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GIS based land use optimization in Hungary

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INTRODUCTION

In our study we investigated how and to what extent is the ecological potential of a region (in Hungary that means the productivity of the soil and availability of water), the average yield of the cultivated plants, the land use of a certain area and the degree of the applied agrotechnology are correlated. We tried to establish where and how it is possible to increase or to improve the crop production through an optimal selection of the habitat. In our conception the landscape typological units particular consideration the soil qualities covering the country surface like mosaics were considered as regional reference areas. Namely, taking into account their net primary production, they may give approximately the same values being genetically and ecologically similar. By their use a more precise ecological classification could be made. The division of the regional typological units into plain types was plotted in detail, while the hilly and mountain types were summarized (Fig. 1).

The investigations were carried out with maize as a reference standard considering that in Hungary the agrotechnical and economical factors are the most similar in maize growing. This was a very suitable plant for the comparison, because it covers about the same percent of the landscape units. Being warm season annual plant the vegetation period and the harvest is in the same year, so the calculation is easier.

Maize is the second most important plant of grain crops in Hungary. The highest extension of its crop area during the past 50 years was recorded at 1.4 million hectares in 1974. Its area declined in line with the increase of yields between 1974 and 1984; the yield of maize was 4.24 t/ha in 1974 and 5.6 t/ha in 1984, which led to the increase of quantity of maize for feeding and export as well, despite decline of its crop area.

Maize is the most important corn fodder in Hungary, and 82 per cent is produced by large farms. After the introduction of new hybrids, maize-growing produces its highest yield in Transdanubia due to the higher amount of precipitation, while the greater part of its average crop area is still found in the Great Plain, where pig-breeding is generally spread. This activity is maintained for the sake of animal husbandry on the areas having poor average yields.

The development of the most favourable crop structure and the most favourable agricultural utilization of an area does not absolutely mean a maximum primary production far above the potential productivity in spite of a preference system advantageous for crops

