural production and environment protection /Table 1/. It was mainly due to the following facts:

- the relatively small size of the country /93 000 km^2/;
- highly variable physiography: meteorological, geological, hydrological conditions, relief, etc., and, consequently, the occurrence of a wide range of different soils with high spatial and time variabilities;
- wide range of landuse problems: highly mechanized, large-scale farming with intensive chemization; concentrated animal husbandry; flexible cropping pattern, appropriate for the given ecological conditions; amelioration of various soils with limited fertility; prevention of various soil degradation processes; agricultural water management; rural and urban development; environment protection; etc.
- particular importance of agricultural production in the national economy;
- high amount of data and information, as a result of long-term meteorological and hydrological observations, detailed geological and soil survey, and mapping.

Soil maps are thematic maps indicating soil information on territorial basis. These information can be measured, calculated or estimated data of simple tests /feeling/, field observations and measurements, and laboratory analyses, as well as remotely sensed data /aerial photographs, multispectral satellite imagery, etc./. Soil maps may indicate single numerical values, categories defined by limit values, interpretations for various purposes, and - on these bases - recommendations for practical landuse and various operations. In Hungary the following levels of "decisions", and consequently, soil maps, can be distinguished:

- national level	1:500 000 scale	with relevant content /number of parameters and categories with their limit values/, data base, accuracy and "fidelity".
- regional level	1:100 000 scale	
- farm level	1:10 000-1:25 000 scale	
- field level	1:5 000-1:10 000 scale	

The rational scale and relevant content of a soil map depends on the main purpose of mapping and its accuracy-probability requirements, and the data base must be in accordance with these requirements. The various soil maps represent an up-to-date, concrete synthesis of soil information according to the given level of soil science and agricultural production. This fact is clearly illustrated by the history of Hungarian soil science and soil mapping /BALLENEGGER and FINÁLY, 1963; ENYEDY and HINRICHSSEN, 1989; STEFANOVITS, 1968; VÁRALLYAY, 1985/. It can be characterized by the periodical fluctuation of analysis and synthesis, the preparation of large-scale /analytical/ soil maps and their generalization into medium and small scale /synthesis/ soil maps.

The main etaps of Hungarian soil mapping can be summarized, as follows:

1. *Agro-geological mapping*

The first agro-geological map, including some soil information, as parent material, texture and organic matter status, was prepared by J. SZABÓ for Békés-Csanád county in the scale of 1:576 000 as early as 1858.

Large-scale agro-geological maps were prepared between 1890 and 1910 by eminent geologists of the Agrogeological Department of the Royal Hungarian Geological Institute by INKEY, HORUSITZKY, TREITZ, TIMKÓ, GÜLL, LÁSZLÓ and others /cit. in: BALLENEGGER and FINÁLY, 1963; STEFANOVITS, 1968/
- on 1:25 000 scale cartographic sheets for physico-geographic regions;
- in the scale of 1:14 500 or even 1:3 500 for large farming units.

The majority of the prepared more than 30 maps was published in printed form. The colour-printed maps indicate agrogeological characteristics, such as geological strata, parent material, soil texture and organic matter content. The map sheets were completed with coloured schematic soil profile illustrations and were supplemented by Hungarian and German explanatory booklets, containing the field description of soil profiles and borings, the results of some simple laboratory analyses, a short description of the physicogeographical characteristics of the area, and recommendations for its rational agricultural utilization.

Such maps were prepared only for some thousands of hectares and the promising action was subdued by the Great War /1914-1918/.

2. *The first synthesis*

TIMKÓ /cit. in: BALLENEGGER and FINÁLY, 1963; STEFANOVITS, 1968/ had drawn up the first soil map of Great Hungary in the scale of 1:900 000 in 1914. On the basis of his experiences in Russia he used the taxonomy units of the classical Russian /Dokuchaev/ genetic soil classification, distin-

Table 1

Thematic soil maps in Hungary

No.	Map	Scale	Date of preparation	Prepared for	Content	Author/s/	References
1.	Practical soil maps	1:25 000	1935-1955	the whole country per topographical map sheets	m, tm, fd, ld, e	Kreybig and coll.	KREYBIG, 1937
2.	Large-scale genetic soil maps	1:10 000	1960-1975	60% of the agricultural land of Hungary, per farming units	m, tm, fd, ld, e	Coll.	SZABOLCS, 1966
3.	Soil conditions and the possibilities of irrigation	1:25 000	1960-1970	present and potential irrigated regions	6 thematic maps fd, ld	Coll.	SZABOLCS, DARAB, VÁRALLYAY, 1969
4.	Large-scale maps for amelioration projects	1:5 000- 1:10 000	1960-	amelioration projects /occasionally/	m, e	Coll.	
5.	Soil factors determining the agro-ecological potential	1:100 000	1978-1980	the whole country per topographical sheets	m /with an 8-digit code/, c	Várallyay, G. Szűcs, L. Murányi, A. Rajkai, I. Zilahy, P.	VÁRALLYAY et al., 1979, 1980, 1985
6.	Agro-topographical map	1:100 000	1987-1988		m /with a 10-digit code/, c	Várallyay, G. Molnár, S. Szűcs, L.	VÁRALLYAY, MOLNÁR, 1989

