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HIDROTECHNICS

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GIS AND HYDRAULIC MODELING FOR WATER DISTRIBUTION AND SEWER NETWORKS

BY

IULIUS EDUARD KELLER, *DAVID BEALE and **GABRIEL BĂDESCU

Abstracts: There are thousands of hydraulic models implemented around the world, many of which are linked to GIS. All GIS users can greatly leverage the value of their data by using it to build models quickly. However, these links require more than the wholesale import of raw GIS data into a model. To deliver maximum value, the model needs additional functionality to manage GIS data import and export.

Key words: GIS, hydraulic modeling, waer distribution networks.

1. Introduction

Commercially available models are reviewed with comments on their suitability and to assist in the preparation of the procurement contract a draft model specification has been prepared. In addition a range of GIS options have been assessed together with their links to the network models.

For hydraulic modeling a three stage process is undertaken.

Stage 1 – data collection and model building

Stage 2 – model verification with comparison of observed flow and level or pressure data

Stage 3 – use of the models in investigative and predictive mode

2. Main Use of GIS

The main uses of the Geographical Information System (GIS) in implementing for water distribution networks and sewer networks are:

Data Collection: Conventionally data on networks is collected and stored in paper format. This is not only labour intensive and error prone but makes data retrieval and use very tedious. Using technologies such as GPS and digital cameras, data collection can be faster and more accurate and GIS can provide integration of data. In areas where digital data is not available paper plans can also be scanned and used. For newly developed areas where no data is available aerial photographs or satellite images can be used. It is also possible to use a combination of raster and vector data.

Data Storage: Data on network components can be stored in GIS for spatial querying. The main data that will be stored will be pipe and node locations and characteristics. Pipe data is held in the system in a node and line type format. This is ideally suited to the pipeline type layout with nodes and connecting pipe-work. Data can be input in several ways, either directly onto to the screen, from a digitiser, or from previously captured data that can be read into the database as long as it has a record of its grid co-ordinates and connectivity. The GIS includes an import facility for standard GIS to enable interoperability.

Data Mapping: generating the mapping of water, wastewater and storm water networks for various criteria using GIS makes everyday querying based on specific criteria quick, easy and understandable for engineers. Fundamentally the model presents information, as on a map. But it is an intelligent map in that each item that you can see is supported and described by other data that the user can access by a simple click on the mouse button. There is a great deal of flexibility in the way that data can be used. Background maps in a variety of formats can be supported. The GIS contains a standard database structure to hold all the data that is regularly used for water, wastewater and storm water networks, but the system is not limited to just this data. Any data set can be viewed provided that the information is given either a grid reference or a cross-reference to an item (node or line). With maps and data in the system it is easy to view and interrogate. Information can be viewed selectively, for example with different layers switched on and off as need may be. Or data can be filtered: e.g. only pipes of greater than 100mm diameter can be displayed, or even those greater than 400 mm diameter viewed in blue, and those greater than 200 mm diameter in red. The graphical output can be shown in GIS and other relevant features can also be shown relative to for example, pressure variation. The model output can be overlaid on an aerial photograph of the city and also the location of consumers potentially affected shown. If the population theme is turned on, then the Select feature can select an area of interest highlighting the population at risk.

Analysis: Statistical analysis, data interpolation and spatial statistics to be carried out with in the GIS. Due to the voluminous amount of data that has to be stored in case of water, wastewater and storm water networks the various analysis tools in any standard GIS not only help in Spatial analysis but also in statistical analysis of data sets.

Visualisation: Multimedia data like photographs, videos and 3D panchromatic imagery can be stored as associated data sets to enhance real-life scenarios. This enables site condition assessments for immediate action. Also the visualisation tools in GIS can be used to find patterns and relationships in the huge amounts of data collected like pressure and flow recordings. Also the functions in GIS to plot graphs of the data help the engineers in finding anomalies in the huge data sets that is otherwise impossible to detect. Also 'what-if' scenarios can be generated and effects studied which helps in better and informed decision making.

*GIS in Water Demand Modeling and Design***:** GIS can be used to model hydraulic conditions in spatial terms and can help in design of systems. Performance information is important to network design and in planning. A dynamic, hydraulic, water-distribution model helps to understand the effect of different demands on the network, and allows the informed decisions to be made to allow for future increases in demand. The performance of the network can be tested under extreme conditions. A GIS could establish the actual pressure head in an area based on water network model pressures and actual ground levels and also show the variation during the day.

3. Specification for Network Models and GIS

3.1. Water Network Model

A hydraulic model is a computerized, or digital, representation of a pressured closed pipe potable water supply system. The modeling software predicts hydraulic properties throughout the system: flow, pressure, operational status, tank levels, energy usage, chlorine residuals, water quality, water mixing, etc. The geometry of a hydraulic model is edges and junctions (lines and points). Pipes are represented as edges, and all other features are represented as junctions (connections, pumps, tanks, reservoirs, valves, hydrants, meters, etc.).

In detail the water network modeling software shall:

- Comply with international standards
- Be user friendly and usable by users with limited modeling expertise
- Permit any type of pipe network to be modelled such as trees, loops, grids or any combination
- Model all water network ancillaries including pumping stations, inline pumps and hydrophores, ring mains, valves, fire hydrants etc
- Allow for multiple pipe types
- Calculate water demands from basic data
- Automatically generate a network model from the model data base
- Calibrate the model based on observed data
- Accurately model flows and pressures

- Produce isometric, plan and elevation schematic views of the pipe network with background mapping
- Manage current and historical model network versions, maintaining full details of each modification made to the network geometry and control data, and providing version ID's, date stamps and modeller details for a comprehensive audit trail
- Allow for water leakage to be modelled
- Allow for steady state, extended period, water quality under extended period conditions and transient flow simulations
- Allow for fire flow analysis
- Produce model outputs that can be directly input GIS
- Produce easy to read inclusive reports.

3.2. Wastewater Network Model

A hydraulic model is a computerized, or digital, representation of a closed pipe wastewater collection system together with pressure mains from pumping stations. The modeling software predicts hydraulic properties throughout the system: flow, water levels, surcharge, operational status, wet well levels, storm water overflows, energy usage, water quality, etc. The geometry of a hydraulic model is edges and nodes (lines and points). Pipes are represented as edges, and all other features are represented as nodes (manholes, pumping stations, overflows, etc.).

In detail the waste water network modeling software shall:

- Comply with international standards
- Be user friendly and usable by users with limited modeling expertise
- Permit both free flow and surcharged flow conditions
- Model all wastewater network ancillaries including pumping stations, bifurcations and overflows etc
- Allow for multiple pipe types
- Calculate waste water discharges from basic data
- Automatically generate a network model from the model data base
- Accurately model flows and water levels
- Produce isometric, plan and elevation schematic views of the pipe network with background mapping
- Manage current and historical model network versions, maintaining full details of each modification made to the network geometry and control data, and providing version ID's, date stamps and modeller details for a comprehensive audit trail
- Allow ground water infiltration to be modelled
- Allow for dry weather flows, water quality and storm flows
- Produce model outputs that can be directly input into GIS

- Produce easy to read inclusive reports.

3.3. Storm Water Model

A hydraulic model is a computerized, or digital, representation of a closed pipe or open channel storm water collection system together with storm rainfalls and inflows. The modeling software predicts hydraulic properties throughout the system: rainfalls, storm inflows, flows, water levels, surcharge, etc. The geometry of a hydraulic model is edges and nodes (lines and points). Pipes and channels are represented as edges, and all other features are represented as nodes (manholes, storage ponds, outfalls, etc.).

