Advisory System for Mineral Fertilization Based on Large-Scale Land-Site Maps

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Large-scale soil maps constitute the scientific information basis of rational fertilizer application during the last 40 years in Hungary /VÁRALLYAY sr, 1954; SARKADI et al., 1964; SARKADI, 1975; SZABOLCS, 1966; NIZSALOVSZKY and SIK, 1963/.

Plant nutrient supply in Hungary

Before World War II, the plant nutrient status of Hungarian soils was rather low due to the negative nutrient balance: more plant nutrients were taken up by the cultivated crops and were taken away from a given territory by the yield /by the transported biomass/ than was given as organic manure, green manure and mineral fertilizer. The average rate of fertilizer application was less than 5 kg/ha and only slightly increased up to 1956. In 1950 and 1955 it was 6 and 10 kg/ha, respectively. From this time there had been a sharp increase in the total fertilizer consumption as it is shown in Figure 1. In 1962 the rate of fertilizer application exceeded 50 kg/ha, in 1968 100 kg/ha, in 1973 200 kg/ha and in 1983 it reached 300 kg/ha /118 kg N, 78 kg P_2O_5 and 104 kg K_2O per hectare/. This tendency was one of the reasons of the substantial yield increase in the country. The average yields of the main crops in Hungary between 1950 and 1987 are summarized in Table 1. /Agricultural Statistical Pocket Book, 1989/.

Another consequence of this sharply increasing fertilizer application was that - due to the positive nutrient balance - the nutrient status of Hungarian soils was significantly improved. In the early seventies agrochemical laboratories /well-equipped for soil and plant analyses/ were established in the 19 counties /administrative regions/. A systematical soil survey /with three-year test cycles/ was introduced and a national fertilizer advisory service was organized within the Centre for Plant Protection and Agrochemistry of the Ministry of Agriculture and Food /MÉM NAK/ /BARANYAI et al., 1987/. According to their data, the N, P and K-supply of Hungarian soils shows a rather favourable picture. In Figures 2 and 3 the average AL-soluble P_2O_5 and K_2O contents of Hungarian soils are presented on a schematical grid map, while in Table 2 the distribution of soils with very poor, poor, medium, good and very good relative P and

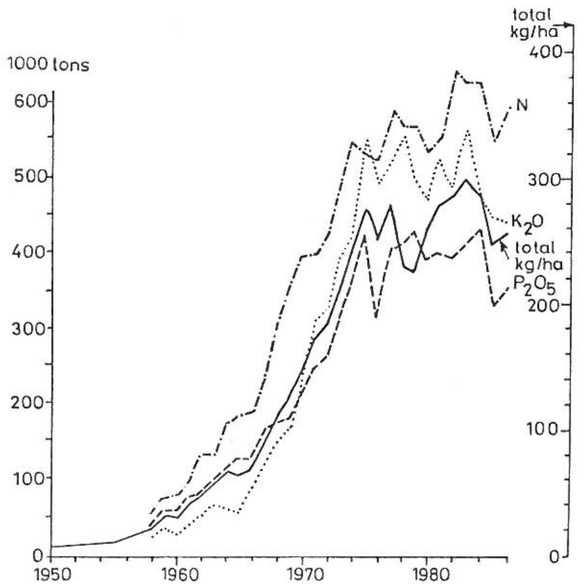

Fig. 1
Use of mineral fertilizers in Hungary

Table 1
Average yields of the main crops in Hungary
/t/hectare/

Year/s/	Wheat 30.3	Maize 24.9	Sugar beet 2.5	Sunflower 8.2	Potatoes 0.9 ж
1951-1955	1.46	2.06	18.69	1.07	8.77
1956-1960	1.50	2.31	21.20	1.10	10.46
1961-1965	1.86	2.61	24.64	0.96	7.91
1966-1970	2.43	3.23	32.52	1.11	10.45
1971-1975	3.32	4.17	33.00	1.24	11.74
1976-1980	4.06	4.85	33.64	1.61	14.16
1981-1985	4.63	6.11	38.90	1.98	18.23
1986	4.36	6.29	36.18	2.19	18.63
1987	4.37	6.13	36.30	2.09	15.97
1988	5.44	5.47	39.26	1.94	18.60

ж acreage in the percentage of the total arable land /4.71 million hectares/, which represents 50.6 % of the total area of the country /9.30 million hectares/ /1987/.