Table 1 continued

No.	Map	Scale	Date of preparation	Prepared for	Content	Author/s/	References
7.	Hydrophysical properties of soils	1:100 000	1978-1980	the whole country per topographical map sheets	m, c	Várallyay, G. Szűcs, L. Rajkai, K. Zilahy, P.	VÁRALLYAY et al., 1980
8.	Limiting factors of soil fertility	1:500 000	1976	the whole country	m	Szabolcs, I. Várallyay, Gy.	SZABOLCS, VÁRALLYAY, 1978
9.	Main types of moisture regime	1:500 000	1983		m, c	Várallyay, Gy. Zilahy, P. Murányi, A.	VÁRALLYAY, 1989a
10.	Main types of substance regime	1:500 000	1983		m, c	Várallyay, Gy. Szűcs, L. Molnár, E.	VÁRALLYAY, 1989b
11.	Soil erosion	1:500 000	1960-1964		m, tm, e	Stefanovits, P. Duck, T.	STEFANOVITS, 1964
12.	Salt affected soils	1:500 000	1970-1974		m, e	Szabolcs, I. Várallyay, Gy. Mélyvölgyi, J.	SZABOLCS, 1974
13.	Susceptibility of soils to acidification	1:100 000 1:500 000	1985-1988		m, c	Várallyay, Gy. Rédly, M. Murányi, A.	VÁRALLYAY et al., 1989
14.	Susceptibility of soils to physical degradation	1:500 000	1985-1988		m, c	Várallyay, Gy. Leszták, M.	VÁRALLYAY, LESZTÁK, 1989

m: soil map; tm: thematic map; fd: field description; ld: laboratory data; e: explanatory booklet;
c: computer storage

guishing and indicating eight zonal, three azonal and one intrazonal soil types in Hungary.

TREITZ /1924/ compiled the "Climazonal soil map" of Hungary /in the scale of 1:1 000 000/ in 1918. His material was presented at the 2nd Congress of the International Society of Soil Science /Washington, 1927/. On the map the main classes of soils and soil forming factors /geology parent material, climate, vegetation/ were indicated simultaneously, giving possibilities for the evaluation of their relationships.

3. 1:25 000 scale practical soil mapping

In 1935 a national programme was initiated by L. KREYBIG for a systematic, 1:25 000 scale practical soil mapping /KREYBIG, 1937/.

These maps were prepared on topographical sheets of 56x75 cm size /262.5 km^2/ for the whole country between 1935 and 1955. The present territory of Hungary was covered by 385 sheets. 105 sheets were published in printed form, 280 sheets are available in hand-painted form, as manuscripts.

The maps indicate soil reaction and carbonate status, salinity-alkalinity status, permanently or temporarily waterlogged areas and forest lands /altogether 7 categories/ by colours; physical-hydrophysical properties of soils and soil depth /altogether 8 categories/ by symbols. These categories were delineated by contours. Five additional soil characteristics for "representative soil profiles" were given on printed maps /expressed by coded categories defined by numerical limit values: organic matter content /8 categories/; total P_2O_5 and K_2O content /5-5 categories/; depth of the humus horizon /cm/ and average depth of the groundwater table /m/. The soil order, type and subtype were expressed by a three-digit Roman number code, according to 'SIGMOND's soil classification. The location of the "representative" and "additional" soil profiles and supplementary borings were indicated on the map, but their "validity areas" were not delineated by contours Each map sheet was supplemented with an explanatory booklet containing information on the physico-geographical conditions and soil formation processes of the area, the description and characterization of soils occurring, and recommendations for their rational utilization /landuse, cropping pattern, agrotechnics/. An Annex with the field description of soil profiles and the results of field measurements and laboratory analyses was attached.

In the early fifties, when the action was successfully completed, Hungary was the first country in the World to have such detailed soil information /1:25 000 scale maps and complementary data base/ for the whole country. These maps represent a good basis for subsequent soil mapping activities, have been successfully used for various soil-related actions within the last fifty years, and represent a valuable treasure of soil information at the present time.

4. Genetic soil map of Hungary /second synthesis/

As the up-to-date synthesis of KREYBIG soil maps, STEFANOVITS, SZŰCS and their co-workers compiled the genetic soil map of Hungary in 1954 and 1961 in the scales of 1:200 000 and 1:500 000, respectively /STEFANOVITS, 1968; STEFANOVITS and SZŰCS, 1961/. On the map 29 genetic soil types and subtypes were distinguished by colours /according to the Hungarian soil classification system /STEFANOVITS, 1981; SZABOLCS, 1966/ and 18 parent material classes were indicated /and delineated/, as well.

The 1:500 000 scale map was the basis of numerous thematic soil maps, such as

Fig. 1

Map of soil erosion in Hungary. /Simplified, schematic version of the original 1:500 000 scale map/. 1: Non-eroded areas; 2: Slightly eroded areas; 3: Moderately eroded areas; 4: Severely eroded areas; 5: Sedimentation territories; 6: Forests

- organic matter resources
- C:N ratio
- $C:P_2O_5$ ratio } /STEFANOVITS, 1968/
- possibilities of soil tillage
- necessity of soil amelioration
- status of soil erosion /STEFANOVITS, 1964/. /The simplified version of this map is presented in Fig. 1./
- limiting factors of soil fertility /SZABOLCS and VÁRALLYAY, 1978/
- hydrophysical properties /DARAB, 1962/
- salt affected soils /SZABOLCS, 1974, 1989/
- possibilities and conditions of irrigation /SZABOLCS et al., 1969/.

