TIR: A COMPUTERIZED CARTOGRAPHIC SOIL INFORMATION SYSTEM

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ABSTRACT

The constantly growing need for rational land use and management require adequate information on the soil. This leads to an enormous amount of soil data and maps. These data are being digitized, edited and incorporated into a digital data base. The data will be available in both graphic and digital form to assist large scale mapping of soils and monitoring of soil processes. To accomplish these tasks the SzATIR software has been designed and is being developed. SzATIR is designed to accept digitizer input, provide comprehensive expert system facilities and produce cartographic and statistical output. The distributed system is operational for an approximately 1o.ooo km^2 area /Pest County/ to search for either location or attributes and display results in a graphic and/or tabular form. Current system development is focused upon the enhancement of local modelling and editing functions, as well as to make this quadtree based thematic GIS compatible with other gridded data sources.

INTRODUCTION

1.1 Soil mapping information

The scientifically based planning and implementation of rational land use and management /amelioration, irrigation, drainage, agrotechnics etc./, ensuring normal soil functions and the maintenance or increase of soil fertility require adequate /i.e. well-defined, quantitative, territorial/ information on the soil /Várallyay et al. 1985/. A large amount of such information is available in Hungary as a results of numerous soil surveys, analysis and mapping projects accomplished is the last 5o years. The comprehensive and up-to-date synthesis, systematically controlled processing of this amount of soil profile data and maps require a computerized cartographic soil information system to enable soil scientists to establish and verify relationships among soil properties, soil caharacteristics and environmental factors or crop yields as well as to survey soil types and monitor soil processes /such as erosion, water-and plant nutrient dynamism, acidification, salinization, alkalinization, structure destruction, compaction etc./.

1.2 Geographic information systems
The recognition of the need for introducing computer technology in cartography lead to digital cartography. This means the formulation of the following basic features: /1/ the need for explicit coding of spatial relationships, i.e. for the definition of a topological structure, /2/ the need for numeric coding of attributes of map-elements, and /3/ the need for transforming spatial data to bit-streams for computers /McEwen et al. 1983/.
Based on these foundations new terminology, data standards, data formats, data quality could be elaborated in the early 8o's, that facilitated the fast and wide spread of geographic information systems. Such systems generally consist of several /input, storage, retrieval and analisys, output/ subsystems, and are capable of cartographic information processing by computers /Marble 1984/.

DATA BASE SOURCES

2.1 Geographic /geodetic base
A number of thematic information systems have been designed in Hungary without a common geographic reference system /Csillag 1985/. The initiative for a Unified National Map System /UNMS/ was introduced and approved for all computerized cartographic applications in 1981 /Joó 1985/. The UNMS involves the regulations for projection, scale, topographic data content and quality, consequently opened the possibility for establishing the geodetic data standards and the geographic reference system /see Fig.1./ of the TIR /Hegedüs 1984/.

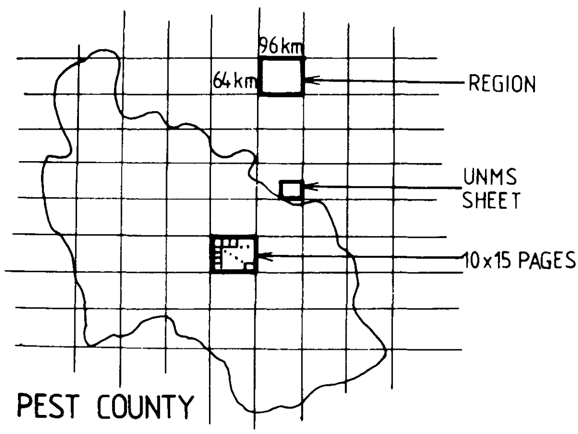

Figure 1. Pest county with the UNMS-grid, the experimental area and the geographic reference system of the TIR.