In detail the storm water network modeling software shall:

- Comply with international standards
- Be user friendly and usable by users with limited modeling expertise
- Permit both free flow and surcharged flow conditions
- Model all storm water network ancillaries including inlets, pumping stations, storage ponds and overflows etc
- Allow for multiple pipe types
- Calculate storm rainfalls
- Include catchment and contributing areas and runoff factors
- Calculate storm inflows from basic data
- Automatically generate a network model from the model data base
- Accurately model flows and water levels
- Produce isometric, plan and elevation schematic views of the drainage network with background mapping
- Manage current and historical model network versions, maintaining full details of each modification made to the network geometry and control data, and providing version ID's, date stamps and modeller details for a comprehensive audit trail
- Produce model outputs that can be directly input into GIS
- Produce easy to read inclusive reports.

It should be noted that most wastewater models include the facility to simulate the behaviour of a storm water networks by including modules for storm rainfall analysis and catchment and contributing area data. In fact in older areas, most nominally separate wastewater networks have significant storm flows and most storm water networks carry wastewater flows.

3.5. GIS

The GIS software must be able to import the water and sewer network data for use in mapping and presentations and have the facility to introduce, edit, spatial analyze, visualise and print the water and sewer data and model results.

In detail the GIS software shall:

- work within very large and/or multiple drawings
- integrate data from various sources and formats (e.g. ESRI Shape files, MapInfo TAB);
- provide multiple users access to the same drawing concurrently
- combine geo-referenced raster imagery with drawings
- view CAD data
- support global projections and co-ordinate systems
- perform data collection functions
- link external databases to the drawing elements
- Allow for operational time series data to be stored and interrogated
- Allow for video data to be displayed
- perform spatial analysis (buffers, spatial query, overlay, etc.)
- produce thematic maps
- enable user to create point, line and area topologies
- hyper-link map elements to pictures, sketched drawings, documents
- export to a wide range of industry standard formats (min. ESRI shape, AutoCAD dwg and dxf)
- printing maps

4. Collected Data

It is anticipated that a water and sewer company will collect the following data:

4.1. Water Supply

- Raw water flows and water quality
- Flows to supply with water quality and pressure
- Flows, pressures and water quality in supply system
- Pump hours run and power consumption
- Reported low pressures and supply failures
- Reported leaks and bursts
- Meter consumption records (Bulk and individual)
- Pipe data observed during repairs and connections
- New pipe data

Table1
Data for Water Network

Mapping
Street location plan
Topographical map with contours
Census data map
Detailed water network plans with catchment areas
Land use plans
Levels along water distribution mains
Utility plans (Electricity, gas, telephone, cable, heating and sewerage)
Demand Data
Population data by area
Population projections
Water supplies
Major water users (location and volumes)
Water Network Data
Schedule of pipes with size, depth, material and age
Schedule of junctions with connectivity
Schedule of valves with location, size, material and age
Operational data (leakage & bursts)
Flows from treatment (average and peak)
Leakage
Ancillaries
Pressure valves, operating limits, size, material and age
Pumping stations (size, levels, pump data)
General
Pressure data
Flow data
Repair data
SCADA data
Capital and operational cost data

4.2. Wastewater

- Inflow to treatment plant including spilled flows and water quality
- Reported surcharged sewers and blockages
- Reported sewer collapses
- Sewer data observed during repairs and connections
- New sewer data

Table 2
Data for Wastewater Network

Mapping
Street location plan
Topographical map with contours
Census data map
Detailed Sewer Network plans with catchment areas
Land use plans
Levels along sewer line
Utility plans (Electricity, gas, telephone, cable, heating and water supply)
Demand Data
Population data by area
Population projections
Water supplies
Major water users (location and volumes)
Industrial discharges
Sewerage Data
Schedule of manholes with size, depth, cover level, material and age
Pipe data with length, diameter, invert levels material and age
Sewer connectivity
Operational data (flooding, blockages & collapses)
Flows to treatment (DWFs and peak)
Dry weather flows
infiltration
Storm flows
Ancillaries
Storm overflows (dimensions and levels)
Pumping stations (size, levels, pump data)
Reservoirs (sizes and levels)
General
CCTV data
Flow data
Repair data
Capital and operational cost data

4.3. Reports of Flooding

- Reported surcharged sewers and blockages
- Reported sewer collapses
- Reports of sewage overflows
- Sewer data observed during repairs and connections

• New sewer data

Table 3
Data for Storm Sewer Network

Mapping
Street location plan
Topographical map with contours
Detailed Storm Sewer Network plans with catchment areas
Land use plans
Levels along drain lines
Utility plans (Electricity, gas, telephone, heating, industrial and domestic waste water and water supply)
Rainfall Data
Depth-Area-Frequency curves
Design storms
Storm rainfalls during flooding
Rain gauges and Thiessen polygons
Storm Sewerage Data
Schedule of manholes with size, depth, cover level, material and age
Pipe data with length, diameter, invert levels, material and age
Sewer connectivity
Operational data (flooding, blockages & collapses)
Details of outfalls to river
Dry weather flows
Storm flows
General
CCTV data
Flow data
Repair data
Capital and operational cost data

4.4. Utility Mapping

• Electric supply network
• Gas network
• Heating pipe network
• Telephone cables
• Cable TV network

5. Conclusion

The key parameter in selection of software is the ability of the GIS and database to store all of the water supply and wastewater network data together with the operational data, so that all of the separate types of data are integrated without extensive customisation by GIS analysts.

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GIS ŞI MODELARE HIDRAULICĂ A REȚELELOR DE ALIMENTARE CU APĂ ŞI CANALIZARE

(Rezumat)

Există sute de modele hidraulice implementate, mult edintre ele fiind integrate cu GIS. Valoare datelor utilizate de GIS creşte prin contsruirea rapidă a modelelor. Această integrare presupune mai mult decât importul datelor. Pentru a lucra la adevărata valoare, modelul are nevoie de funcții suplimentare pentru managementul datelor GIS.

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CONSTRUCTING A SOIL HYDRAULIC CONDUCTIVITY MAP USING PEDOTRANSFER FUNCTIONS AND GIS
APPLICATION TO HOROIATA BASIN, ROMANIA

BY

CRISTIAN-VALERIU PATRICHE and *IONUŢ VASILNIUC

Abstracts: Due to the costs of laboratory or field determinations, pedotransfer functions (PTFs) are used to estimate and predict the spatial variability of hydraulic conductivity (Ks) at different scales. Our purpose was to estimate Ks, and to model its spatial variability at the scale of a small watershed. The data obtained may be further used in studies that imply Ks as parameter. Because we do not have measured data of Ks, the validation of different PTFs has been done through expert opinion and on the basis of the few measured data from the area existent in other studies. Both the validation of the test samples and the crossvalidation indicate the superiority of the spatial model obtained through universal kriging universal with 1st order polynomial spatial trend, at local level.

Key words: GIS, soil hydraulic conductivity, model, algortitm.

1. Introduction

Soil surface plays an important role as interface between the atmosphere and the unsaturated zone, separating hydrologic processes into runoff and infiltration [1]. Soil's hydrologic functioning is defined by the structure of the access routes and of the spaces available for water movement and retention. This relation has a multitude of feedbacks that modify the function according to the changes in structure, and reversely [2].