5. *Large-scale soil mapping*

After the collectivization of Hungarian agriculture /in the early sixties/ a system was elaborated by a large team of theoretical and practical soil scientists, soil surveyors and soil mapping specialists for the large-scale /1:10 000/ genetic soil mapping to satisfy the practical needs of soil information in the large farming units: state farms and co-operative farms /SARKADI et al., 1964; SZABOLCS, 1966/.

Such maps were prepared - mostly between 1960 and 1975 - for about two-thirds of the arable land of Hungary /about 35 000 km^2 from the total of 52 000 km^2 arable land/.

The system of large-scale practical soil mapping consists of four main parts:

- Genetic soil map, indicating soil taxonomy units - types, subtypes and varieties - according to the Hungarian soil classification system, and the parent material.
- Thematic soil maps on the most important physical and chemical soil properties, such as: soil reaction and carbonate status; texture and depth of the soil; hydrophysical properties; salinity-alkalinity status; depth of the humus horizon and organic matter content; plant nutrient status for N, P and K; depth of the water table, salt content and salt composition of the groundwater.
- Thematic maps, indicating recommendations for rational landuse, cropping pattern, amelioration /erosion control, reclamation, irrigation, drainage/, tillage practice and fertilization.
- Data base with explanatory booklet, including a short review on the physico-geographical conditions of the area concerned; description and characterization of the soils occurring and recommendations for their rational utilization; the field description of soil profiles; results of field observations or measurements and data of laboratory analyses.

These maps were widely and successfully used in Hungary and became an easily applicable scientific basis of intensive, large-scale agricultural production, in spite of the fact that generally these maps were not published in printed form /with the exception of a few examples published in the "Genetic Soil Maps" Series by OMMI /National Institute for Agricultural Quality Testing/ /DARAB, 1962; DARAB and FERENCZ, 1969; STEFANOVITS, 1964; STEFANOVITS and SZÜCS, 1961; SARKADI et al., 1964; SZABOLCS, 1966/ and are available only as manuscripts at the farming unit or at the Plant and Soil Conservation Service. The large-scale soil mapping programme /correction and up-dating of available maps and the preparation of new maps for the missing part (~1/3) of the country started again - after a more than ten-year stagnation - in 1986 within the framework of the National Land Evaluation Programme /Guidelines for large-scale soil mapping, 1987/.

A special soil mapping system was elaborated and successfully applied for the prognosis and prevention of the harmful side-effects of irrigation /secondary salinization-alkalization; peat formation/ in the territory of the Tisza irrigation systems /SZABOLCS et al., 1969/. The 1:25 000 scale mapping system consists of the preparation of four "analytical" thematic sheets /soil map; texture and hydrophysical properties; salinity-alkalinity status; groundwater conditions/ and two "synthesis" thematic sheets /"critical depth" of the groundwater table; possibilities, preconditions and recommendations of irrigation/. Such maps were prepared for a large part of the Tisza irrigation systems /~3 000 km^2/ - as hand-painted manuscripts. The maps serve as a comprehensive scientific basis of efficient irrigated farming without any harmful environmental side-effect.

For the farm- and field level planning, implementation and follow-up of various agrotechnical and ameliorative measures towards the optimation of soil moisture regime, a special 1:10 000-1:25 000 scale mapping system was elaborated by VÁRALLYAY /1985, 1989a/. It consists of the preparation of four thematic maps /soil map; map of salinity-alkalinity status; hydrophysical properties; groundwater conditions/ with the application of a digital code system.

Detailed thematic soil maps /1:2 000-1:5 000/ were prepared on a couple of ten-thousand hectares /in manuscript form on blue-print/ for the operative planning and implementation of various measures of soil amelioration, as levelling, terracing, water regulation and management, irrigation, drainage, water- and wind erosion control, soil reclamation, land consolidation, recultivation, landscaping, etc. A special type of the large-scale thematic soil maps is the nutrient status "cartogram", which is prepared for smaller farming units or agricultural fields /plots/ and indicates the nutrient-supply categories of soils for the main nutrient elements and represents an exact basis for rational plant nutrition /SARKADI and VÁRALLYAY, 1989; SARKADI et al., 1964; SZABOLCS, 1966/.

6. *Medium-scale soil mapping*

Medium scale /1:50 000-1:200 000/ soil maps serve as the soil information basis of the regional planning, management and organization of soil-related human activities.

In the Research Institute for Soil Science and Agricultural Chemistry /RISSAC/ of the Hungarian Academy of Sciences:

- the new genetic soil map of Hungary was prepared in the scale of 1:100 000 /VÁRALLYAY and SZŰCS, 1978/;
- the map of possibilities and soil conditions of irrigation was compiled in the same scale. (This map was prepared on the basis of the 1:25 000 scale mapping system mentioned above /SZABOLCS et al., 1969/ and indicates the possibilities of irrigation from the viewpoint of soil conditions /3 categories/; the preconditions of effective irrigation without any harmful side-effects /3 categories/; and some general directives /applicable dosage, frequency, rational method/ for irrigation /3 categories/);
- 1:75 000 scale maps were prepared on the status of soil erosion /non, slightly, moderately and strongly eroded soils, occurrence of gully erosion, territories affected by wind erosion, places of sedimentation /BALLENEGGER and FINÁLY, 1963; STEFANOVITS, 1964/, and a methodology was elaborated for the 1:100 000 scale mapping of erosion risk assessment /cit. in ENYEDY and HINRICHSSEN, 1989/.

The 1:200 000 scale genetic soil map of Hungary, prepared at the Plant and Soil Conservation Service of the Ministry of Agriculture and Food was published in colour-printed form in 1984.