2.2 Soil data

The main sources of the TIR soil data base are as follows:

- 1:25.ooo soil maps of L.Kreybig's survey /1935-1955/
- 1:lo.ooo operational genetic soil maps of co-op farms
- data on soil profiles of the land evaluation program
- 1:loo.ooo agro-ecological maps of soil factors

/Várallyay-Szücs 1978, Várallyay et al. 1982./

Table I. Soil data inputs of the TIR

Points	Maps
soil type	geomorphology
relief	slope categories
depth to humus horizon	slope exposures
texture	parent material
concretions	soil erosion
parent material	genetic categories
pH /H2o/	soil reaction and carbonate status
pH /KCl/	water-soluble salts
hydrolitic acidity	depth to humus horizon
exchangeble acidity	organic matter content
carbonate content	soil texture
water.soluble salt content	total water capacity /VKT = pF 0/
ion composition of the aqueous extract	field capacity /FC=pF 2.5/
EC paste	wilting percentage /WP=pF 4.2/
alkalinity against phenolphtalein	available moisture content /AMR=FC-WP/
organic matter content	saturated conductivity
humus-stability index	unsaturated conductivity
clay-mineral composition	mean depth to water table
particle size distribution	max. depth to water table
sticky point according to Arany	min. depth to water table
thickness of capillary fringe	groundwater concentration
fine fraction %	ion composition of the groundwater
specific surface	
CEC	
base saturation /T-S/	
exchangeable cation composition	
Na^+ / /Na^+ +K^+ +Ca^{2+} +Mg^{2+}/	
SAR	
infiltration rate	
saturated hydraulic conductivity /K/	
unsaturated capillary conductivity	
characteristic points of the pF-curve	

The input data on soils /see Table I./ are divided into two parts:
- POINTS : characteristic properties of the soil profiles /borings/, identified by their UNMS coordinates;
- CONTOURS: physico-geographic soil maps of 1:25.ooo scale, while lines are used only coding geographic information.

The digitization of point-data /apprx. 4 Mbyte/ was completed in 1985, while the input process of map-data /apprx. loo Mbyte/ is currently going on.

COMPUTATIONAL FEATURES

3.1 System description
A distributed system has been developed: both the data storage and manipulation are shared between the host mainframe and the local microcomputer /see Fig.2./. The SzATIR software controls all GIS procedures from data capture through data storage and analysis, retrieval to data presentation. The entire software was designed by Egyszög Ltd. and has been implemented in FORTRAN and COBOL.

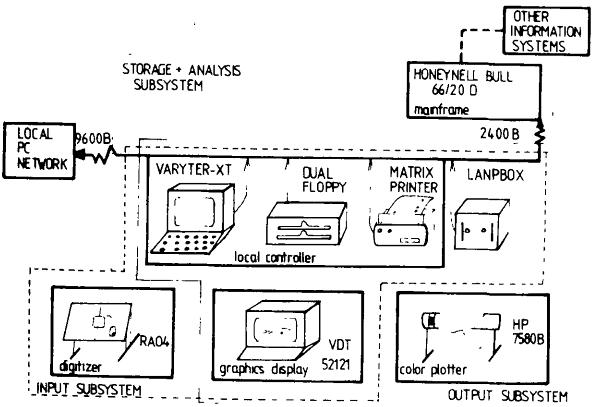

Figure 2. TIR - system scheme

2.2 Data capture
Point, line and region data are hand digitized from sheets, with o,5 mm resolution /64ox96o pixels/ according to the flow-chart on Figure 3. Three levels of error checking are performed:
- the catalogue, containing the complete list of polygons /identifier, colour, number of arcs/ provides control of structural-syntactic errors,

- the work-files, containing record-headers for all arcs of each polygon and its neighbours, facilitates the control of semantic errors,
- visual inspection helps the operators on both graphic devices to easily follow the input procedure.

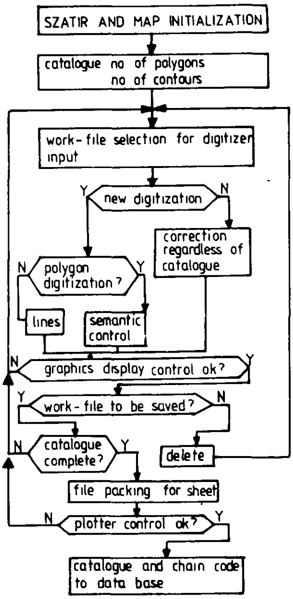

Figure 3.
Data capture flow-chart of the TIR

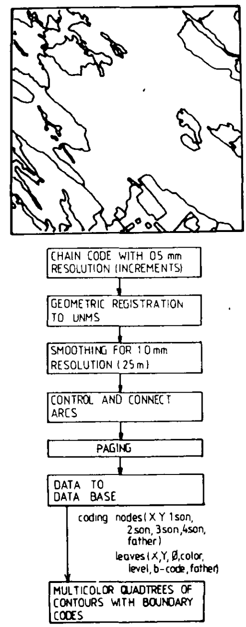

Figure 4.
Procedure for contour-data to enter the data base

3.3 Data base management system

There are two controversial requirements concerning data base management:
- to minimize storage space for the compensation of the slow modem (cf. interactivity), and
- to optimize map/data processing capabilities.