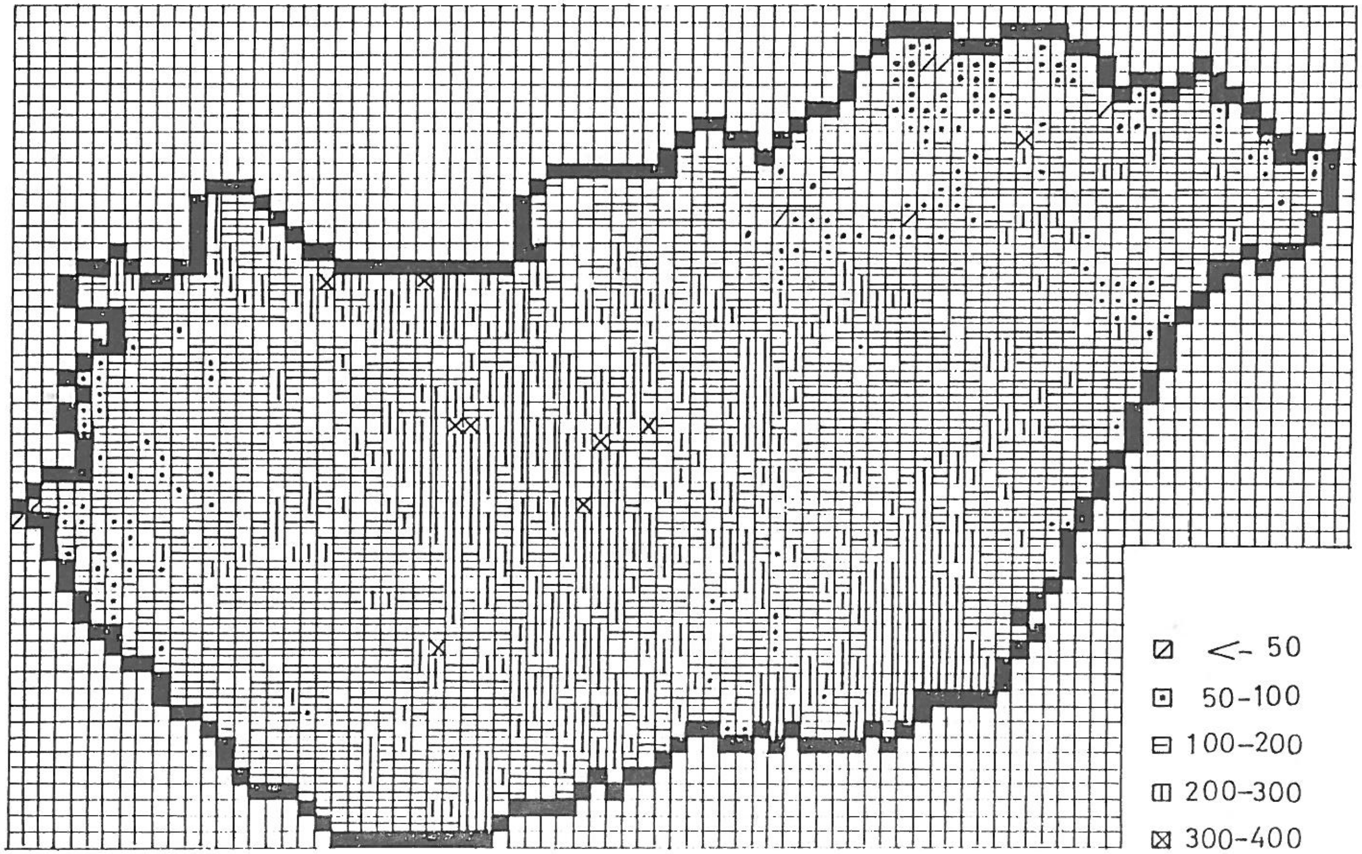

Fig. 2
Average AL-soluble P_2O_5 content in Hungarian soils /1984/

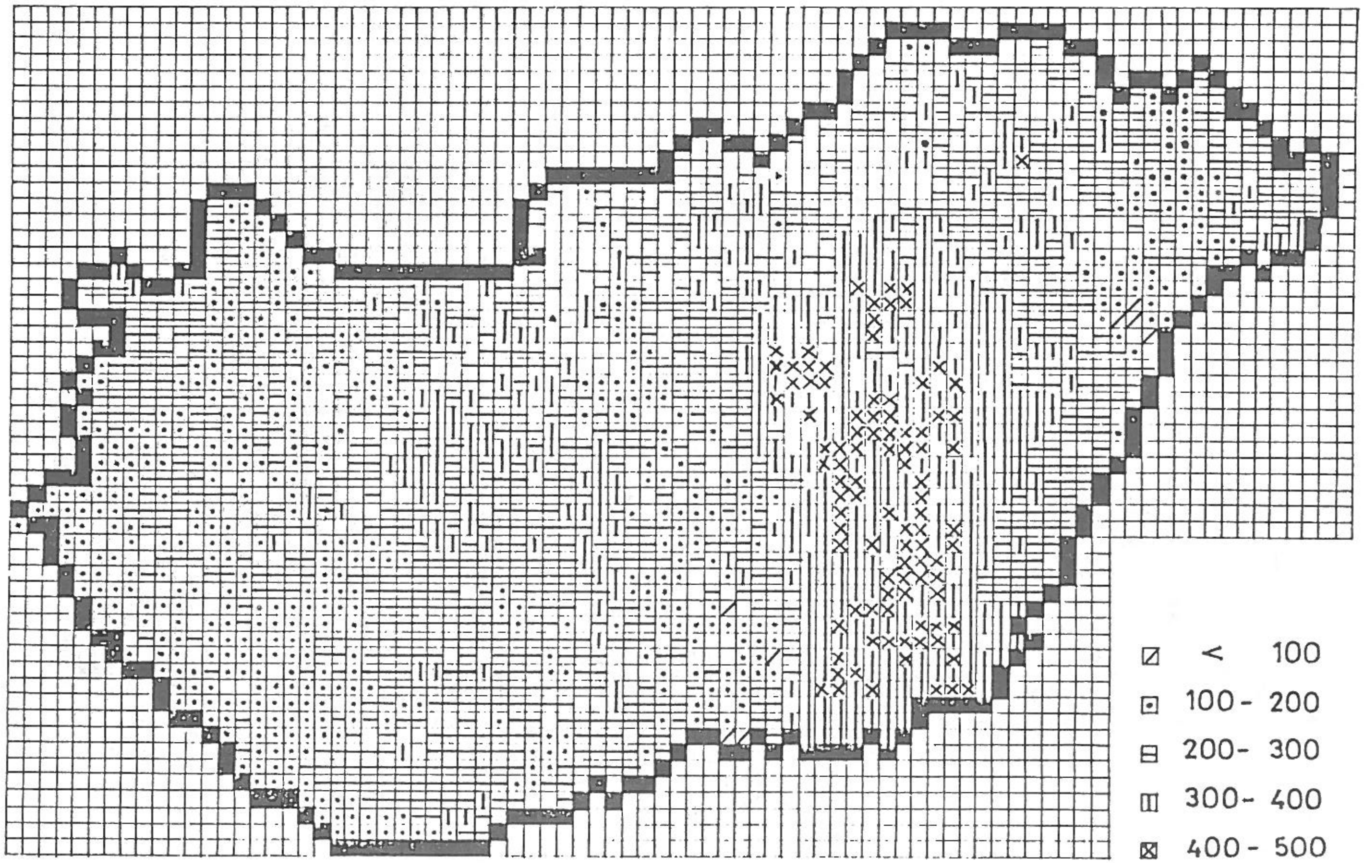

Fig. 3
Average AL-soluble K_2O content in Hungarian soils /1984/

K supply categories are summarized in the I. /1978-1981/ and II. /1982-1985/ observation cycles /BARANYAI et al., 1987/.

The general tendencies were similar all over the country, but show great variations in the details, due to the high variability of climatic, hydrologic, relief and soil conditions and to the great differences in

Table 2

Distribution of the relative P and K supply categories in Hungary /in the percentage of the total investigated area/ [BARANYAI et al., 1987]

Plant nutrient	Cycle	Nutrient-supply categories				
		very poor	poor	medium	good	very good
P	I.	1.5	14.0	36.6	37.5	10.4
	II.	4.0	10.0	22.0	34.0	30.0
K	I.	1.2	10.9	40.5	34.6	12.8
	II.	7.0	15.0	28.0	30.0	20.0

I. Nutrient observation cycle /1978-1981/
II. Nutrient observation cycle /1982-1985/

land use, cropping pattern and the applied agrotechnics, including fertilizer application. For the illustration of these territorial differences in Table 3 the yields of the main crops /in 1986/ and the distribution of the above mentioned 4 nutrient-supply categories are summarized for 5 counties, representing greatly different agro-ecological conditions. Békés and Szolnok are situated in the southern and central part of the Great Hungarian Plain respectively, and can be characterized by relatively dry and warm climate, flat /or nearly flat/ surface, chernozem-type soils on the loess plateaus /more in Békés/ and hydromorphic soils /sometimes salt-affected/ in the Tisza and Körös alluvial plains /more in Szolnok/. Tolna is the southern part of Transdanubian loess plateau with undulating surfaces covered by chernozems and Raman brown forest soils. Zala is in the SW part of Transdanubia /Prealpine region/, Nógrád is the western part of the Northern hilly region and both can be characterized by relatively humid climate, undulating surfaces and various types of brown forest soils, sometimes considerably eroded /LÁNG et al., 1983/.