Among the most important parameters linked to soil water state and dynamics are the hydraulic ones. The most important such properties are water retention in soil, the relation between the volumetric water content θ and its potential h, the characteristics of hydraulic conductivity, and the relation between hydraulic conductivity K and the water content or potential [3]. Soil properties needed to describe or model infiltration, water movement in soil, water storage and intake by plants are the water retention curve, and soil's hydraulic conductivity (K) as a function of theta, h or T.

Hydraulic conductivity describes the easiness in water's way through soil. It is a constant of the proportionality between the water flux and the hydraulic gradient [4].

There are several field and laboratory methods for the direct measurement of hydraulic properties, but they are complex and time consuming. For this reason, and for more general applications, have been developed a series of simpler estimating techniques to obtain these relations on the basis of soil properties that are easier to measure. These are the pedotransfer functions (PTFs), statistical correlations between soil texture, soil organic matter, water potential in soil and Ks, which may offer quite correct estimations for many analyses and decisions.

The PTFs have gained recognition during the last years as approaches in translating simple soil characteristics into complicated parameters. At the beginning of PTFs development, many of them have been constructed with the help of linear regressions. Still, these have been replaced by non-linear regressions, due to the amendment in soil hydraulic properties estimations. The major disadvantage of the regression equations is that must be described a priori relations between the grain size data and the hydraulic characteristics, through well defined models of estimating soil hydraulic parameters.

2. Materials and Methods

The analysis has been conducted on a sample area from Tutovei Hills, more precisely in Horoiata basin. The region's individuality is given by the relief fragmentation under the shape of elongated hills oriented approximately north-south, separated by a network of consequent valleys.

Our objective was to construct a hydraulic conductivity map, conductivity being a parameter that enters a multitude of other calculation formulas, which estimate for example erodibility or pollutant dispersion in soils.

The database used is made up of over 140 soil profiles realized by OSPA Vaslui, taken from other authors' studies or sampled by us. The most delicate problem implied by this study was the lack of measured hydraulic conductivity values. Being difficult and costly to measure, this parameter (and not only) does not enter the range of usual determinations conducted in Romanian in the soil survey programs.

Because of this reason we appealed to the PTFs that estimate this parameter, which tough are quite numerous. In the recent literature may be found a multitude of such functions, estimated through different methods and departing from different data sets (soils with different characteristics). There are also several studies that have attempted to evaluate / compare such functions. Thus for example Oliver and Webster (1990) appreciated that Cosby's (1984) method gives good results. Vereecken (1995) [5] evaluated the performance of 11 different theoretical models for predicting unsaturated hydraulic conductivity. Among the methods elaborated by Brackensiek, Saxton, Cosby and Vereecken, Tietje O. & Hennings V. (1996) [6] appreciate as best being that of Cosby. The variability of Cosby's method leads to a standard deviation of Ks of 2.7 for sand, 5.6 for silt and 3.5 for clay. Wagner B. et al. (2001) [7] have evaluated 8 known and accepted PTF's for the evaluation of Ks. Gijsman et al. (2002) have also conducted an analysis of eight modern estimation methods, noticing a significant discrepancy between them. They concluded that the method elaborated by Saxton et al. (1986) is the best. Borgensen and Schaap (2005) [8] appreciate that the predictions of the Rosetta model give high errors due to a weak performance at 10 and 100kPa. Matula et al. (2007) [9] consider that the equations of Wosten (1997) give acceptable results. Among the latest studies of this type is that of Manyame et al. (2007) [10], who have determined the prediction ability of three functions: Campbell, van Genuchten and Vauclin, and concluded that the first performed better.

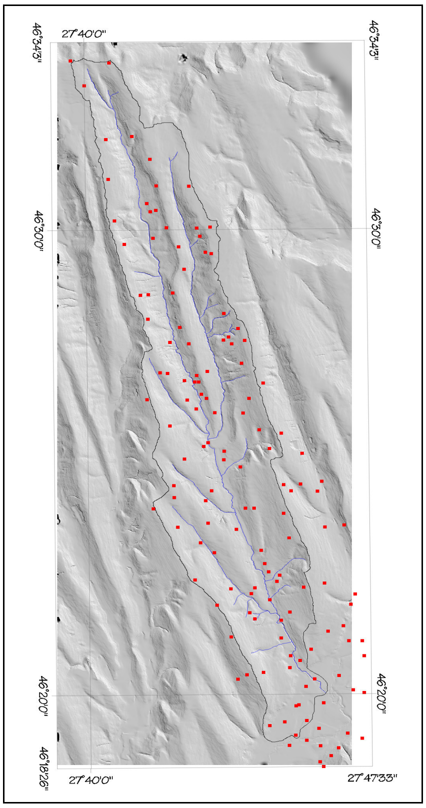

Fig. 1 – Study area and the position of the sampled profiles.

Wagner et al. (1998) [11] affirm that the prognosis capacity of the models that are based only on inputs of textural parameters is limited due to soil variability.

As it can be noticed, different authors indicate a certain PTF as performing better, fact that can only mean that each of the equations gives good results only if applied to areas with similar conditions or to soils with similar properties as those used in the deriving of the functions.

As Nemes A. et al. (2003) [12] appreciate, new approaches for the development of PTFs are continuously introduced, yet their applicability to other locations than those from where the data have been collected is rare. The authors say that the PTFs derived from international soil databases may be an alternative, yet a comparison test with the nationally-derived ones is always useful.

A limitation of the majority of the studies that evaluate FTPs is that the main estimation errors sources remain unclear. In these studies, it is not clear if the differences between the datasets used for the deriving of the FTPs (dimension, origin, validity) or the differences in the developing algorithms lead to a function to be better than other. They suggest that having a smaller set of relevant data may be better than using a larger but more general database. In this idea, [13] postulation that the use of the indirect methods is acceptable as long as the uncertainty of the estimations is given remains very truthful.

Because we do not have measured data of hydraulic conductivity, the validation of different PTFs has been done through expert opinion and on the basis of the few measurement data from the area existent in other studies.

The pedotransfer functions used for the estimation of hydraulic conductivity were those of Campbell and Shiozawa (1994), Dane and Puckett (1991), Puckett et al. (1985), Cosby et al. (1984), Cosby et al. (1984), Saxton et al. (1986), Saxton et al. (1986), Vereecken et al. (1990), Wosten (1997), Brackensiek et al. (1984) [14, 8, 15, 10, 9, 16, 17, 18, 19, 5, 11].

3. Results and Discussions

The analysis of some statistical parameters such as average, minimum, maximum and standard deviation, together with the comparison of the evaluated data with those from the existent literature, led to the choice as Ks estimating PTF of that of Wosten (1997). Wosten's equations have predicted with a higher accuracy than other PTFs and other hydro-physical parameters such as field capacity, wilting point, available and total water capacity.

For the spatial modeling of Ks were tested different kriging variants: ordinary, universal kriging with 1^{st} order polynomial spatial trend applied at global (whole region) or local level, regression and regression-kriging models. Also were tested different methods of experimental semivariograms: circular, spherical, exponential, stable.

Table 1
Statistical Results for the Used Methods

Independent sample validation			
Statistical quality parameters	Universal kriging, 1st degree global polynomial trend	Universal kriging, 1st degree local polynomial trend	Regression kriging
R^2	0.649	0.677	0.461
Slope of correlation line	0.511	0.558	0.386
Mean error	– 8.686	– 9.520	– 9.969
RMSE	29.962	28.902	30.238
Crossvalidation			
R^2	0.412	0.478	0.353
Slope of correlation line	0.384	0.479	0.312
Mean error	– 0.340	– 1.359	– 0.327
RMSE	29.269	27.542	27.148

For the regression model were tested as potential predictors the rectangular coordinates, DEM, filtered DEM in 500X500m moving window, slope, 100x100m moving window filtered slope, the NS and WE components of exposition, surface curvature (profile, plan curvature). The progressive regression model obtained uses as explicative variables the Y coordinate (variation NS) (inverse correlation) and altitude (direct correlation), but has a low explanation degree (21% of the Ks variance).