These requirements lead to the combination of chain-code and quadtree representation.

Quadtrees of regions are constructed by pages (256x256 pixels): first boundaries are encoded and then regions are converted, similarly as described by H.Samet (Samet 1980). Levels of the quadtree are coded in the page-relative coordinates of the lower-left corner of the nodes. The efficiency of this type of storage and unionintersection operations on it for binary images were pointed out by (Dyer 1980). Currently experiments concern the establishment and test of an effective multicolour quadtree-based DBMS (making use of colours and boundary-codes, i.e. 4. and 6. subfield of leaves' codes: see Fig.4.), in spite of the generally applied binary ones.

3.4. Data retrieval and query

Data can be retrieved from the data base using its query language. The initialization of the query starts with area selection: the highest acceptable level is a region, and a country, a set of pages or a polygon can be defined for restrictiong unnecessary data, as well as depth intervals (for point data). Readout is executed when data or map types (connected with any of the following logical operators: &, +, \ ), and specific conditions (data type → R → number, where R can be any of the following relations: =, \ =, >, <, >=, <=) are listed. Additionally SzATIR, certainly, accepts data from tapes of previous runs. Map mainipulation is allowed for previously defined maps (and their combinations with logical operators), and there is a sequence of commands for recording a map. An arbitrary set of points can be defined by conditions on data-types, value-intervals, previously defined sets and maps, as well as by locational functions (e.g. nearest n).

```
TARTOMANY= 54;                                       - region definition
SOKSZOG   = 6440.7858,                               - polygon definition
            6954.7866,
            6952.8420,
            6400.8420'
ADATOK    = PHH2O,                                   - data type selection
            CACO3,
            HUMUSZ,
            HUMUSZVAST1,
            FIZIKFELESEG;
PONT      = K1&K2;                                   - data source selection
GOODSET   = CACO3 5&                                 - conditions:
            PHH2O /.6&PHH2O 6.5&                       ranges to define
            PHKCL 6&PHKCL 7%                           a set of points
            HUMUSZ 2&
            HUMUSZVAST1 30&
            FIZIKFELESEG=03+FIZIKFELESEG=05,
GOODMAP   = /EROZIOS+                                - restriction to the
            /DEGRADALT;                                complements of maps
SZAMOSSAG;                                           - number of points
                                                       command
A GOODSET    HALMAZ PONTJAINAK SZAMA:   955
=
STATISZTIKA PHH2O GOODSET,                           - statistics of a
                                                       given type of data
GYAKORISAG..........................  2/8              for the given set
ATLAG...............................    7.22           of points
SZORAS..............................    4.52
SZORASNEGYZET.......................   20.98
RELATIV SZORAS......................    0.63
MINIMUM.............................    6.51
MAXIMUM.............................    7.60
TERJEDELEM..........................    1.19
```

Figure 5. Sample query for point data describing optimal agricultural fields in a given area

Data retrieval can be represented with a set of commands concerning the total number of points, area of a map, statistics for data types and/or maps (categories). In addition a plotter-ready raster code of any quadtree(s) can be received by the local controller and be plotted according to UNMS standards.

A limited set of help and technical control functions (reset, list valid commands, list valid syntax etc.) assist to perform interactive functions in a more user-friendly environment.

CURRENT STATUS AND DEVELOPMENT

4.1. Usage

The design and development of the TIR is a significant contribution to the solution of several soil mapping problems. The system itself not only provides an opportunity for data retrieval and analysis, but during its use, methodological benefits can be achieved either in soil science or in computer cartography.

The TIR in its present phase can be used

- in the planning and implementation of rational land use and cropping pattern, according to ecological conditions
- in estimating the necessity, the predictable impact and efficiency of the application of various agro-technical measures
- in its implementation and control on national, regional, farm and field levels
- in the prediction of unfavourable soil degradation processes
- in land and soil evaluation
- in the protection of the environment
- in soil science-agrochemistry-soil biology research, and
- for educational purposes.

4.2. Future development

One of the most attractive features of the TIR is the opportunity to introduce, test and verify various scientific models, that concern its data base. The enhancement of the local expert system functions of the GIS is a field of intensive R and D activity.

Another area of interest is the multidisciplinary use of the information system, that requires compatibility and communication with other (e.g. meteorological agrochemical) data bases.

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