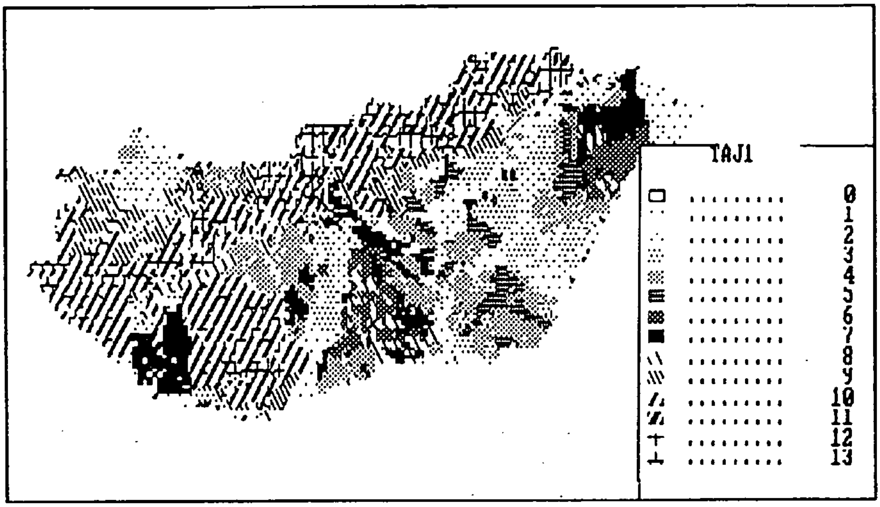

Figure 1 Landscapes types in Hungary

1 - alluvial plain with cultivated grassland;inundated flood-plain along rivers with alluvial soils and remnants of groves and marsh forests; 2 - poor drained flood-plain, alluvial plain cultivated grassland with meadow soil and peat-bog; 3 - alluvial plain; cultivated grassland predominantly with groundwater table at medium depth meadow chernozems; 4 - alluvial fan mantled by loess; loess plain; chernozem or meadow soil; 5 - terraced and loess plain with lowland chernozem; 6 - fixed sandy plain with mosaical Astragalo-Festucetum rupicolae acacia and poplar forests, vineyards and orchards; 7 - fixed sandy plain with chernozem; cultivated grassland; horticulture and arable land; 8 - interdunal depressions with high groundwater table, marshy or salinic meadow soils; 9 - alluvial fan on basin margin; cultivated grassland of dense drainage network; mosaical remnants of Quercetum petraeae-cerris forests chernozem and forest soils; 10 - smaller hills in intermontane basins; cultivated grasslands with remnants of Quercetum forests and deep groudwater table; 11 - independent hilly regions dissected by erosion-derasion valleys; mostly cultivated grassland remnants of mixed forests; 12 - forested landscape types in mountains of medium hight; 13 - major valleys within various hilly or mountainous landscape types

with high primary productivity. It seems to be much more important, especially in regions with poor ecological conditions, to develop a crop structure better adjusted to the ecological conditions and based e.g. on industrial plants assuring the highest income.

METHOD

Thematic maps from the National Atlas of Hungary (1989) served as input data. The digital technology of the graphic material was based on the AutoCAD software. To manage and to manipulate the data we used MAP for the PC (Sandhu et al. 1987) program. According to our aims and possibilities all data are stored and elaborated too, in a raster, which can be used very simply. For this method a raster-raster and a vector-raster transformer is needed (e.g. to build remote sensing data digitally into the information system). The transition and/or the transformation between the vector-basic AutoCAD and the raster-basic MAP were ensured by MicroGIS (Kertész,Á. - Márkus, B. -Mezősi,G. 1990). In the MAP a resolution of 2.5 x 2.5 km could be reached. At the vector-raster transition calculated by Switzer method the mistake was 7.5 %, just within the acceptable accuracy (there is some difference from map to map).

RESULTS

Net Primary Production

The investigation of the NPP is one of the most important tasks of ecology since the material and the energy potentially available for heterotrophs are concerned here. It is much easier to assess NPP than GPP as the latter requires data on the intensity of photosynthesis and on active radiation. Assessments of NPP have been made since over 2 decades. Most of them are empirical formulae using the measurable relationship between climate parameters and NPP. For regional investigations the "Miami" (1) and the "Thornthwaite Memorial" models (2) (Lieth, M. - Box, E. 1972) are used. The "Miami" model describes the effect of the two most important climatic factors: precipitation and temperature.

$$P_p = 3000\,(1 - e^{-0.000364P}) \tag{1a}$$

and

$$P_T = 1 + e^{1.315 - 0.119T} \tag{1b}$$

where P_p and P_T=NPP (g/m^2/year), P=average yearly precipitation (mm), T=average yearly temperature (°C).

$$P_E = 3000\,(1 - e^{0.000969(E-20)}) \tag{2}$$

where P_E = NPP (g/m^2/year), E=actual evapostranspiration (mm).

For the assessment of former (1) the actual evapotranspiration and for (2) the regional precipitation have to be known. On the basis of investigations carried out in test areas (Kertész, Á. - Mezősi, G. 1989), the results obtained in the (2) case seemed to be better. In our further calculations this correlation was applied. We can use these models to assess the NPP of a larger area, so only the trends and tendencies of the change of these NPP values were taken into account (Fig 2.).