Seeing only the yields and the distribution of nutrient-supply categories it can be stated that the yields are higher in those counties where the soils are better supplied with plant nutrients: see the results of Tolna and Békés vs. Nógrád and Zala. But the fact is that in Tolna and Békés not only the nutrient status of soils is better /as one of the factors of soil fertility/, but their other ecological conditions /climate, relief, etc./ are also more favourable. Soil fertility and productivity is not equal with the nutrient status of soil in spite of the fact that sometimes there are close correlations between them.

Problems in fertilizer application

The similar tendency of yield increase /Table 1/ and increasing rate of fertilizer application /Figure 1/ suggest the conclusion for the decision makers, that the further increase of yields /which was determina-

Table 3

Average yields and N, P and K supply of soils in five counties in Hungary

County	Average yields of the main crops, t/ha,1986				
	Wheat	Maize	Sugar beat	Sun-flower	Potatoes
Tolna /A/	5.36	7.32	38.0	2.41	21.2
Békés /B/	4.83	7.51	40.8	2.27	20.8
Szolnok /C/	4.23	5.92	34.8	2.27	19.3
Nógrád /D/	4.31	4.55	23.0	2.19	15.8
Zala /E/	3.44	6.05	27.4	2.18	17.4

Distribution of nutrient-supply categories /in the percentage of the investigated area/ I. cycle

	N					P					K				
	vp	p	m	g	vg	vp	p	m	g	vg	vp	p	m	g	vg
A.	4.3	12.1	39.7	38.7	5.2	0.1	2.3	19.4	51.3	26.9	0.5	4.8	27.6	49.1	18.0
B.	1.1	9.1	31.2	50.7	7.9	0.2	4.2	17.6	41.3	36.7	0.4	7.1	16.5	26.7	49.3
C.	6.0	14.8	39.4	36.2	3.6	1.4	12.5	30.8	29.8	25.5	2.4	5.7	22.9	35.5	33.5
D.	34.0	26.0	26.6	10.5	2.9	5.2	15.3	32.9	29.1	17.5	1.4	4.4	30.1	43.7	20.4
E.	27.1	40.2	21.4	7.9	3.4	6.9	16.3	32.5	27.6	17.6	14.4	22.5	34.0	20.8	8.3

tively prescribed in the national plans of Hungarian agriculture/ can be obtained simply by the further increase of fertilizer application /~ the increase-curves can be extrapolated/. This false idea was supported by the mis-interpretation of some oversimplified relationships between the yield and the plant nutrient status of soil /e.g. which can be drawn from the data of Table 3./ which leads to such false conclusions /or feelings/ that all unfavourable land-site characteristics, soil fertility limitations and even agrotechnical inadequacies can be counterbalanced and compensated by using more fertilizers. As a consequence of such mis-interpretations all administrative efforts were taken to stimulate /or even press/ the increase of fertilizer application. It became one of the main "parameters" of the evaluation of agricultural farming units /state farms, collective farms/ and even their leading specialists. Up to the early eighties the price of fertilizers was rather low in Hungary /due to a considerable state subsidy on fertilizer production - reflecting the over-emphasized quantity concept/ and this directly led to an unfavourable polarization tendency in fertilizer application:

/a/ better soils → rich farm → higher rate of fertilizer application /in spite of the lower requirements ← better nutrient status of soils/ → overdosage / → increasing losses → environmental side-effects/;

/b/ poor soils → poor farms → lower rate of fertilizer application /in spite of the higher requirements ← lower nutrient supply of soils/ → underdosage / → low yield/.

This polarization is clearly reflected by the data of Table 2: the acreage of both "very poor" and "very good" nutrient supply categories were increased between the I. and II. nutrient test cycles.

The total yearly consumption of fertilizers became more or less constant from the mid seventies /with normal yearly fluctuations/ at /or near to/ a level of 1.3-1.4 million tons/year /550-600 thousand tons of nitrogen, 350-400 thousand tons of phosphorus and 450-500 thousand tons of potassium/, which means an average rate of 250-300 kg/hectare /Fig. 1/ /Agricultural Statistical Pocket Book, 1989/. According to the "official" global quantity concept /"favourable, good = high, large"; "high level of fertilizer application technology = high dose"/ attention was focused on the increase of total consumption /or average total rate of application/, it was the point of discussions, its stagnancy was criticized. The concept neglected /or at least underestimated/ the significance of other soil fertility parameters and the importance of their improvement, and did not take into consideration the changes in the Hungarian agricultural development:

- the home food-market became practically saturated and the forecasted intensive export-increase failed /→ stabilized or even decreasing quantity requirements/;
- sharply increasing quality requirements;
- radically increasing significance of efficiency and economy → necessity of input rationalization;
- increasing hazard of environmental side-effects /pollution of air, water and soil resources, various soil degradation processes; etc./.

