

GIS APPLICATION FOR LAND CAPABILITY SURVEY IN HUNGARY

UPORABA GIS PRI UGOTAVLJANJU PRIMERNOSTI TAL NA MADŽARSKEM

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Abstract

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GIS application for land capability survey in Hungary*

During the present transformation of Hungarian agriculture land as a commodity is also being included into the market economy. Since a higher level of mechanisation or fertilisation cannot be envisaged under the present economic conditions, the natural fertility of land tends to become – along with numerous economic factors – a major component of land prices. In order to promote the optimal design of crop pattern, a land capability survey and agroecological zoning project was launched. The procedure consists of three phases: establishment of a computer data base; constructing suitability indicators for the major crops and comparing them with land conditions; delimitations of agroecotopes and agroecological zones.

Izvleček

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Uporaba GIS pri ugotavljanju primernosti tal na Madžarskem

V prehodnem obdobju je postala obdelovalna zemlja na Madžarskem blago, ki je vključeno v tržno gospodarstvo. Ker v sedanjih gospodarskih razmerah ni možna višja stopnja mehanizacije in uporabe umetnih gnojil, je postala naravna rodovitnost tal pomemben element njene cene. Da bi izoblikovali optimalno razporeditev poglavitnih kultur, smo se lotili projekta ugotavljanja primernosti tal in agroekološke rajonizacije. Postopek je sestavljen iz treh faz: vzpostavitev računalniške podatkovne baze, iskanje pokazateljev primernosti za glavne kulture in njihova primerjava s talnimi razmerami; ugotavljanje agroekotopov in agroekoloških con.

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LAND PRICING IN HUNGARY

Under the conditions of socialist economy there were major restrictions to the purchase of land and, therefore, no true land prices existed. Although a 100-score land assessment system for physical properties was set up, it has never been complemented with a generally accepted economic valuation. The new government brought back the hundred-year-old and to a great extent obsoleted 'gold-crown' system and applies it in the procedure of land reprivatisation. At present, a new market of land is being created nationwide and, given the considerable regional and local variation in the physical endowments for farming – not to mention the region-to-region variance in labour, capital and other resources – it is extremely difficult to foresee what prices will be acknowledged in the individual regions. As for all commodities, the relationship between demand and supply will decide land prices in the end.

Along with economic factors, however, land evaluation can also contribute to the establishment of price levels. In the present-day situation, when large-scale investments into farming fail, the role of the natural potential of land is upgraded. Land evaluation helps farmers find the types of land use with profitable production (with respect to both quality and quantity of produces) and without remarkable damage to the environment.

LAND CAPABILITY SURVEY

In order to promote the optimal design of crop pattern, a land capability survey and agroecological zoning project was launched in the Geographical Research Institute in 1982. The procedure consists of three phases:

- establishment of a computer data base (including parameters of relief, availability of heat and water and soil properties);
- constructing suitability indicators for the major crops grown on the arable lands of Hungary (wheat, maize, lucerne, sunflower and sugar-beet) and comparing them with land conditions;
- delimitation of agroecotopes and agroecological zones.

In our system land capability is expressed by ranking environmental conditions according to the demands of the most important arable crops in Hungary. The crops selected cover

the largest harvest areas in Hungary: winter wheat, maize, lucerne, sunflowers and sugar-beet (Table 1).

Table 1: Major field crops in Hungary by harvested area (percentage of arable land).
Tabela 1: Površine pod poglavitnimi poljščinami na Madžarskem (% orne zemlje).

Crop	1980	1990
Winter wheat	26.8	25.9
Maize	26.4	23.0
Lucerne	8.1	6.5
Sunflower	3.1	5.4
Sugar-beet	2.2	2.8

The project involves the survey of one county per year and to date it has been completed for the Transdanubian counties. In the meantime, some methodological developments have been made, including the application of ARC/INFO Geographical Information System (E S R I, 1989) for data input, the combination of environmental parameters to form complex land qualities (to which the ecological demands of plants are really directed) in coverage.

In the present stage of the project the physical potentials of Pest county are surveyed. It is an intriguing task to rate areas according to their agroecological value in this region around Budapest, where the demand for land is the greatest (Petrásovits et al., 1984).

THE GEOGRAPHICAL INFORMATION SYSTEM APPLIED

Since the counties of Hungary have hundreds of hectares of agricultural land, the amount of data to be processed is so large that any method of storage and evaluation other than by computer is not feasible (Kertész - Mészösi, 1989). We had to rely on a convenient GIS package to achieve our goals.