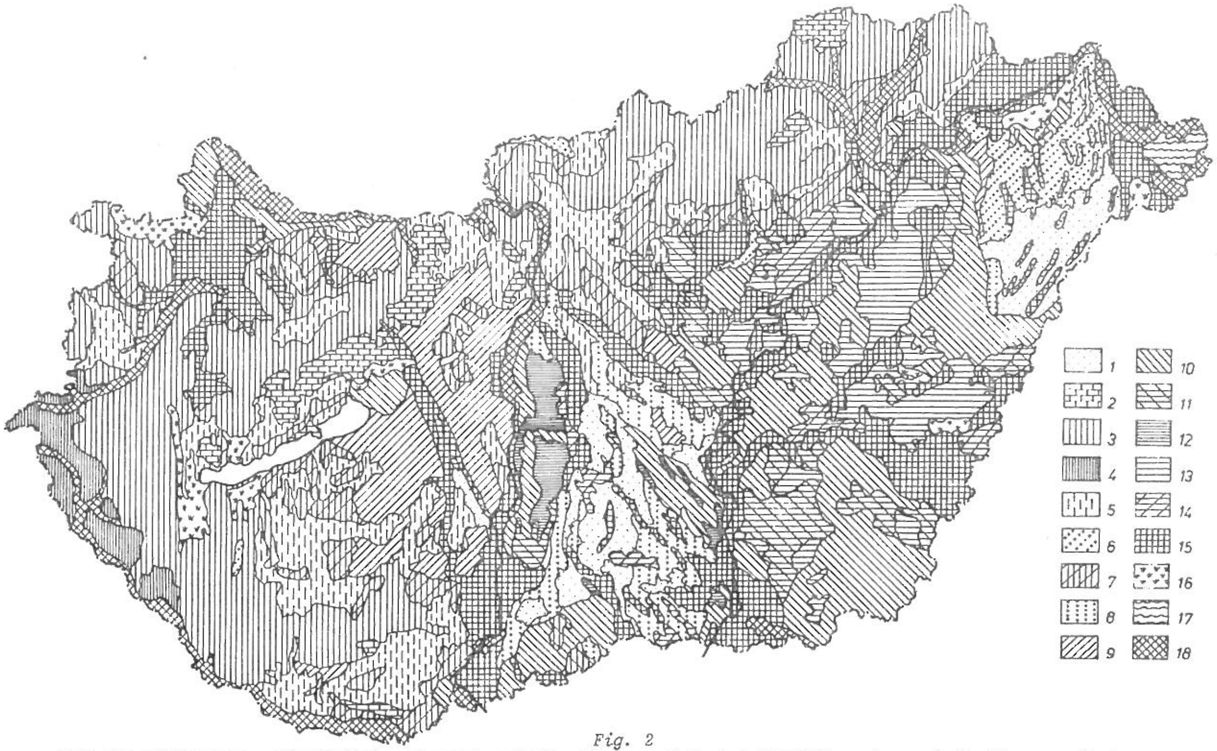

Fig. 2

Soil map of Hungary. /Simplified, schematic version of the original 1:100 000 scale map/. 1: Blown sand, humous sandy soils; 2: Rendzinas, erubase soils, "nyirok"; 3: Lessivated brown forest soil; 4: Pseudogleys; 5: Brown earths /braunerde/; 6: Brown forest soils with alternating thin layers of clay substance /"kovárvány"/; 7: Chernozem brown forest soils; 8: Chernozem-type sandy soils; 9: Pseudomyceliar /calcareous/ chernozems; 10: Lowland chernozems, meadow chernozems /the term "meadow" is related to hydromorphic character/, terrace chernozems; 11: Lowland chernozems with salt accumulation in the deeper layers, meadow chernozems with salt accumulation in the deeper layers, solonetzic meadow chernozems; 12: Solonchaks, solonchak solonetzes; 13: Meadow solonetzes, meadow solonetzes turning into steppe formation; 14: Solonetzic meadow soils; 15: Meadow soils, peaty meadow soils; 16: Peat, ameliorated peat; 17: Soils of swampy forests; 18: Alluvial soils. The stony soils /solid rock is on or near the surface/ and the acidic, non-podzolic brown forest soils are not indicated on the map because of their negligible occurrence

Fig. 3

Map of soil reaction and carbonate status. /Simplified, schematic version of the original 1:100 000 scale map/. 1: Strongly acidic soils; 2: Slightly acidic soils; 3: Calcareous soils /effervescence with dilute acid from the surface/; 4: Salt affected soils, non-calcareous from the surface; 5: Salt affected soils, calcareous from the surface