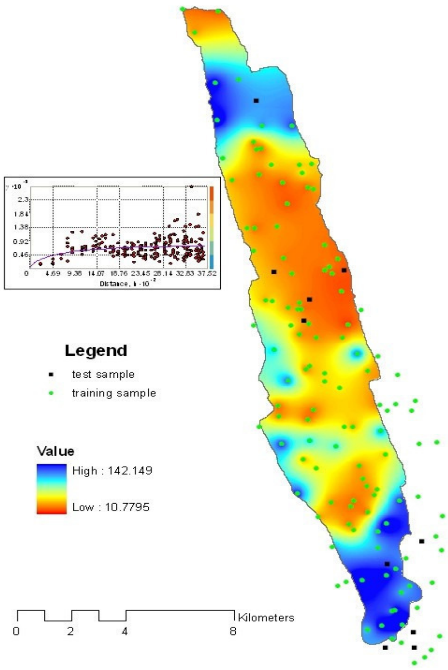

Fig. 2 – Hydraulic conductivity map obtained through 1st degree local polynomial trend universal kriging.

Validation was conducted by comparing the real values with the predicted ones for a random test sample of 10 profiles which was not included in the spatial modeling.

As can be seen from Table 1, the statistical quality parameters for both independent validation sample and crossvalidation procedure (the determination coefficient - R^2, the slope of correlation line, the mean error, the root mean square error – RMSE), indicate that the 1^{st} degree local polynomial trend universal kriging gives the best results.

4. Conclusions

Both the validation at the test samples and the crossvalidation indicate, through the reduced values of RMSE, the higher values of the correlation coefficients and of the correlation line angle, the superiority of the spatial model obtained through universal kriging universal with 1^{st} order polynomial spatial trend, at local level.

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ELABORAREA HĂRȚII CONDUCTIVITĂȚII HIDRAULICE FOLOSIND FUNCȚII DE PEDOTRANSFER ŞI GIS

Aplicație la bazinul Horoiata, România

(Rezumat)

Datorită costurilor ridicate de laborator sau de experimentare în teren, funcțiile de pedotransfer (PTFs) sunt folosite pe scară largă pentru estimarea unor parametri complecsi de sol. Scopul studiului nostru a fost estimarea conductivității hidraulice (Ks) şi modelarea variabilității spațiale a acestui parametru la scara unui bazin hidrografic de dimensiune mică. Rezultatele obținute pot fi mai departe utilizate in studii care implică conductivitatea hidraulică. Deoarece nu am dispus de măsurători, aprecierea corectitudinii diferitelor funcții de pedotransfer testate s-a făcut pe baza verosimilității rezultatelor şi comparării acestora cu o serie de valori măsurate în zona studiată preluate din diferite studii. Atât validarea cu eşantion independent cât şi validarea încrucişată, indică superioritatea modelului spațial obținut prin kriging universal cu suprafață de tendință polinomială de ordin 1 derivată la nivel local.

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G.I.S APPLICATION IN ORDER TO DETECT THE SMALL HYDROGRAPHIC BASINS MENACED BY HIGH FLOOD DURING TORRENTIAL RAIN EVENTS

BY

AUGUSTIN IONUȚ CRĂCIUN

Abstract: This study aims the possibility of applying G.I.S technology in order to detection those hydrographic basins, that by their characteristics of land use, hydrologic soil conditions, morphometry, give the optimal conditions for flash flood manifestation. The algorithm is based on the integration of a method that takes into account some physical parameters of the basin (physiographical method) in G.I.S medium.

Key words: GIS, hydrographic basin, torrential events, algorithm.

1. Introduction

The evaluation of high flood produced in small basins, and in the same time finding some alternatives of their real time estimation, are usual interests for hydrologist researchers from Romania. Torrential rain events have the biggest impact in these basins, due to their high intensity, favoring the generation of "flash flood".

For estimating the high flood in small basins there had been developed a number of stochastique and determinist methods in the same time (*Diaconu C., Şerban P., 1994; Mic Rodica, Corbuş C., 1999*).

The use of G.I.S for evaluating high floods of high flood risk, takes part of a group of recently concerns, knowing that we assist of an accelerate development of this domain in the last 10-15 years (*Haidu I., Sorocovschi V., Imecs Z., 2003, Păcurar V.D., 2005 ş.a.*).

Drobot R., 2007 identifies the characteristics of "flash flood" in torrential rain conditions as followed: the area of basin varies from some Km^2 to 200 Km^2; the time of concentration is smaller then 6 hours; the rainfall duration is smaller than the time of concentration of basin (maximum 3 hours); the depth of high flood generated is > 100 mm.

A number of researchers, especially French ones, use for small hydrographic basins the concept of *"bassin versant"* (*Ambroise, B., 1998*, *Laborde J. P., 2000*).

Some elements that contribute to producing and evolution of high flood in these basins are: the area and basin shape index, slope side, slope stream channel, drainage density, afforestation index, hydro-physical soil characteristics. On these adds some aspects of exploitation of environment by humans: the lack of anti-erosion means and of torrents correction, deforestations, inadequate agricultural activities, buildings or residual deposits near by the banks of rivers.

The effect of these factors is reflected in the increasing of runoff speed, decreasing of time of concentration, increasing of runoff coefficient, decreasing the vegetation and soil water retention capacity, increasing the erosion process that goes to increasing of alluvial deposits etc.

The main *objectives* of this study refer to:

- the analysis, using G.I.S, of the parameters that compose physiographical method;
- the study of some basins that, by their reduced surface, can be constitute areas of flash flood manifestation;
- the detection of basins with the biggest flood vulnerability in the conditions of torrential rains;

The detection of the basins susceptible for flood is very important in forecast activity, helping to the emission of warnings that can limit the damages induced by the flood. In the same time, it can be initiate some gauges of erosion rate reduction by increasing the afforestation areas, regularization of the river etc. For authorizing the houses construction, it would be recommended to take into account the risk of such hydrological events.

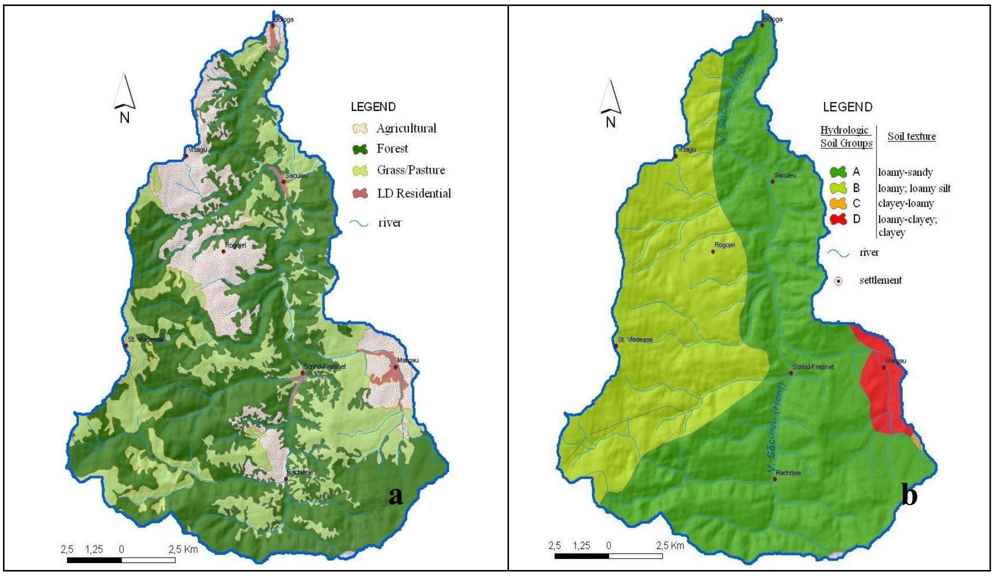
The area proposed for analysis corresponds to Hydrographic Basin of Săcuieu (Henț), a component part of Vlădeasa Massif (in Apuseni Mountains), having a surface of approximately 220 km^2.