Land evaluation tasks are now often solved using a Geographical Information System (Burrough, 1989). In 1982 a land capability survey and agroecological zoning project was launched under the guidance of Prof. L. Góczán in the Geographical Research Institute of the Hungarian Academy of Sciences. Data input consists of coded relief, heat and water availability and soil parameters. The calculation of land suitability for the main arable crops of Hungary takes place in an ARC/INFO GIS, applying suitability indicators which confront the environmental conditions present with the ecological demands of crops.

The first program for land capability survey (Lóczy, 1988) was written on a Commodore 64 computer in 1983 and the output maps were produced by an EPSON text printer. At that time, it was difficult to set map coordinates correctly and when compiling maps from the individually assessed sheets, the 'edge effect', a phenomenon well-known from the classification of remotely-sensed images, often occurred.

Recent developments in the instrumentation of the Geographical Research Institute has

led to a much favourable situation for the application of GIS techniques. The hardware presently available for our project includes an AT 468/33 MHz PC of 8 Mbyte Random Access Memory and twice 200 Mbytes on hard disks. In order to command the GIS properly there are two monitors connected to the PC: an 1024x768 pixel colour monitor with 1 Mbyte card capable of showing 256 colours and a 14-inch Hercules monochrome monitor for texts.

Mapped data are digitised on an A0 digitising tablet. For feeding data labelled by geocoordinates (points, lines and polygons) with high precision an ARC/INFO 3.4 Plus GIS is applied. The accuracy of data input remains invariably within the accuracy limits of the thematic maps to be digitised.

The input storage capacity required for the 532,503 hectares of agricultural land in Pest county (1990) is ca. 2.7 Mbytes (Table 2).

Table 2: Storage capacities required for input into the land capability GIS of Pest county.
Tabela 2: Pomnilniške kapacitete za vnos podatkov GIS za županijo Pest.

Parameter groups	Content	File type	Memory requirement
Relief	3 parameters combined	dwg	2,138 kbyte
Heat availability	8 monthly mean tempr.	coverage	106 kbyte
Water availability	7 monthly + winter prec.	coverage	155 kbyte
Soils	7 parameters combined	coverage	ca. 300 kbyte

AutoCAD version 10 is used for digitising contour lines and Digital Terrain Models are constructed using IDRISI version 4.0 (E a s t m a n, 1992), which is supplied with two DTM modules: the first creates DTM from points, while the second from isolines. For the model the elevation values of the four corner points of a rectangular area to be digitised are needed. First, the IDRISI program produces profiles along the four edges, then creates a set of horizontal profiles in rows followed by vertical profiles in columns and diagonal ones running from left to right and right to left across the area. The final elevation recorded for each cell is that of the profile with maximum slope. The DTM is convertible into ILWIS 1.3 (I T C, 1992).

DATA ACQUISITION

Varying estimates place the costs of data acquisition at 80-90 per cent of the total expenses of building a GIS. Complaints about the high costs of purchasing data from government agencies and private companies are more and more frequent (R h i n d, 1992). This is a particularly serious problem in the case of fundamental research, where the application of results is not so obvious as, for instance, in industrial development. In Hungary, some data suppliers already operate on a market basis; at the same time, the resources of the Hungarian Academy of Sciences tend to be rather restricted.

In the land capability survey the basic source of information is the 1 to 100,000 scale agrotopographic map series of Hungary (V á r a l l y a y et al., 1979), now complete for the

entire area. These maps are in the projection of the uniform national map system. As an overlay on topographic data, the maps show a 10-digit code for each polygon and it informs about soil type, the character and depth to parent material, organic matter content, permeability and water storage conditions – altogether 9 soil parameters. Local corrections of this map are made taking advantage of the data base for the physical land evaluation system, which consists of a dense network of soil profiles (as many as 5,000 sites for Pest county supplied with coordinates obtained from the regional Land Registry Office). The point information is integrated into the soils data base – lacking the necessary personnel – along typical cross-sections.

Climatic data are collected from the observation series in the Climatic Atlas of Hungary (for the period 1940-1960; K a k a s, ed., 1960) and corrected from meteorological (data series extended up to 1970) and water management publications (data of first-order stations up to 1988).