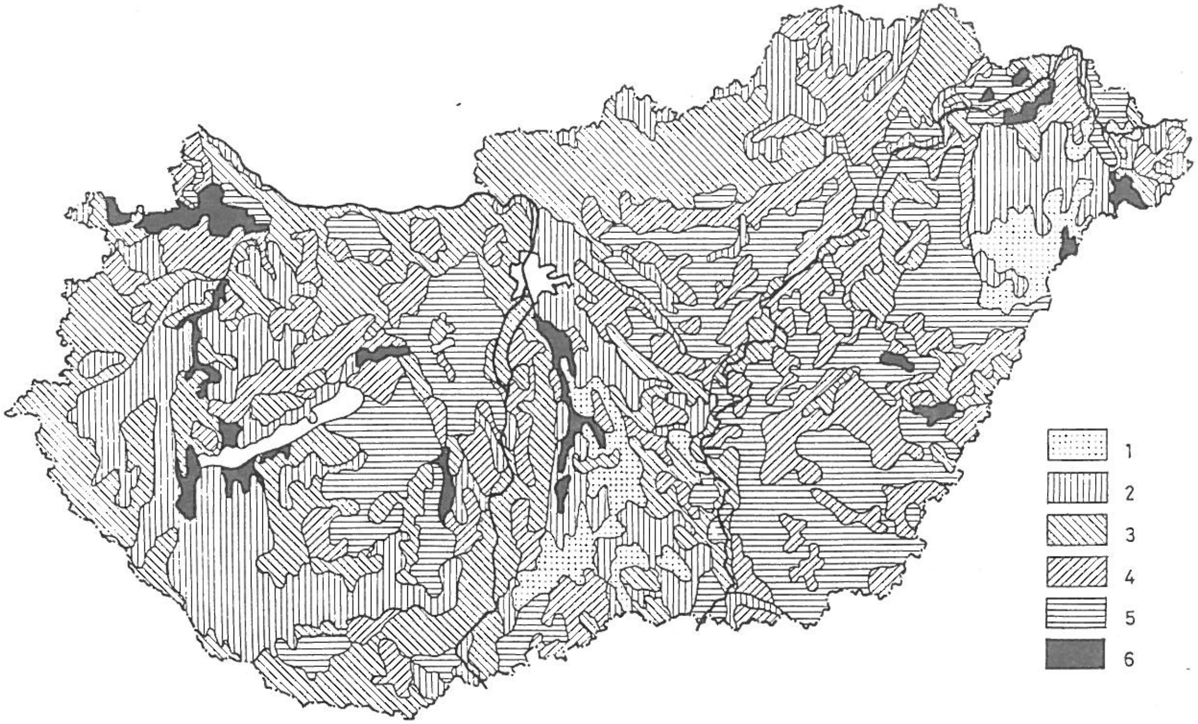

Fig. 4
Map of organic matter content (t/ha). /Simplified schematic version of the original 1:100 000 scale map/. 1: <50; 2: 50–100; 3: 100–200; 4: 200–300; 5: 300–400; 6: >400

Within the scope of the programme of the Hungarian Academy of Sciences entitled "Assessment and evaluation of the agro-ecological potential of Hungary", a 1:100 000 scale map was prepared at RISSAC on the soil factors determining the agro-ecological potential /VÁRALLYAY et al., 1979, 1980, 1985/. On the map - based on all available physico-geographical and soil information - the following characteristics were indicated, using an 8-digit code system:

1. and 2.: Soil types and subtypes /31 units/;
3.: Parent material /9 categories/;
4.: Soil reaction and carbonate status /5 categories/;
5.: Soil texture /7 categories/;
6.: Hydrophysical properties /9 categories/;
7.: Organic matter content /6 categories/;
8.: Depth of the soil /5 categories/.

The generalized maps of the above mentioned soil characteristics were compiled separately, as well, in 1:500 000 scale, mainly for demonstration purposes. As examples, the simplified versions of the map of soil types and subtypes; soil reaction and carbonate status; and the organic matter resource of soils are presented in Figs. 2, 3 and 4, respectively. The map of soil texture is given in an other paper of this issue /VÁRALLYAY, 1989a/.

The complete data base of the original 1:100 000 scale map /including territorial data/ were computer-stored, according to the contoured elementar soil mosaics /polygon-list/.

The map /prepared in 100 copies, as a manuscript/ quickly became popular among practical users. To satisfy further needs the revised information content of the map - completed with two more codes, expressing clay mineral associations of the soil /STEFANOVITS, 1989/ and the "bonitation value" of soil fertility - were printed on 1:100 000 scale, 32x48 cm size /~ 1 556 km^2/ topographical map sheets. In addition to soil characteristics, the map indicates the landuse pattern and main vegetation types, and gives information on the most important parameters of the meteorological conditions, as well. The printed agrotopographical maps are commercially available for the users since 1985 /VÁRALLYAY and MOLNÁR, 1989/.

Based on the agrotopographical map, the following thematic maps were prepared for the whole country in the scale of 1:100 000 or 1:500 000:

- detailed hydrophysical properties of soils, 1:100 000 and 1:500 000 /The National Atlas of Hungary, 1989; VÁRALLYAY et al., 1980/;
- main types of soil moisture regime, 1:500 000 /The National Atlas of Hungary, 1989; VÁRALLYAY, 1989a/;
- main types of substance regime in soils, 1:500 000 /The National Atlas of Hungary, 1989; VÁRALLYAY, 1989b/;
- hazard of waterlogging and overmoistening due to soil conditions, 1:100 000 /VÁRALLYAY, 1989a/;
- susceptibility of soils to acidification, 1:100 000 and 1:500 000 /VÁRALLYAY et al., 1989/;
- susceptibility of soils to physical degradation /structure destruction, compaction, 1:500 000 /VÁRALLYAY and LESZTÁK, 1989/.

As examples, the simplified map of the main types of substance regime in soil /Fig. 5/ and the map of susceptibility of soils to acidification /Fig. 6/ are presented. The maps of hydrophysical properties of soils, the main types of soil moisture regime, and the susceptibility of soils to physical degradation are given in an other paper of this issue /VÁRALLYAY, 1989a/.

The maps represent the necessary soil information basis of the national /or even regional/ level planning of various actions of agricultural water management, soil moisture control and complex amelioration.