Fertilizer application practice either does not react, reacts slowly or not satisfactorily to these changes, because of the surviving elements of the global quantity concept, psychological inflexibility and lack of adequate /stimulating or even pressing/ economy regulations.

The global quantity concept concealed the real problems of fertilizer application technology, as:

- non-adequate N-P-K ratio /not according to the crop requirements, nutrient status of soil, climate-weather conditions/;
- non-adequate type of fertilizer /not according to the soil conditions/;
- lack of Ca, Mg and micronutrient application /ensuring harmonized nutrient supply of plants/;
- time of application is not in accordance with the climatic /weather/ and soil conditions, and with the dynamism of nutrient uptake of plants;
- non-uniform distribution of fertilizers /or non-differential distribution of fertilizers according to the variability of soil properties and plant nutrient status/ within an agricultural field;
- non adequate soil application and lack of the necessary supplementary agrotechnical operations.

The main reasons of these inadequacies are the limited commercial availability of various fertilizers, their limited assortment, non-rational regional distribution; lack of adequate technical infrastructure for uniform /or differential/ distribution of fertilizers within the vegetation period of cultivated crops /according to the dynamism of their physiological requirement and nutrient uptake/.

The overdosage and not appropriate application technology reduce the efficiency of fertilization, results in increasing losses /filtration losses, leaching, abiotic or biotic immobilization, etc./ and may lead to unfavourable environmental side-effects as acidification /due to non-adequate type of fertilizer, lack of simultaneous lime application/, pollution of surface waters by phosphorus /due to surface runoff and erosion/ and groundwaters by nitrates /due to overdosage, non-uniform distribution, etc./. It must be emphasized, however, that these harmful side-effects are not inevitable consequences of rational fertilization, and by following the instructions of the scientifically-based advisory system, they can be prevented, eliminated, or at least moderated up to a certain tolerable limit.

Previous advisory systems in Hungary

The first attempts for scientifically based fertilizer application were made before World War II in Hungary by KREYBIG, DWORAK, VÁRALLYAY sr. /1954/ and their co-workers.

After World War II, VÁRALLYAY sr. proposed a comprehensive method with the systematic and regular measurement of "available" nutrient content of the soil and taking into account the influences of other soil properties /soil reaction, carbonate content, texture/ on the nutrient regime of soil and on the efficiency of applied fertilizers. Based on these data and field experiments he established relative "nutrient supply" categories of soils, indicated their categories on large-scale soil maps and gave recommendations for the required quantity of the major nutrient elements, as well as for the rational fertilizer application technology. Later, in the National Institute for Agricultural Quality Testing /OMMI/ the sufficient soil survey, sampling and laboratory analysis capacity for systematic and regular soil nutrient status observations had been developed in six regional soil testing laboratories and VÁRALLYAY sr.'s system was further developed by NIZSALOVSZKY and SIK /1963/, ROMLEHNER and others.

In the early sixties a comprehensive system was elaborated by a large team of specialists for large-scale genetic soil mapping, and it was properly used by state farms and cooperative farms as a scientific basis of large-scale crop production /SARKADI et al., 1964; SZABOLCS, 1966; VÁRALLYAY, 1989/. In the system thematic soil maps were prepared on the most important "practical" soil properties and on the recommendations for rational land use, cropping pattern, agrotechnical and ameliorative measures. In this series, maps were prepared on the status of major nutrient elements in soils /indicating relative "nutrient supply" categories/ and recommendations were given for the rational dose of fertilizers. These recommendations were based on the nutrient-supply categories, taking into account the specific crop requirements, the forecasted yield level and some modifying factors /leaching losses; nutrient content of plant residues, organic or green manures; residual effects of the previous crop or applied organic and/or mineral fertilizers/ /SARKADI et al., 1964; SZABOLCS, 1966/.

This system was further developed after the reorganization of OMMI to a Centre for Plant Protection and Agrochemistry /CPPA/ and a rather comprehensive system was elaborated by a team of specialists /ANTAL, 1987; BUZÁS, 1983; Guidelines for Fertilizer Application...., 1979/. In the mid seventies well-equipped soil testing laboratories were organized in all of the 19 counties of Hungary, using unified sampling, analysis and evaluation procedures. A systematic programme for the control of plant nutrient status of soils was organized with 3-year test cycles, and fertilizing recommendations were given annually for about half a million hectares. In the beginning, these recommendations were used properly and efficiently in the large-scale state farms and cooperative farms /BARANYAI et al., 1987/.