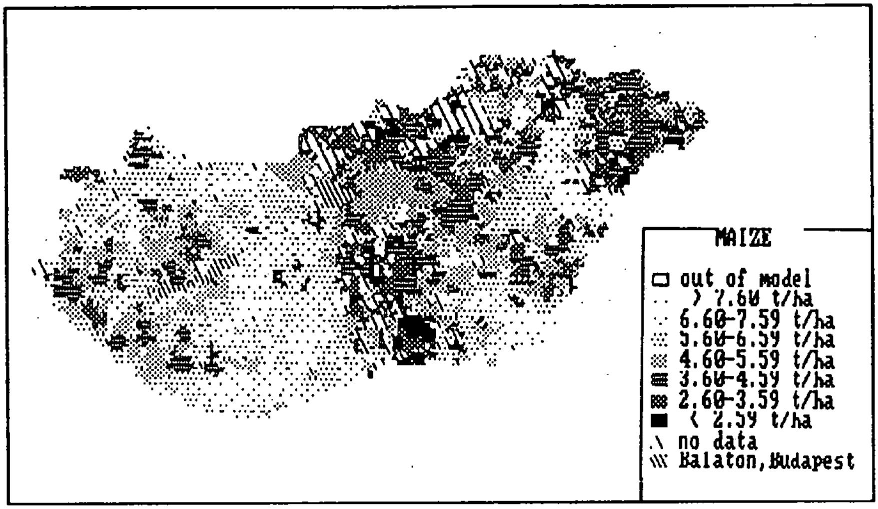

Figure 2 Net Primary Production in Hungary (calculated with Miami model) t/ha

Conflicts between the ecological factors and the yield of maize

In Table 1 it can be seen that in the case of landscape types asterisked with a star there is contradiction between the greet NPP values (it means a good availability of water) and the yield which does not reach even the average value. This is the most striking in the south-western part of the country where the landuse of the meadows, pastures and forests is relatively significant, too, in addition to the arable land. (More than 50 % of the country surface is covered by arable, its 14 % by pastures and meadows, and its 18 % by forests.)

Besides the availability of water an important factor, which influences the average of the crop is the soil score value (land capability index). The 100-score common in Hungary, began to come in general use in the last years (0 is the worst value, 100 is the best one) and involves correction factors of reliefs and climate, as well. The relationship between the soil score value and the average yield (as well as the NPP, too) is shown in Table 2. It car be seen that the average yield decreases simultaneously with the deterioration of the quality most considerably in the two last categories.

Table 1 Primary productivity (NPP) and the maize production (YIELD) for different landscape types

Landscape types (Fig. 1.)	Area %	Average YIELD for years 1980-84 t/ha	NPP ±0.2 t/ha	Conflict
1	16.46	6.03	10.24	-
2	5.06	4.75	9.88	-
3	5.72	5.53	9.91	-
4	10.41	5.95	10.12	-
5	2.21	6.22	9.86	-
6	4.30	3.85	9.77	+
7	8.29	4.42	10.41	+
8	2.96	4.17	10.16	+
9	6.64	5.73	10.35	-
10	24.40	5.40	10.57	-
11	1.28	4.05	10.27	+
12	5.04	4.64	10.39	+
13	7.74	4.81	10.41	+

Table 2 The NPP and the yield (maize) for soil score value (SSV) in Hungary

	SSV (point)	Yield t/ha	NPP t/ha
1.	>80	6.25	10.28
2.	65-80	5.75	10.22
3.	50-64	5.27	10.81
4.	35-49	4.33	10.32
5.	20-34	4.10	10.39

Use of fertilizers

The use of fertilizers and also the applied agrotechnology can significally modify the corn. The amount of the used fertilizers and the average yield of the maize (and the NPP) are compared (Table 3).

Consumption of fertilizers and the use of chemicals in farming in general played a dominant role in the growth of yields (Table 4).

Table 3 The yield (maize) and the NPP for different fertilizers application category

kg/ha	Area %	Yield t/ha	NPP t/ha
< 150	21.4	4.71	10.15
150-200	20.7	4.85	10.19
201-250	24.8	5.25	10.28
251-300	16.1	5.50	10.36
301-350	10.1	6.15	10.46
351-400	4.3	6.47	10.45
> 400	2.6	6.59	10.48

Table 4 Fertilizer application with different yields

Yield t/ha	Area %	Fertilizer kg/ha
7.60	7.5	304
6.60-7.59	11.9	285
5.60-6.59	20.8	255
4.60-5.59	19.5	224
3.60-4.59	14.9	210
2.60-3.59	8.5	184
<2.59	4.5	157
no data	12.4	Proposals