AUTOMATED ECOLOGICAL ASSESSMENT

Land capability is established in the ARC/INFO GIS with the help of suitability indicators. The latter are tables which rate the coded environmental conditions according to the ecological demands of crops (L ó c z y, 1984). The varying sensitivity of the individual crops is built into the system in the form of weighting.

A special overlay technique is applied to allow the joint assessment of factors which exert a combined influence on the site value (e. g. monthly precipitation values are assessed against soil texture). This step is implemented in the vector system of ARC/INFO. Overlays, however, produce an innumerable set of minor areal patches, which disturb the interpretation of results. Therefore, the next step is the rasterisation of the maps produced using the ILWIS statistical module (V a n d e r K n a p p, 1992). The resulting 'generalised' maps are suitable – after repeated smoothing – to delimit agroecological sites with approximately identical potential. The built-up areas, forests and water surfaces are out of model and removed from the computer maps by a masking technique either in vector or raster form.

For the map representation of the results of the assessment a Hewlett Packard PaintJet is available. The approximate original scale of maps on the monitor screen is 1 to 760,000, but it is also possible to plot A0 size maps on HP plotter.

EXAMPLE: ASSESSMENT MAPS FOR LUCERNE CULTIVATION IN PEST COUNTY

To illustrate the way the ARC/INFO GIS is used to survey the regional variation in land capability, partial assessment results are shown here.

Since the ecological requirements of plants are directed to major land qualities rather than to simple land characteristics, it seemed to be the purpose to integrate some of the input parameters. On the maps shown monthly average rainfall values appear together with soil textures or parent materials, since the availability of water may greatly vary with the

grain size of the soil and its parent material. The considerable water demands of lucerne in the critical months are shown in Table 3.

Table 3: Water demand of lucerne in the months of its growing season in Pest county (in mm).

Tabela 3: Potrebe lucerne po vodi v vegetacijski dobi v županiji Pest (v mm).

Station	April	May	June	July	August	Sept.	Total
Gödöllő	36	92	123	146	119	71	587
Budapest	39	95	126	143	124	76	603

Naturally, the variation in these demands largely depends on monthly mean temperatures. The pattern of monthly demands, however, is similar for both stations.

In April the amount of precipitation satisfy the demands of lucerne over most of the county area. In contrast, drought conditions occur as early as June, when only the mountainous parts of the county receive sufficient amounts of rainfall. In the month of the highest water demand, in July (Fig. 1), low scores of suitability are recorded. The pattern changes only in September (Fig. 2), when higher-than-average water supply is observed for most of the area.

Brown forest soils on loess parent material excel on the assessment map of soil types, alluvial soils show medium values and some patches of the Buda Mountains (barren slopes on calcareous bedrock) are entirely unsuitable for lucerne cultivation (Fig. 3).

The results presented here are only partial achievements of our project. The processing and assessment of ecological data is under way and the land capability GIS is also subject to further improvement.

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UPORABA GIS PRI UGOTAVLJANJU PRIMERNOSTI TAL NA MADŽARSKEM

Povzetek

V procesu sedanjega spreminjanja madžarskega kmetijstva je bila tudi obdelovalna zemlja kot tržno blago vključena v tržno ekonomijo. Ker v zdajšnjih gospodarskih razmerah ni možna večja uporaba mehanizacije in umetnih gnojil, postaja naravna rodovitnost tal, poleg številnih ekonomskeih faktorjev, najpomembnejša sestavina cene zemlje. Ugotavljanje primernosti tal pomaga kmetovalcem poiskati najprimernejši tip rabe tal za čim bolj donosno proizvodnjo, brez večje škode za okolje.

Projekt ugotavljanja primernosti tal in agroekološko rajonizacijo smo začeli izvajati na Geografskem inštitutu v letu 1982. Postopek je sestavljen iz treh faz:

- vzpostavitev računalniške podatkovne baze (podatki o reliefu, količinah toplotne in vode, značilnosti tal itd.),
- ugotavljanje pokazateljev primernosti za najpomembnejše pridelke (pšenica, koruza, lucerna, sončnice, sladkorna pesa) in njihova primerjava z značilnostmi površja,
- omejevanje agroekotopov in agroekoloških rajonov.

Projekt zajema po eno županijo letno, tako da so bile doslej obdelane že vse transdanubijske županije. V tem času smo izpopolnili metodologijo, npr. z vključitvijo ARC/INFO geografskega informacijskega sistema (E S R I, 1989) v oblikovanje podatkovnih baz in kombiniranjem posameznih parametrov okolja v kompleksne pokazatelje kvalitete tal. V tem letu poteka ugotavljanje fizičnogeografskih potencialov županije Pest.