Later, because of the changes in the Hungarian agricultural development, lack of land-site differentiated rationalization stimulating economic regulations, and due to the great differences in the ecological conditions and management levels of the farming units, only a part of these recommendations were /or could be/ follosed by fertilizer application practice. This was the main reason of the unfavourable polarization in the nutrient status of soils, the decreasing efficiency of fertilizers, and - in some places - the occurrence of environmental side-effects. A much smaller /but still considerable/ part of these unfavourable changes was the consequence of some weak /questionable/ points of the recommendation system. The two most important from these are:

- not properly defined and applicable land-site categories /with heterogeneous definitions; mixing genetic taxonomy units with soil characteristics/ /ANTAL, 1987/.
- not "nutrient-specific" applicability of the category system to convert determined /measured/ available nutrient contents into relative /soil specific/ nutrient-supply categories of soils /the same land-site categories were used for N, P and K/.

It turned out that the limit values of nutrient-supply categories need some corrections and the fertilizer-efficiency factors have to be modified, as well.

The central advisory service /CPPA, and after a new reorganization Crop Protection and Soil Conservation Service, CPSCS/ made an attempt in 1987 for the revision of the system. During this revision only the limit values of the nutrient-supply categories were modified /following some central directives for the stimulation of the global increase of fertilizer consumption/ - without any verified experimental basis. Consequently, the attempt failed to be successful /New Guidelines for Fertilizer Application, 1987/.

This is why we found it necessary to revise the previous systems and to elaborate a new computerized system for rational fertilizer application. We accept the general concepts of the previous systems, draw conclusions on the experiences of their practical application, take into consideration the changes and new trends in Hungarian agricultural development, use all available new information, and try to improve the criticized points of the previous systems. The work, which was carried out by a multidisciplinary team in the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, was possible because during the last years

- a lot of new analytical data, many experimental results and practical experiences have accumulated;
- SARKADI /1975/ and BUZÁS /1983/ summarized the scientific bases of fertilizer application;
- VÁRALLYAY and his coworkers elaborated a category-system for the determining factors of the agro-ecological potential of Hungary; as well as for the hydrophysical properties and moisture regime of soils /VÁRALLYAY, 1986; VÁRALLYAY, 1989/.

The present system

The main consecutive steps of the system are as follows:

/1/ The soil/s/ of the area concerned has to be classified according to a new land site category system. The elementar units of land-site categories were characterized by a 3 digit code.
The 1st digit of the code expresses the main character of the water and and substance regimes of soils or the main soil fertility limitations, as follows:

/1/ Migration type /downward flow ≈ with upward flow; no groundwater influence; relatively dry climate/

/2/ Leaching type /downward flow is dominant; no groundwater influence; relatively humid climate/.

Table 4

Elementar units of the land-site category system

1. digit /Main classes/	2. digit	3. digit	4. digit	Existing number of different elementar mosaics
1 Migration type	**Texture** 1 SP < 30 2 30–35 3 36–42 4 43–50 5 > 50	**Soil reaction and carbonate status** 1 pH_{KCl} < 4,0 $CaCO_3$ % Ø 2 4,0 – 5,5 Ø 3 5,6 – 6,5 Ø 4 > 6,5 Ø 5 > 6,5 < 1 6 > 6,5 1–5 7 > 6,5 5–15 8 > 6,5 > 15	**Organic matter content** Will be introduced later. At present: 0	40
2 Leaching type				40
3 Hydromorphic type				40
4 Skeletal soils	1 Blown sand 2 Loose rediments on the surface 3 Solid rock is on the surface 4 Gravel, fragmented rocks	1 pH_{KCl} < 4,0 $CaCO_3$ % Ø 2 4,0 – 6,5 Ø 3 4,0 – 6,5 < 5 4 > 6,5 > 5	0	16
5 Salt-affected soils	ESP/B/– A-horiz.cm– 1 Solonchak – – 2 Solonchak-solonetz – – 3 Slightly solonetzic 5–15 – 4 Solonetzic 15–25 – 5 Shallow solonetz > 25 < 7 6 Medium solonetz > 25 7–15 7 Deep solonetz > 25 > 15	**Texture** 1 SP < 35 2 36–42 3 43–50 4 > 50	**Soil reaction and carbonate status** 1 Non calcoreous from the surface 2 Calcareous from the surface 3 Highly alkaline /pH_B > 8,5/	84
6 Shallow soils	1 Calcareous, 2 Non calcareous } loose, gravel, fragmented rocks 3 Calcareous, 4 Non calcareous } hard, solid rock, cemented layer	**Depth** 1 < 20 cm 2 20–40 cm 3 40–80 cm	**Texture** 1 SP < 35 2 36–42 3 43–50 4 > 50	48
7 Peat soils	**Organic matter content** 1 < 15 % 2 > 15 %	**Soil reaction and carbonate status** 1 pH_{KCl} < 4,0 $CaCO_3$ % Ø 2 4,0–6,5 Ø 3 > 6,5 < 5 4 > 6,5 > 5	0	8
8 "Human-made" soils	0	0	0	?
				~276