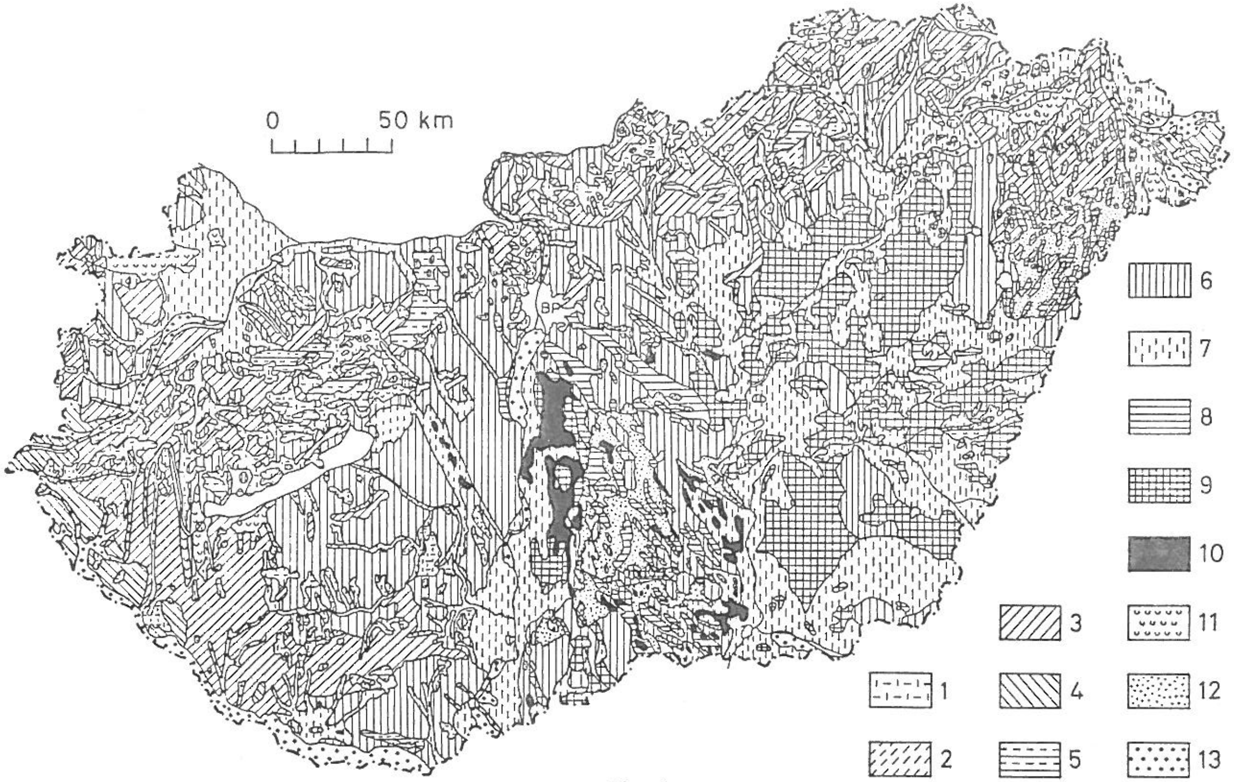

Fig. 5

Map of the main substance regime types of Hungarian soils. /Simplified schematic version of the original 1:500 000 scale map/. 1: Severe surface erosion; 2: Heavy leaching; 3: Moderate leaching; 4: Substance regime under the influence of temporary stagnant water within the soil profile, due to high atmospheric precipitation /pseudogley/; 5: Organic matter accumulation in the surface horizons /as a consequence of extreme moisture regime due to shallow depth /rendzinas//; 6: Equilibrium-type; 7: Substance regime under the permanent influence of groundwater; 8: Heavy carbonate accumulation; 9: Moderate accumulation of water soluble salts and/or exchangeable Na^+; 10: Heavy accumulationof water soluble salts and/or exchangeable Na^+; 11: Organic matter accumulation /peats/; 12: Negligible substance regime /sand/; 13: Substance regime under the influence of rivers and surface streams