2. Methodology

For identify the hydrographic basins menaced by high flood generated by torrential rain events, it was used the *physiographic method*. This method is based on the analysis of some physico-geographical elements of the basin such as: *landuse*, *soil texture*, *hydrologic soil groups*, *soil and vegetation water storage capacity*, *lag time*, *time of concentration*.

The main steps in algorithm application are:

• generate the layers that refer to landuse and to Hydrologic Soil Groups (HSG) (Fig.1). According to USDA the soils can be classified, by water infiltration capacity, in four groups: *A* – high capacity, specific to sandy or loamy-sandy texture, infiltration rate >7,62 mm; *B* – medium capacity, specific to loam and sandy-loamy texture infiltration rate 3,81- 7,62 mm; *C* – low capacity, specific to clayey-loamy texture, infiltration rate 1,27-3,81 mm; *D* – very low capacity, specific to loamy-clayey and clayey texture, infiltration rate 0-1,27 mm.



a *b*

Fig. 1 – Hydrographic Basin of Săcuieu. Spatial distribution of landuse (*a*) and pedogeographical characteristics (*b*).

• the spatial representation of *CN* (**C**urve **N**umber) from *SCS* model (**S**oil **C**onservation **S**ervice) based on intersect of themes mentioned before and attribution of corresponded values (USDA, National Enginering Handbook, 1997). In this study for spatial repartition of CN index it was used *L-THIA GIS* (*L*ong-*T*erm *H*ydrologic *I*mpact **A**ssessment) extension. Through this extension, it was reclassified, by attributing values from 1 to 4 (for Hydrologic Soil Groups), respective from 1000 to 8000 (for landuse) and sum those two themes (Fig.2).

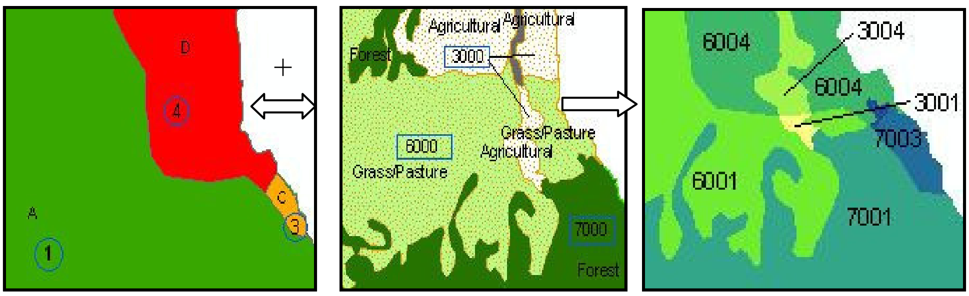


Fig. 2 – Sum of layers necessary for computation of CN index.

• the computation of potential watershed storage **S** using the equation:

(1) $$S = \frac{25.400}{CN} - 254 \quad \text{(mm)}$$

• the computation of lag time T_L (T-lag), defined as the time between the peak of storm event and the flood peak that; for determine this parameter, USDA (1997) developed the next equation, adapted to Romania territory by *Drobot R., 2007*:

(2) $$T_L = (3{,}28084 \cdot L)^{0{,}8} \cdot \frac{(S+1)^{0{,}7}}{1900\sqrt{I_B}} \quad \text{(hours)}$$

unde:

L – length of drainage line (m);

I_B – average watershed slope (%);

• the computation time of concentration (T_c) using the equation:

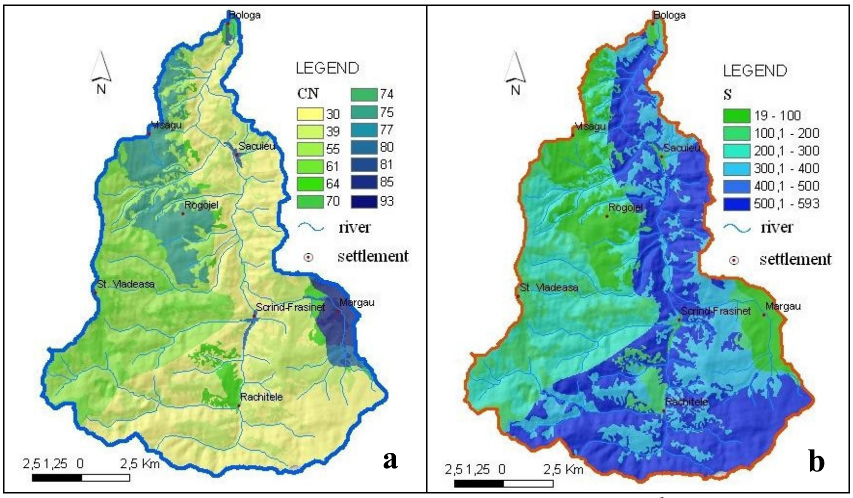
(3) $$T_c = 1{,}67 \bullet T_L \quad \text{(hours)}$$

After that, it follows the selection of those basins that are characterized by a time of concentration ≤ 6 hours.

3. Results and Discussions

The hydrologic soil response, landuse and a number of morphometric elements of the studied area also (drainage surface, slope, length of drainage line etc.) all these are variables that are used to determine a lot of parameters, such a soil and vegetation water retention capacity, lag time, time of concentration etc.

The computation of potential storage (**S**) was realized starting from CN index repartition (Fig.3*a*), using equation (1). Following the results (Fig.3*b*), we can observe the highest water potential storage in the afforestation areas from the eastern part of the basin, overlapped to loamy-sandy soil; these go to a reduction of runoff potential, favoring infiltration process. The lowest values correspond to agricultural areas and to settlements. Soil texture is loamy either loamy-clayey or clayey, having low infiltration rate, fact that can determine an acceleration of runoff.



a *b*

Fig. 3 – Hydrographic Basin of Săcuieu. Spatial distribution of CN index (*a*) and potential storage (*b*)

Using G.I.S function <u>*B*atch *W*atershed *D*elineation</u> there had been delimited in the studied area a number of 27 basins (*b1 ... b27*) with surface < 10 km^2 (Tabelul 1). Six of these basins have their outlet point near by settlements (b27 – upstream of Săcuieu; b25 – upstream of Scrind Frăsinet; b14 – upstream of Răchiţele; b8, b9, b10, b11 – upstream of Margău) (*Fig.4*). Rogojel is a component part of the basin b3, but, by his extension on interfluvial area, is somehow protected of floods events.