/3/ Hydromorphic type /upward flow is dominant; strong groundwater influence; relatively dry climate/.
/4/ Skeletal soils.
/5/ Salt-affected soils.
/6/ Shallow soils.
/7/ Peat soils.
/8/ "Human-made" soils.

The parameters and limit values of the 2nd, 3rd and 4th digits of the code are summarized in Table 4. In the table the existing number of elementar mosaics in each main category is also given. According to these figures altogether about 280 different soil mosaics can be distinguished in Hungary.

/2/ The soil/s/ of the area concerned has to be classified into aggregated land-site groups, using a matrix table which was compiled on the basis of the specialists of the various major plant nutrients. In the matrix table all of the 280 distinguished soil mosaics were classified into

Table 5
Categories of N-supply
/on the basis of humus content/

Aggregated land-site group \ N-supply categories	1	2	3	4	5
	Humus content, in percentage				
I	< 1.0	1.0-1.7	1.8-2.4	2.5- 3.0	3.0 <
II	< 1.5	1.5-2.0	2.1-3.0	3.0- 3.5	3.5 <
III	< 2.0	2.0-2.5	2.6-3.5	3.6- 4.0	4.0 <
IV	< 2.5	2.5-3.0	3.1-4.0	4.1- 5.0	5.0 <
V				5.0-15.0	
VI				15.0 <	

Table 6
Categories of P-supply

Aggregated land-site group \ P-supply categories	1	2	3	4	5
	AL-soluble P_2O_5 content mg/kg				
I	0-30	31- 60	61-100	101-180	181 <
II	0-40	41- 80	81-120	121-200	201 <
III	0-50	51-100	101-150	151-240	241 <
IV	0-60	61-120	121-170	171-270	271 <
V	0-70	71-150	151-200	201-300	301 <
VI	0-80	81-180	181-250	251-400	401 <

Table 7
Categories of K-supply

Aggregated land-site group \ K-supply categories	1	2	3	4	5
	AL-soluble K_2O content, mg/kg				
I	0- 50	51- 80	81-120	121-160	160 <
II	0- 60	61-100	101-150	151-200	200 <
III	0- 80	81-120	121-180	181-250	250 <
IV	0-100	101-150	151-210	211-280	280 <
V	0-120	121-180	181-250	251-320	320 <
VI	0-150	151-210	211-280	281-350	350 <

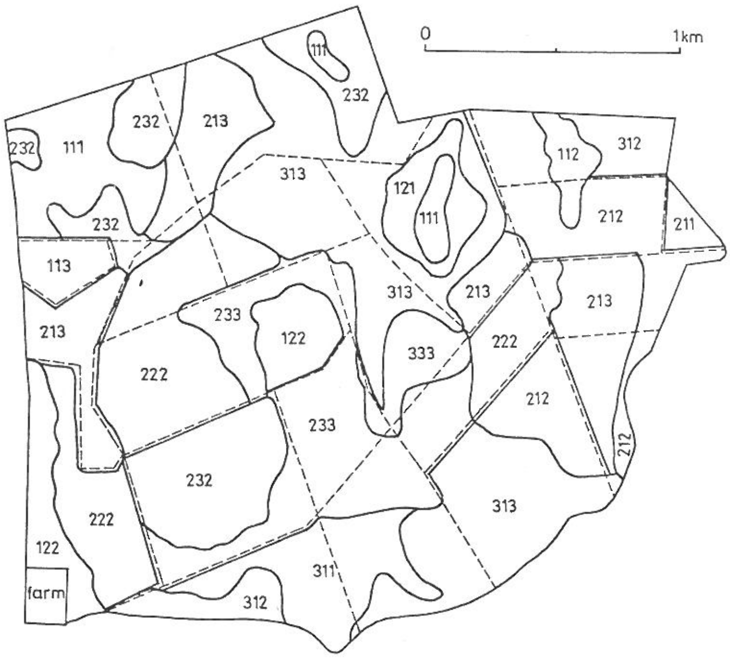

Fig. 4
Map of nutrient status of the soil at the "Egyetértés" Cooperative Farm in Kerekalja /Scale: 1:10 000/. 1st number: Nitrogen supply; 2nd number: Phosphorus supply; 3rd number: Potassium supply of the soil. 1 = weak; 2 = medium; 3 = high