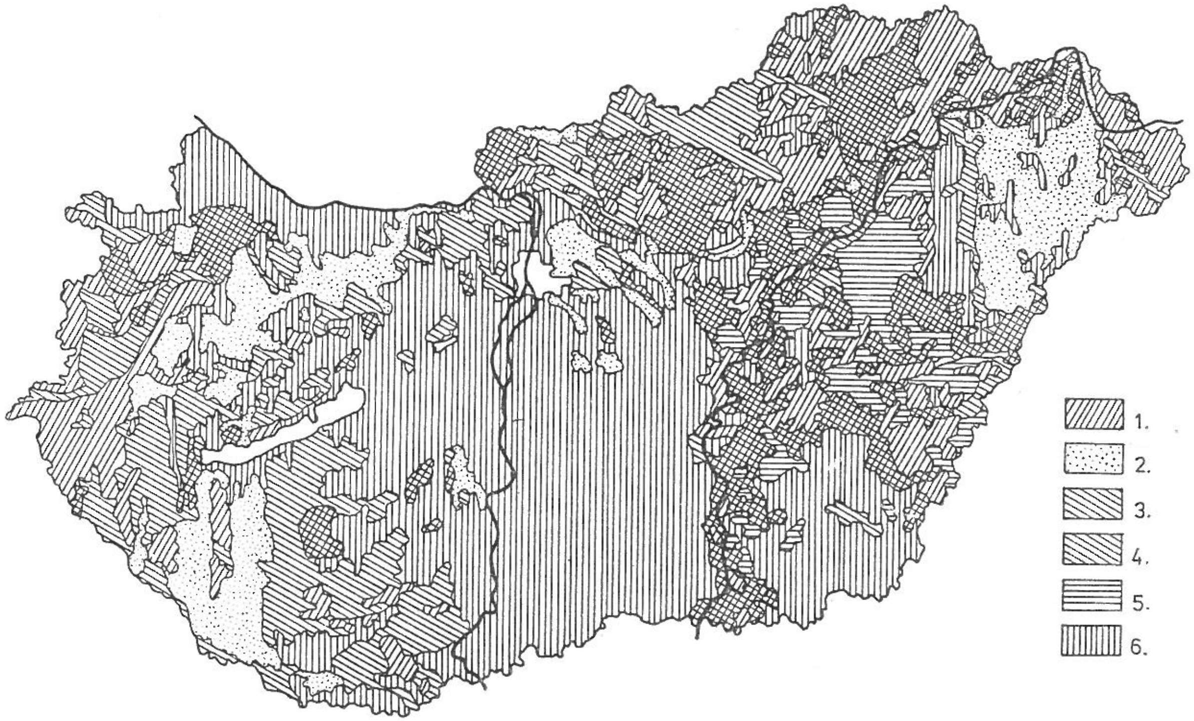

Fig. 6

Map of the susceptibility of soils to acidification in Hungary. /Simplified, schematic version of the original 1:500 000 scale map/. 1: Strongly acidic soils; 2: Highly susceptible soils due to their low buffer capacity; 3: Susceptible soils due to their medium buffer-capacity; 4: Moderately susceptible soils due to their high buffer-capacity; 5: Slightly susceptible soils; 6: Non-susceptible soils

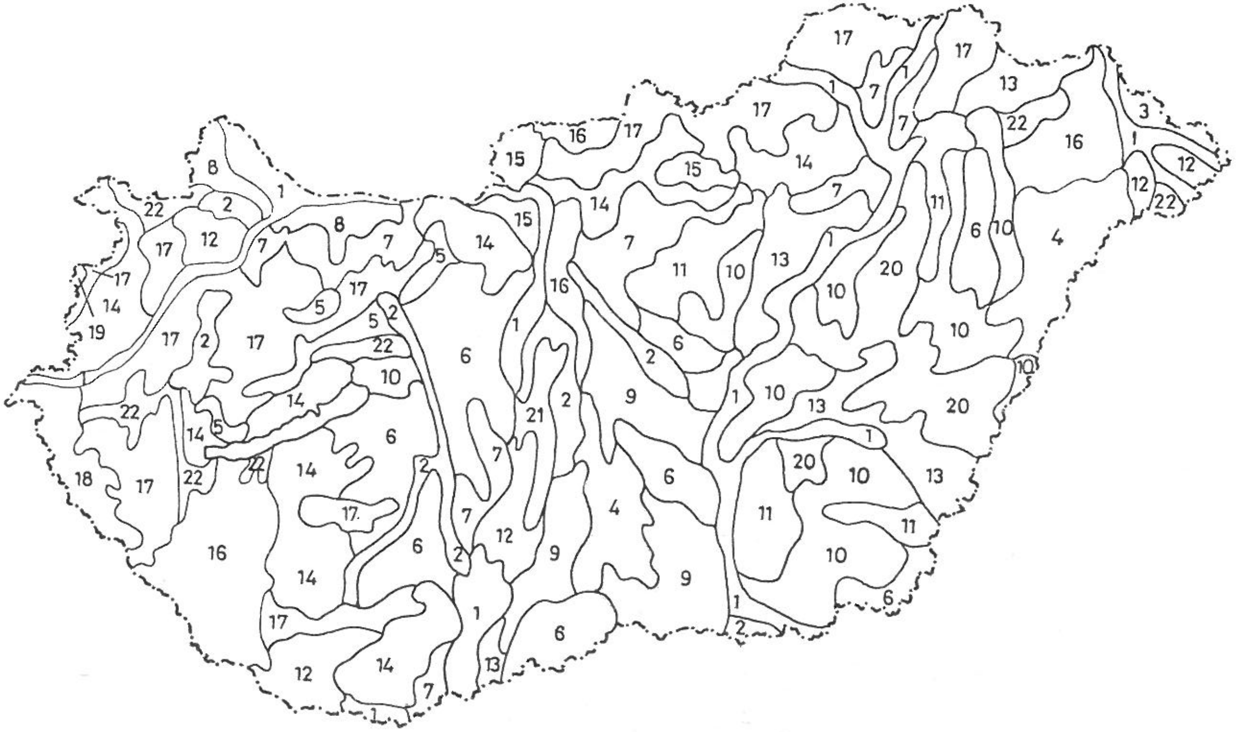

Fig. 7

FAO Soil Map. I. Fluvisols: 1. Alluvial soils. II. Gleysols: 2. Peaty meadow soils; 3. Soils of swampy forests. III. Regosols: 4. Blown sand. IV. Rendzinas: 5. Rendzinas. V. Chernozems: 6. Pseudomycelial /calcareous/ chernozems; 7. Chernozem brown forest soils; 8. Terrace chernozems; 9. Chernozem-type sandy soils. VI. Phaeozems: 10. Meadow chernozems; 11. Meadow chernozems with salt accumulation in the deeper layer; 12. Meadow alluvial soils. VII. Vertisols: 13. Meadow soils. VIII. Cambisols: 14. Brown earths /Ramann brown forest soils/; 15. Brown earths formed on volcanic tuffs/. IX. Arenosols: 16. "Kovárvány" brown forest soils/sandy brown forest soils with thin interstratified layers of colloid and sesquioxide accumulation. X. Luvisols: 17. Brown forest soils with clay illuviation. XI. Pseudogleys: 18. Pseudogleys. XII. Acrisols: 19. Acidic brown forest soils. XIII. Solonetzes: 20. Meadow solonetzes. XIV. Solonchaks: 21. Solonchaks. XV. Histosols: 22. Peats