Prvi računalniški program za ugotavljanje primernosti tal (L ó c z y, 1988) je bil napisan 1983 za računalnik Commodore. Današnja opremljenost Geografskega inštituta je veliko boljša in mnogo primernejša za uporabo tehnik GIS (računalnik AT 486/33 MHz z 8 Mb RAM in dvema trdima diskoma po 200 Mb).

Osnovni vir podatkov za ugotavljanje primernosti tal je agrotopografska karta Madžarske v merilu 1 : 100 000 (V á r a l l y a y et al., 1979). Na teh kartah je na topografski podlagi

prikazana desetštevilčna koda za vsak poligon, ki vsebuje informacije o tipu prsti, značilnostih in globini matične podlage, vsebnosti organskih snovi, prepustnosti in kapaciteti prsti itd. Klimatski podatki se nanašajo na opazovalno obdobje 1940-1960 iz Klimatskega atlasa Madžarske (K a k a s, ur., 1960), korigirani z novejšimi meteorološkimi in hidrološkimi podatki.

Primernost tal ugotavljamo v geografskem informacijskem sistemu ARC/INFO s pomočjo pokazateljev primernosti. To so tabele, ki vrednotijo podatke o okolju glede na ekološke zahteve poljščine (L ó c z y, 1984). Različna občutljivost posameznih poljščin je upoštevana s ponderiranjem.

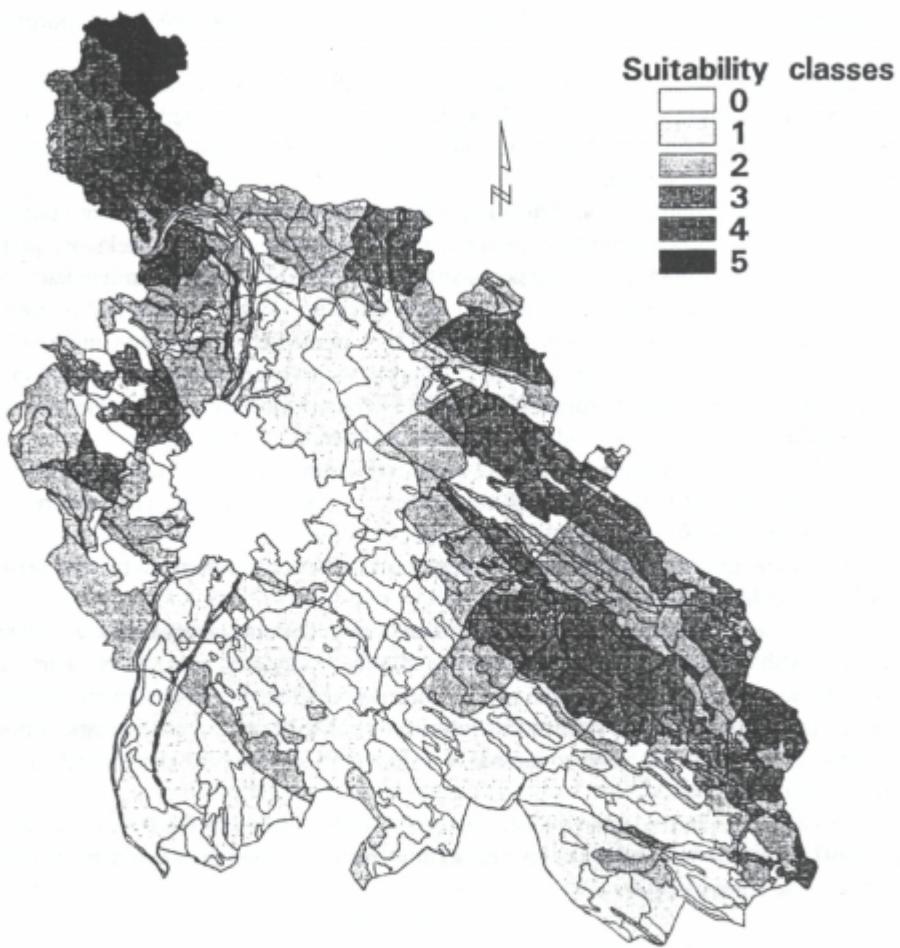
Za skupno vrednotenje faktorjev, ki družno vplivajo na primernost tal, je uporabljena posebna metoda prekrivanja (npr. množine mesečnih padavin glede na teksturo prsti). Ta postopek poteka s pomočjo vektorskega sistema ARC/INFO. S prekrivanjem kart nastane nešteto zelo majhnih območij, ki ovirajo interpretacijo rezultatov, a jih lahko izločimo z rasterizacijo kart (V a n d e r K n a p p, 1992) s pomočjo statističnega modula ILWIS (I T C, 1992). Tako 'generalizirane' karte so primerne za omejevanje agroekoloških enot s približno identičnim potencialom. Pozidana območja, gozdove in vodne površine izločimo iz modela s pomočjo mask, bodisi v vektorski ali rasterski tehniki.