The results show that there is a conflict between the NPP values and the ecological conditions. Yields best correlate with the applied farming technique. In one hand we suggested that in Hungary an area marked out for maize growing should be situated in some of the landscape types plotted without an asterisk in Table 1. This amounts 71.4 % of the country surface. On the other hand, it should be met the soil quality categories from 1 to 3 of Table 2. Supposing that maize growing is the same in every landscape unit, the average yield can be increased by 5.2 % - from 5.38 t/ha to 5.66 t/ha - merely optimal selection of the landscape types, not more than 28.6 % is excluded (Fig.3). On other hand it should be met the soil quality categories from 1 to 3 of Table 2. The quantities of this soil types cover 74.7 % of the whole surface. Using this soil types the yield can be

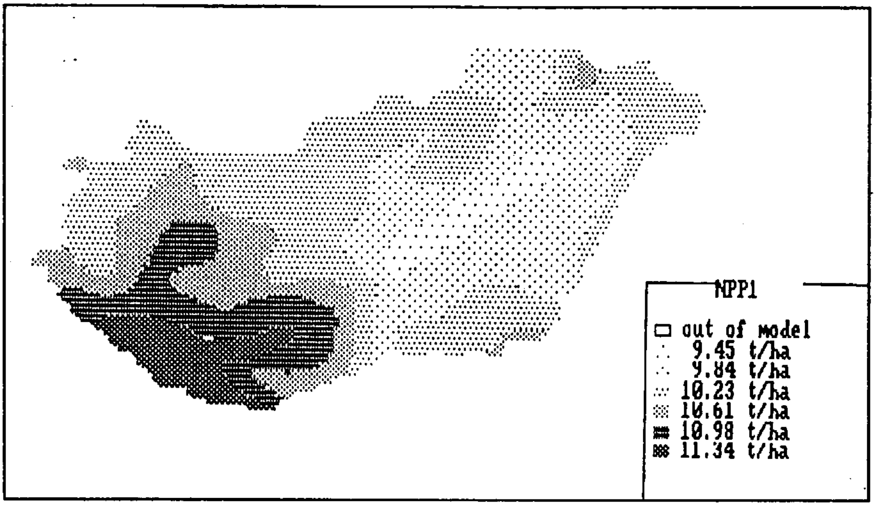

Figure 3 Maize production in Hungary (1984-89)

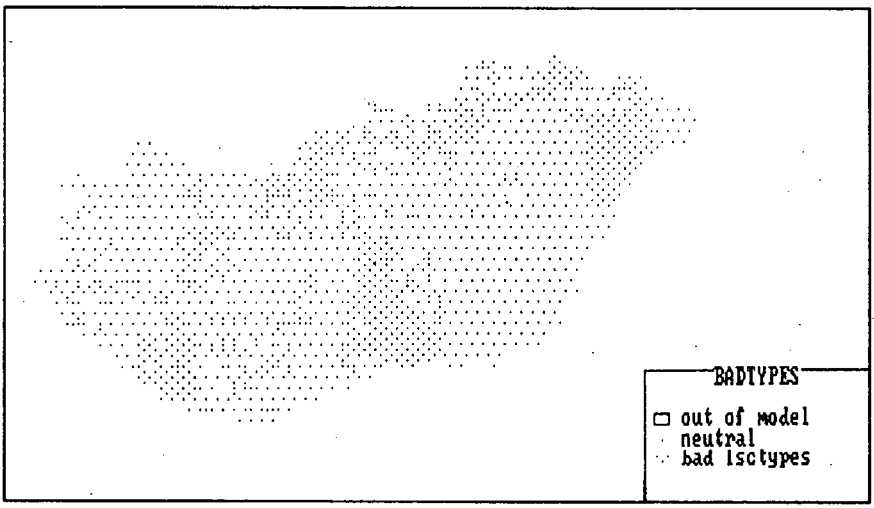

Figure 4 The situation of bad and neutral soil types from the point of view of yield

inceased by 6.4 % - from 5.29 to 5.63 t/ha (Fig.4). 28.6 % of excluded landscape types and 25.3 % of the excluded soil are situated in the two-third part of the same area. The residual soils and landscape types with favourable producing capacity - 64 % of the surface - may result in a similar increase - 0.41 t/ha, this is 7.6 % (Fig. 5).