7. Small-scale soil mapping

The relatively quick development of international co-operation in the field of soil science necessitates the comparative evaluation of the relationships and correlations between the Hungarian and other soil classification systems, and - based on these studies - to introduce a "common language" for mutual understanding. For this purpose the following maps were prepared:

- 1:5 000 000 scale soil map of Hungary for the FAO-UNESCO World Soil Map Programme;
- 1:1 000 000 scale soil map of Hungary for the FAO European Soil Map Programme /the simplified version of this map is shown in Fig. 7/ /The National Atlas of Hungary, 1989/;
- 1:5 000 000 and 1:500 000 scale maps of salt affected soils in Hungary for the ISSS /International Society of Soil Science/ World Map of Salt Affected Soils Programme /SZABOLCS, 1974/;
- 1:5 000 000 scale map for the Global Assessment of Soil Degradation /GLASOD/ Programme.

All the above-listed soil information were summarized /or at least were taken into consideration/ in the computerized geographical soil information system of Hungary: HunSIS = TIR /KUMMERT et al., 1989/.

Problems and further tasks of soil mapping in Hungary

It can be concluded from this short review on the "state of art" of Hungarian soil mapping that the main problems of soil mapping were and are as follows:

a/ to indicate three- or four-dimensional characteristics, as soil properties with their vertical, horizontal and time variabilities;

b/ to extend point information /data on soil profiles or on individual soil layers/ into spatial ones;

c/ to establish categories for various properties defined by limit values or other criteria, based on measurements, calculations, estimations or special interpreations.

Classical soil survey and mapping

- select various morphological, physical and chemical soil parameters, e.g. diagnostic horizons with their characteristic sequence and properties for the definition of various soil classes at different taxonomic levels of soil classification;
- use visible or easily detectable attributes for their preliminary delineation during the field survey; use physiographic information, indicated on the basic topographical maps /contours; water-network; landuse pattern→ moisture conditions, etc./ during the final drawing of the soil map contours;
- use - in most of the cases - soil taxonomy units as the "carrier" of one or more soil properties.

This was the only, and quite acceptable approach for a long time in soil survey, and it has considerable grounds in the present, modern soil mapping, as well, especially when there are close casual relationships between the registered and the derivated soil characteristics. If such relationships are missing, or the correlation is not appropriately close, other approaches are required, because of

- the rapidly increasing accuracy requirements for soil maps as a scientific basis of expensive, complex technical measures;

- the rapid development in analytical methods which do not limit the accuracy of soil information.

The two most promising from these new approaches are remote sensing with computerized digital pattern recognition analysis and the application of various geo-statistical procedures. They have to be used not instead of, but in addition to the "classical" soil survey and mapping.

In Hungary, the researches on the further development of soil mapping are carried out in the following main directions:

- Modelling of various soil processes;
- Correlation analysis between microrelief - natural vegetation - soil characteristics - moisture regime - surface and groundwater conditions. Such studies are going on in the salt affected areas of the Hortobágy and Kiskunság National Parks.
- Study of the relationships between the reflectance properties and the physical, mineralogical, physico-chemical and chemical characteristics of soils.
- Study of the applicability of various remotely-sensed data for soil mapping; regional monitoring of soil moisture regime, natural ecosystems, moisture and nutrient stresses in various crop canopies.
- Application of various geo-statistical methods for the characterization of spatial variability of soil properties
  - in a highly heterogeneous salt affected land under extensive grazing;
  - in a heterogeneous sand-hill area with poor grassland;
  - on a "homogeneous" chernozem soil with high productivity under intensive agricultural use.

For the mapping of various soil properties - in most of the cases - it is necessary to create categories and class characteristics have to be defined by single values. This is a rather subjective, purpose- and scale-dependent task, because categories /groups, classes/ have to be established according to the actual objectives, scale and the given conditions. Because these are not constant, the classes, and their limit values are also not generalizable. If it is so, the maps have to indicate not only the class characteristics, serve as a basis for delineation of mapping contours, but the registered /described, observed, measured, calculated, estimated/ single values as well. In such cases the rearrangement of classes according to new limit values, appropriate for a new task, or for changed conditions, is a relatively simple computational procedure, especially if the data base gives opportunities for the application of geo-statistical procedures. Without the indication of registered single values and their exact location, such contour-rearrangement according to new class limits is almost impossible, or at least irrationally expensive and decreases the accuracy and fidelity of the indicated soil information.

In Hungary - as it was discussed earlier - numerous category-systems were elaborated during the 50-year history of soil mapping /See References/. The development of the computerized geographic soil information system /HunSIS/ was a great step forward in this direction, making possible the simultaneous storage of point data and maps of class characteristics and the rearrangement of delineated contours according to given class limits /KUMMERT et al.,1989/. The results of all soil investigations were and are back-feeded to HunSIS and used for the improvement of the existing soil mapping practice and advisory system.

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