Za kartografsko predstavitev rezultatov uporabljamo risalnik Hewlett Packard PaintJet. Prvotno merilo kart je na računalniškem zaslonu 1 : 760 000, vendar pa je možno izrisati karte do formata A0.

Za ilustracijo postopka ugotavljanja regionalnih razlik v primernosti tal so v prispevku prikazani delni rezultati vrednotenja.

Ker se ekološke zahteve rastlin bolj odražajo v poglavitnih kvalitetah tal kot v preprostih značilnostih površja, je potrebno nekatere vhodne parametre združiti. Na karti je npr. povprečna mesečna množina padavin prikazana skupaj s teksturo prsti ali matično podlogo, saj je razpoložljiva količina vode močno odvisna od velikosti delcev prsti ali matične podlage. Razlike v potrebah po vodi so seveda v veliki meri odvisne od povprečnih mesečnih temperatur.

Prikazani rezultati so samo majhen del tega obsežnega projekta. Obdelava in vrednotenje ekoloških podatkov se nadaljuje, geografski informacijski sistem za ugotavljanje primernosti tal pa se še izpopolnjuje.

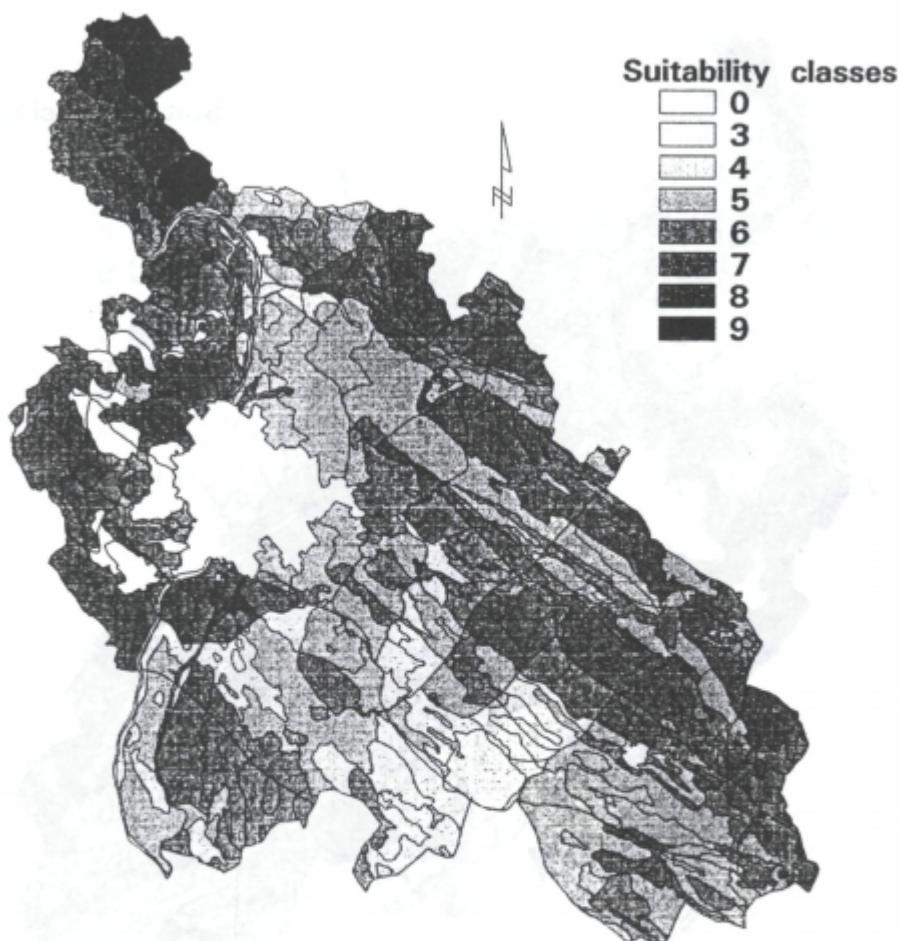


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Project leader: Loczy, D. PhD.
by: Szalai, L.