nutrient element-specific aggregated land-site groups. For N, P, K and Mg 6-6 /I-VI/, for Ca 3 /I-III/ aggregated groups were distinguished. In reality one elementar mosaic can be classified into different aggregated land-site groups in the case of N, P, K, Ca and/or Mg.
The introduction of such possibility makes the system flexible and reliable, eliminates the weak points of the previous systems in this respect and considerably improves their applicability.

/3/ The nutrient status of soil can be characterized by relative "nutrient supply" categories. The limit values for these nutrient supply categories are summarized for nitrogen in Table 5, for phosphorus in Table 6 and for potassium in Table 7. On the basis of measured organic matter content /in the case of N/, AL-soluble P_2O_5 and K_2O content and knowing the aggregated land-site group to which the soil was classified, it can be put into the proper nutrient supply categories. 5-5 such categories were distinguished for N, P and K and marked with /1/-/5/ numbers /instead of the confusing verbal expressions as low, poor or weak; medium; high, good/. These relative categories are indicated on the large-scale maps /1:10 000/, serving as the soil information basis of rational plant nutrition. Such a map is shown in Figure 4.

Table 8
Fertilizer requirements of crops

Crop		Nutrient kg/t Specific quantity' /S/	Multiplication factors for the categories of nutrient supply /M/				
			1	2	3	4	5
Winter wheat	N	27	1.2	1.1	1.0	0.8	0.4
	P_2O_5	11	2.5	2.0	1.5	1.0	–
	K_2O	18	1.5	1.0	0.5	–	–
Maize	N	25	1.3	1.1	1.0	0.8	0.4
	P_2O_5	11	2.0	1.5	1.0	–	–
	K_2O	20	2.0	1.5	1.0	0.8	–
Sugar beet	N	4.0	0.8	0.8	0.5	0.4	0.2
	P_2O_5	1.0	2.0	1.5	1.0	0.5	–
	K_2O	6.0	2.0	1.5	1.3	1.0	–
Potatoe	N	5.0	1.4	1.2	1.0	0.8	0.7
	P_2O_5	2.0	2.0	1.5	1.0	0.5	–
	K_2O	7.0	2.0	1.5	1.3	1.0	–
Sunflower	N	41	1.2	1.0	0.8	0.6	0.4
	P_2O_5	20	2.0	1.5	1.0	–	–
	K_2O	70	2.0	1.5	1.0	0.5	–
Alfalfa	N	27	0.8	0.6	0.4	0.2	–
	P_2O_5	7	2.5	2.0	1.5	1.0	–
	K_2O	20	2.0	1.5	1.0	0.5	–

/4/ In Table 8 the fertilizer requirements of the main crops are summarized. In the first column the "specific quantity" /S/ is given, expressing the required quantites /kg/ of N, P_2O_5 and K_2O for the production of 1 ton yield.

This basic value has to be corrected by the multiplication factors /M/ according to the determined nutrient supply categories /see above/. Consequently, the fertilizer requirement /F/ can be calculated as follows: F = yield x S x M

/5/ The following factors were taken into consideration as modifying factors:

/a/ N-requirement modifying influence of the previous crop /it is a negative value in the case of legumes and a positive value in the case of cereals, maize, sugar-beet, sunflower, etc./;

/b/ The nutrient content of plant residues remain on the field after harvesting the yield /without subsurface biomass/.

For the determination of Ca and Mg requirements a special sub-system was elaborated, where, in addition to the plants Ca and Mg requirements, other /not directly plant-nutritional/ aspects were also taken into consideration, as: leaching losses; necessity of acidity reduction /improvement of acid soils/; prevention of soil acidification /due to acid depositions, unbalanced fertilization, use of acidic by-products, wastes or sewage waters/; improvement of soil structure; etc. At present the system does not give recommendations for micronutrient application.

Practical application

The development of the system was partly financed by the KSZE Corn Production System /Szekszárd/. In 1988 - developing the necessary algorithms and softwares - the system was further developed into an operational computerized system, and it was properly and efficiently used on more than half a million hectares. In the future the system is planned to be combined with a similar system of soil moisture control.

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