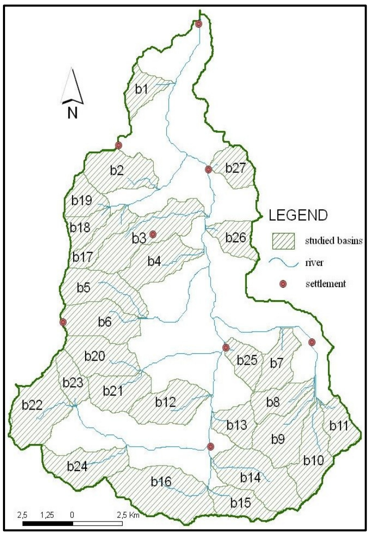


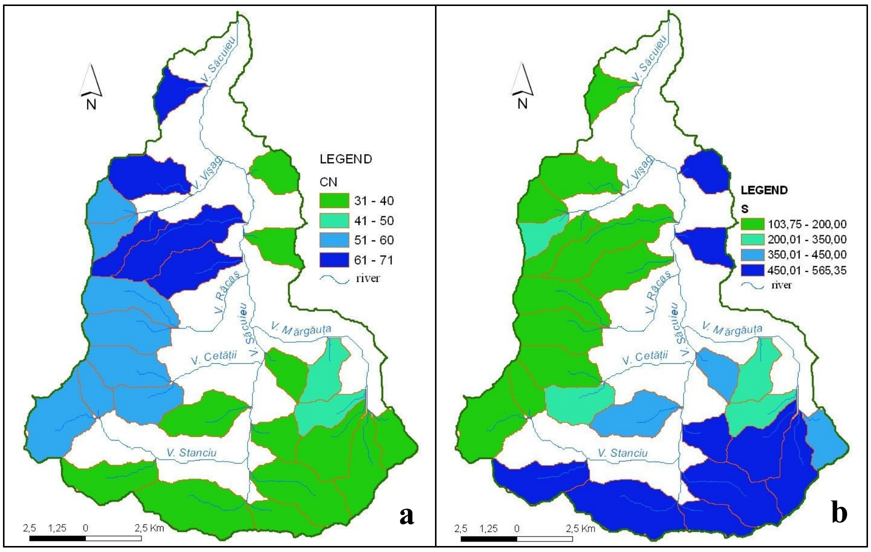
Fig. 4 – Watershed delineation for analyzed basins.

The average values of CN indices, for each basin, there had been obtained as weighted average with the partial surfaces F_p, characterized by the partial indices CN_p. The results are shown in Table 1 and Fig. 5*a*.

The lowest average values of CN index correspond to the basins that have a high afforestation index and hydrologic soil conditions specific to group A. Five of these basins, characterized by domination of agricultural and pasture landuse and a loamy soil texture, present the highest values of CN index (61 – 71). Starting from the average values of CN index it was determined the average potential sub-watershed storage using the equation *(1)*.

The results are presented in Fig. 5*b* and Table 1.

The length of drainage line (L_B) for each basin it was determined by G.I.S, using *XT*ools extension (Table 1). *The average watershed slopes* (I_B) had been obtained by Digital Model Elevation exploring, the highest values were observed in the sub-watershed on the left side of Săcuieu.



a *b*

Fig. 5 – Hydrographic Basin of Săcuieu. Spatial distribution of average CN index (*a*) and potential storage (*b*) for analyzed basins

Applying equation (2) there had been obtained the *lag time* (T_L) for each analyzed (Table 1, Fig.6*a*). Next, using the equation (3) it was determined the *time of concentration* (T_C) of each basin (Table 1).

Table 1

The Values of Parameters Necessary for Applying the Physiographic Method

Basin	F (km^2)	CN	S	L_B (m)	I_B (%)	T_L (hours)	T_C (hours)
b1	2,72	67	125,10	1172,84	21,81	2,46	4,11
b2	5,64	71	103,75	2259,36	22,39	3,60	6,01
b3	7,85	61	162,39	5084,57	23,45	9,19	15,34
b4	5,38	67	125,10	2781,95	22,5	4,83	8,07
b5	5,84	57	191,61	3476,76	31,55	6,56	10,95
b6	5,79	58	183,93	2297,81	30,96	4,62	7,71
b7	3,67	46	298,17	1261,83	13,82	5,99	10,01
b8	3,42	43	336,70	1997,93	19,32	7,97	13,31
b9	5,74	35	471,71	3120,78	20,26	14,07	23,50
b10	5,65	32	539,75	2831,66	17,44	15,42	25,75
b11	3,26	37	432,49	1331,66	10,23	9,43	15,75
b12	5,38	40	381,00	2482,79	28,71	8,48	14,16

Table 1
Continuation

b13	3,16	35	471,71	1145,97	26,46	5,52	9,23
b14	7,77	32	539,75	3672,49	27,4	15,14	25,29
b15	3,52	31	565,35	1491,54	23,62	8,19	13,68
b16	9,56	32	539,75	3193,91	28,06	13,38	22,35
b17	3,17	63	149,17	1122,54	29,53	2,31	3,85
b18	2,46	55	207,82	631,54	36,18	1,66	2,76
b19	2,85	58	183,93	699,7	33	1,73	2,89
b20	5,39	56	199,57	1979,23	32,63	4,23	7,06
b21	4,44	54	216,37	1638,52	32,13	3,87	6,47
b22	7,51	57	191,61	2673,2	24,68	6,01	10,03
b23	2,62	59	176,51	491,42	34,29	1,24	2,07
b24	5,68	36	451,56	2849,65	31,79	10,13	16,92
b25	2,77	37	432,49	763,25	23,51	3,98	6,65
b26	3,03	31	565,35	1036,98	29,95	5,44	9,09
b27	3,06	34	493,06	612,84	26,06	3,48	5,81

From the analysis of the results referred to time of concentration can observe that, from the 27 basins initial selected, just 7 of them are characterized by time of concentration ≤ 6 hours. These basins are shown in *Fig.6b* by red contour.

In consequence, the basins numbered by *b1*, *b2*, *b17*, *b18*, *b19*, *b23*, *b27*, with surfaces, in the most of cases, smaller than 5 km^2, present time of concentration values from 2,07 to 6 hours. These values are explained by very low afforestation rates, a dominance of loamy soil texture, average slopes in most of the case over 25 – 30 %, length of drainage lines < 2 Km.

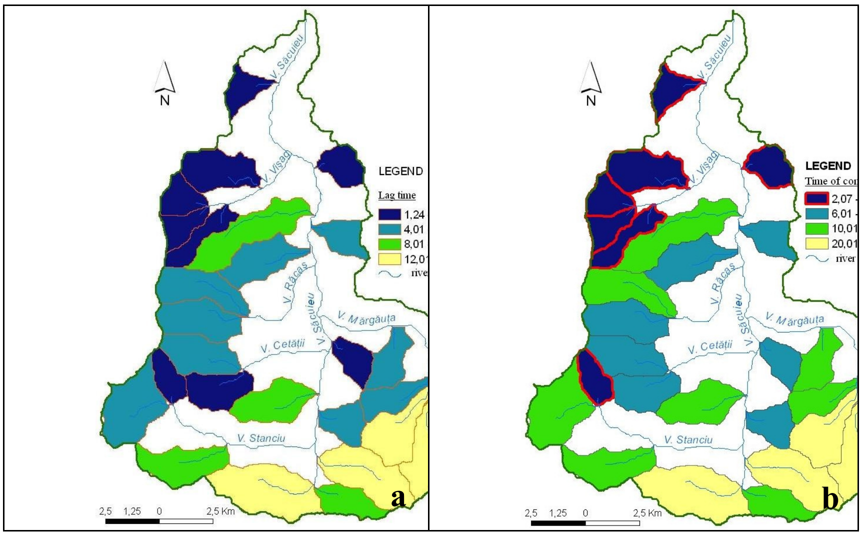


Fig. 6 – Hydrographic Basin of Săcuieu. Spatial distribution of average

lag time (a) and time of concentration (b) for analyzed basins.