Fig. 1: Assessment of precipitation in July combined with soil texture type for lucerne cultivation in Pest county. 0 = unsuitable, 9 = highest suitability in Hungary.

Slika 1: Ocena julijskih padavin v kombinaciji s teksturo tal za pridelovanje lucerne v Županiji Pest. 0 = neprimerno, 9 = najvišja primernost na Madžarskem.



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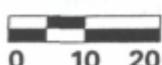


Fig. 2: Assessment of precipitation in September combined with soil texture type for lucerne cultivation in Pest county.

Slika 2: Ocena septembrskih padavin v kombinaciji s teksturo tal za pridelovanje lucerne v županiji Pest.

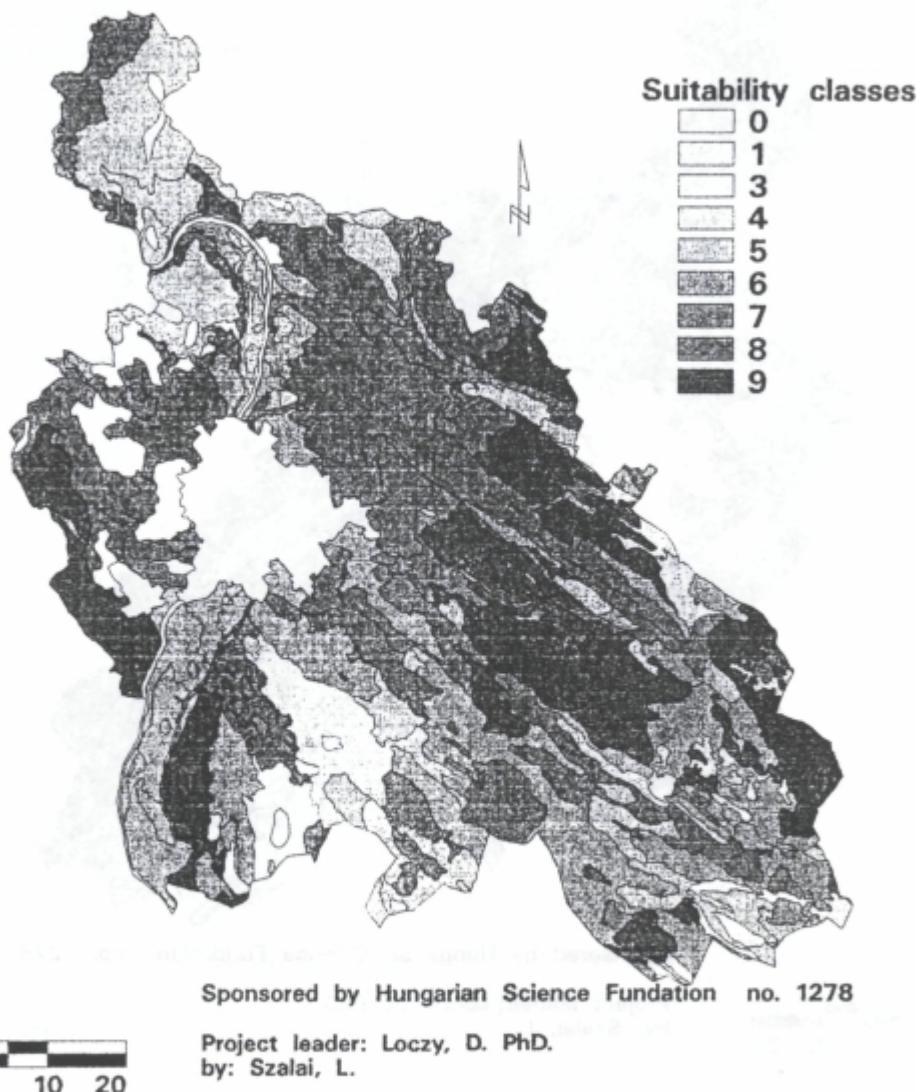


Fig. 3: Assessment of soil type for lucerne cultivation in Pest county.
Slika 3: Ocena tipov tal za pridelovanje lucerne v županiji Pest.