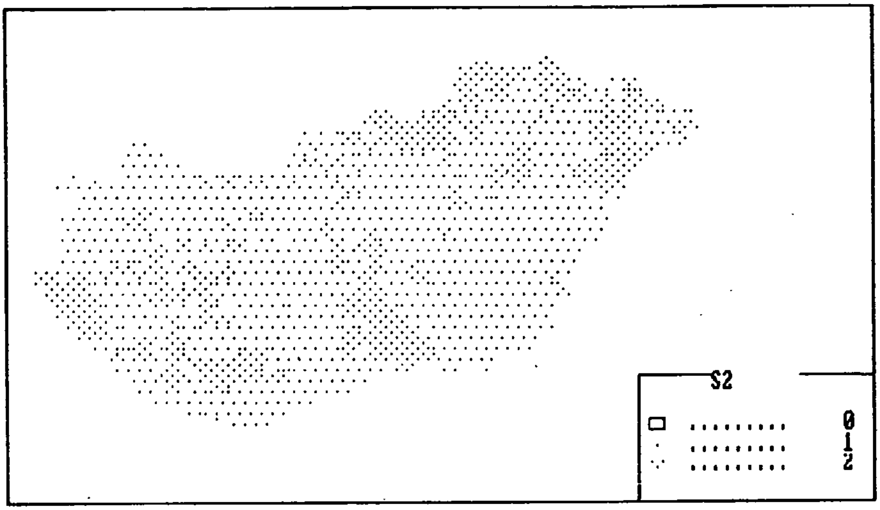

Figure 5 The residual soil and landscape types with a favourable -1 and unfavourable -2 producing capacity

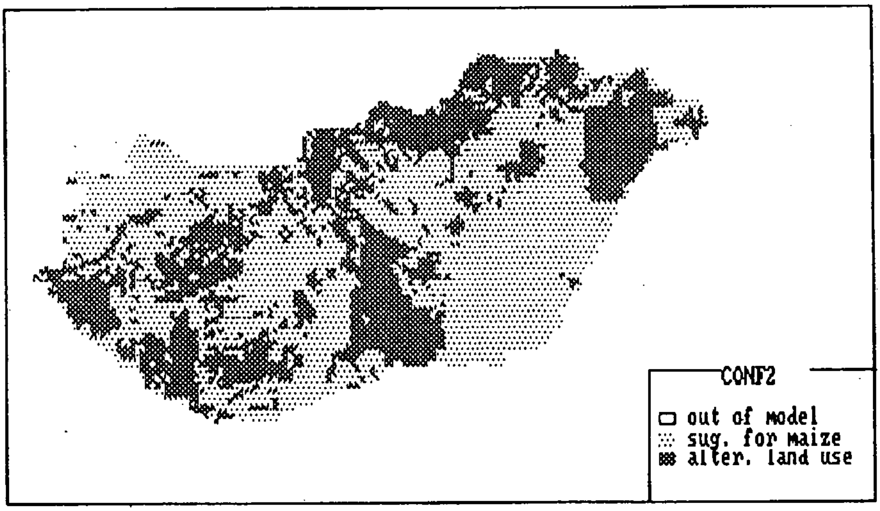

Figure 6 Areas suggested for maize production and alternative land use utilization

Data from literature prove (Szász, G. 1989) that the chemical fertilizer is more effective (+10-35 %) in these areas. To sum up it may be stated that by concentrating the cultivation in the areas plotted in Fig.2., the increase of the crop capacity may exceed 10 % . The real increase of yield depend on plant, soil type and climate, so it is very difficult to quantify exactly and predict regionally the growth. Using average data a prediction is shown on Fig. 6. The excluded areas are suggested to be developed in the first place as forests.

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