4. Conclusions

The use G.I.S for hydrological analyses in the small hydrographical basins presents the advantage of fast recovery of the necessary information.

By using some G.I.S functions it can be realized the integration of calculus equation that permits spatial representation of the analyzed process.

Regarding this study, all the parameters that compose the physiographic method had been computed using some G.I.S functions such as: *D*erive *S*lope, *F*ield *C*alculator, *M*ap *C*alculator, *B*atch *W*atershed *D*elineation, functions of *L*THIA *GIS* extension, functions of *XT*ools extension ş.a.

For detection of the hydrographical basins menaced by high flood during the torrential rain events, must be used some other methods: runoff coefficient method; estimation of a stream power index, flood danger index etc.

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APLICAȚIE G.I.S PRIVIND IDENTIFICAREA BAZINELOR HIDROGRAFICE MICI AMENINȚATE DE VIITURI ÎN TIMPUL PLOILOR TORENȚIALE

(Rezumat)

Studiul vizează posibilitatea aplicării tehnologiei G.I.S pentru identificarea acelor bazine hidrografice, care prin caracteristicile legate de folosința terenurilor, trăsăturile hidrice ale solurilor, morfometrie, oferă condiții optime pentru manifestarea unor viituri rapide. Algoritmul se bazează pe integrarea unei metode, ce ia în calcul o serie de parametrii fizici ai bazinului (metoda fiziografică), în mediul G.I.S.

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THE ELABORATION OF THE CADASTRAL ENSEMBLE PLANS - A BASIC ELEMENT FOR GIS IN THE TERRITORIAL ADMINISTRATIVE UNITY

BY

MIHAI TURCULEŢ, *SERGIU POPESCUL and **ANGELA POPESCUL

Abstracts: There are presented the contents and the way of elaboration of the ensemble cadastral plan and the informational stratums for the collected data within the creation of the cadastral real estate goods from the point of view of professional formation of the students of the specialty ,,Cadastre and Land Administration". As an informational basic support there were used satellitari images set on the site Google EARTH.

Key words: GIS, cadastral maps, data base.

The modern cadastre in Moldova begins with the adaption of the land code which recognizes the right of private property on the land and the imitation of the privatization process of the agricultural fields, gardens, afferent lots to the industrial buildings, etc.

During this period there were executed works for the privatization and registration of the mentioned land categories being the elaboration of the cadastral plans in the extravillein of the localities during the deploying of the Land National Program as well as from the intravillein and extravillein of the localities from the first Cadastre project, being advanced different requirements both technical order and social one.

The formation of the real estate goods in the extravillein was made on the basis of the land administration plans elaborated on the basis of terrestrial classical elevations and aerial. With this purpose coordinates among which the local ones MoldRef or arbitrary. The registration of the real estate goods was made on the basis of the juridical documents being accompanied with cadastral plans without doing a rigou-rous test on the field. But one of the actual requirements of the cadastre (The Declaration of the FIG concerning the cadastre (1995)) requires its elaboration and daily keeping according to the technological level and reached informational one. With this goal it was created the National Geodesical network corresponding with satellitary observation using the receptors GPS, the position being given in the system of coordinates MR 99 (MoldRef 99).

At present, the cadastre of real estate goods in the Republic of Moldova covers approximatively 70 percent from the total surface. The cadastre serves not only for recording real estate goods taxation perception, its goal is to solve problems of economical and social order by transforming itself in a cadastre with multifunctional statute. Unfortunately, Moldova has some problems of technical, social and economical order. We will mention some of them: the absence of an ensemble plan on which will be presented in a unique coordinates system, many owners hold the titles confirming the ownership right, but not having registered in the register of the real estate goods. The materialization on the lot did not take info account the territory arrangement plans. The surface held by an owner does not allow the foundation of a viable enterprise because of the division and little sizes of the lot sectors, etc. The transition to the market economy and being in such a period it was appeared an imposable number of landowners as well as the increase of the different type of transitions.

It created in its turn a series of inconveniences concerning the rapid supplying of the cadastral information. All these problems require a rapid solving, the information in this case obtaining itself the role of product. The success of the cadastre functioning in great measure will be determined by the professional abilities that the specialists of this branch possess then. But for this it is necessary to have at the disposal a strong material basis. The Republic of Moldova confronts itself with different problems of technical order and in the domain of the specialist's formation in higher education institutions. The absence of the financial resources does not permit the securing of modern equipment that should essentially raise the quality of engineers' formation in the branch of Cadastre and Territory Arrangement. The future specialists are also insufficiently prepared in the capitalization of the GIS potential. The introduction of the real estate cadastre in an administrative territory for realizing the identification, evidence, recording and the representation on the cadastral plans of all real estate goods respecting the technical norms is a very difficult and long standing process that can not keep the step with actual imposed requirements and the raised rhythm of the intervened changes and especially in the developing countries. The efficiency of cadastre is determined by the information utilization for problems solving from the sphere of planning and rural spaces administration, for reasonable utilization of the resources in order to a durable development. For these reasons it is imposed the stocking in a unique system of all the information by which is described and submit to an analysis the rural or urban space. For eliminating the shortcoming in this direction a primary solution should be the Index Plan elaboration that would permit the centralization of all juridical, cadastral and cartographic documents that will considerably reduce the cadastral data collecting from the lot, the activity that is not possible in the case of a making up of the basic cadastral plan, or a numerical cadastral plan.

The index plan must contain ample information and namely: the limits of the cadastral territorial unities, linear elements, cadastral sectors, constructible perimeters, cadastral identifiers, etc.

The importance of the cadastral plan is evidently as it follows:

- a commune examination and analysis of the cadastral documents;
- it does a relation with the basis of georeferencial data;
- it allows a rapid integration of the informations in index cadastral plan both from the existent cadastral documents and from those ones made up after realizing of the index cadastral plan, as a result of the real estate transactions, etc.
- it may be easily integrated into GIS.

The presented work describes the results of the elaboration of an index plan as part of a mayoralty using for the support stratum the set images on the sight Google EARTH, having as purpose the students' familiarization with the elaboration methodology and utilization of the cadastral documentation as well as the mode of position of the lot sectors that were raised in the system of arbitrary coordinates. In order to form the ensemble plan there are being used the took over images by order (print screen) establishing the room height of 400 m being blocked the possibility of the relief presentation.

The reunion of the images was effectuated with the help of the program CorelDraw Graphics Suite X3 (Fig. 1).

Fig. 1 – Reunion of the images in the program CorelDraw Graphics Suite X3.

The number of images depends on the examined surface, but this elevation is the biggest one in order to reduce the appeared errors because of different factors. The students have the possibility to utilize diverse formats for raster images studying their advantages and disadvantages. After images reunion it is obtained the ensemble plan in the JPEG format that may be examined with software MapInfo Professional. This image must be submitted to the georeferenciation operation for being repeated at true position and to have the corresponding sizes. By this operation they are familiarized with works of coordinates transformation.

For the georeference more variants are recommended among them the more effective are the determination of the geodesical coordinates of the points directly on Google EARTH and their transformation in MR 99, as well as the utilization of the points of determined, known coordinates by observations GPS that may be with accuracy identified on the satellitary images. The both results gave results of the same precision.

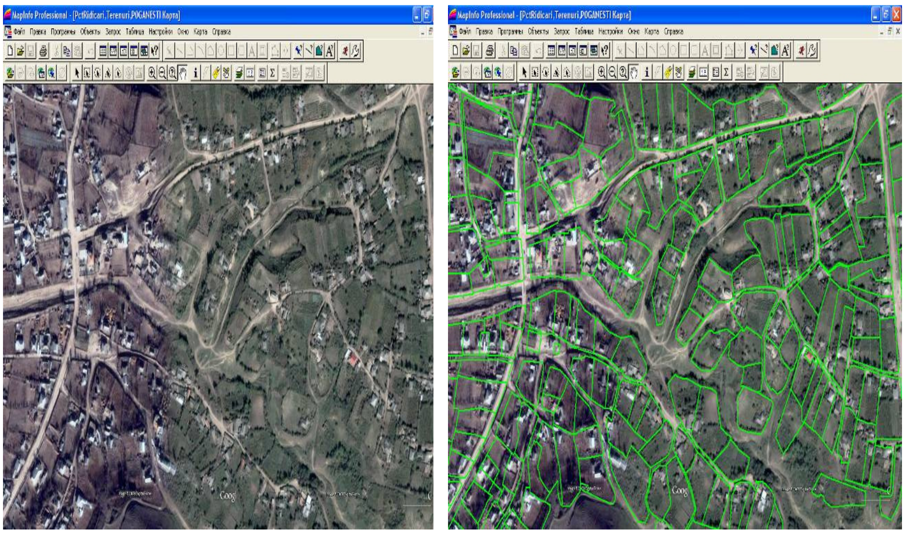

Fig. 2 – Cadastral ensemble plan.

The result of the georeference showed that the precision of the point's position is approximatively one meter. After the georeferenciation it was obtained the support plan (Fig. 2.) that had been compared by overlapping of the stratum of lots and formed buildings during the cadastre creation from the commune intravillein that in their were repeated at RGN (National Geodesical Network).In the result of this comparison it was observed that the uncoincidence in some case reaches the score of 14 m, but this uncoincidence had a systematical character evidencing itself at the boundaries between the photograms. These 14 m were excluded by separated georeferenciation of the images for different photograms.

After the plan testing there were overlapped all systematized and accumulated informations. During the cadastre elaboration in a mayoralty, our students were familiarized with the creation technology of one cadastral data basis.

Conclusions

In the result of the effectuated investigations they were made the following conclusions:

- the financial administration of locality, not depending on the size of this one, represents a complex activity in which is utilized a great volume of information and a big variety of knowledge and professional competences;
- the studies showed that practically in the absence of a cadastral plan of index the position of the sectors of lots is not precisely determined;
- the precise indetermination of the position of the lot sectors embitters the solution of the problems for ownership rights protection. The holders of land have title but they do not precisely know where the object is;
- for the identification on the field of the real estate holdings, OCT must supply to the interested person some informations about the coordinates of the boundary points expressed in the system of coordinates MR 99;
- the analysis of the index cadastral plan elaborated on the support of the cartographical materials from Internet may assure a precise positions of 1 - 3 m;
- the materials being in the data basis of OCT having as a support the plan of a graphical evidence the precision of the position is of 30 - 50 m;
- a lot of land sectors can not be included in the index cadastral plan, as their form and sizes do not correspond to the reality;
- our students with a particular interest elaborate the plans for their native locality, correcting the plans and the elaborated materials in different stages, having the possibility to evaluate the quality both of the raising, projection works and those one for drawing on the field;
- the collected materials may constitute the basis of a GIS.

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ELABORAREA PLANULUI CADASTRAL DE ANSAMBLU CA ELEMENT DE BAZA PENTRU GIS IN CADRUL UNEI UNITĂŢI ADMINISTRATIV TERITORIALĂ

(Rezumat)

Este prezentat conţinutul si modul de elaborare a planului cadastral de ansamblu şi a straturilor informaţionale pentru datele colectate in cadrul creării cadastrului bunurilor imobile, din punct de vedere a pregătirii profesionale a studenţilor de la specialitatea ,,Cadastru si Organizarea Teritoriului”. Ca suport informaţional de bază sunt folosite imagini satelitare postate pe site-ul Google EARTH.

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APLICATIONS OF THE GIS TECHNIC IN EVALUATING THE EROSION PROCESS ON THE SLOPE LANDS.

BY

GABRIELA BIALI

Abstracts: This paper presents a GIS application to prognosis and evolution process of land degradation through erosion. The results from the research show the advantages of using these GIS techniques and argues the importance of this area of environmental engineering.

Using Geographical Information Systems technology for the management of environmental parameters has become a normal fact.

These techniques can be used both for studies undertaken on small areas (by the order of a few hectares) and for impact studies of regional or even national level.

Key words: GIS, erosion pixel, programs, model MMT.

1. Introduction

Both globally and in our country, erosional degradation processes particularly affect the agricultural land, because of "coverage" worse that they provide land for agriculture but and inability to adapt farming practices to the requirements of perfect soil protection and conservation, subject to the above processes.

In Romania, this process of degradation (pollution in modern organic sense) is extended to almost half (47%) of the agricultural area of the country, that on about 7 million hectares, [4].

The negative effects of erosion are considerable for Romania, especially through continuous decline of soil fertility by clogging river and lakes, by impairing communication lines and socio-economic targets located in towns or on the slopes or the environment (by pollution, degradation of microclimate, geographical landscape of ruin, damaging people's living conditions, depopulation).

Using Geographical Information Systems technology for the management of environmental parameters has become a normal fact.

These techniques can be used both for studies undertaken on small areas (by the order of a few hectares) and for impact studies of regional or even national level.

2. The Importance of the Subject and Research Locations

When referring to the establishment erosional risk, especially large areas, this approach involves detailed knowledge of all factors involved in the process of degradation, that the parameters characterizing climate, topography, soil, the use of land, farming technologies, etc.

Given however that all these parameters have a spatial distribution, or receive a certain amount at each point in space, this complex action of monitoring can be achieved only within a spatial information system, [3].

If we want to establish the risk of the erosion, especially on a bigger plan, this approach involves the detailed knowledge of all the factors that participate in the process of deterioration also of all the parameters that characterize the weather, the relief, the soil, the way of utilization of the land, the technologies of agricultural exploitation. Knowing that all these parameters have a spatial distribution (which means they all have a certain value in each point of the space) the complex action of monitoring could be realized only in a informational system of the space (spatial informational system), [1].

By introducing this kind of technology a whole ecological monitoring could be obtained and in this way the capable parts could watch in a permanent condition the situation of the natural resources, generally the environmental factors and also of the anthropological impact, based on the parameters and measurements of spatial coverage and also of the temporal coverage which would assure the information necessary for the strategy and tactics to prevent the consequences of the environmental factors and of the human activities, to elaborate the prognoses and the distribution of the operational control over the actions of amelioration of the ecological situation, [5].

This study presents the GIS techniques referring to the evolution of the process of degradation of the territory by erosion in the hydrological basin of Antohesti (Fig.1) which is situated in the superior basin of Berheci River in Bacau County. On a surface of 3963 hectares, the relief is strongly fragmented, presenting a relief energy of around 330 m with averages slopes over 15%. The slopes are affected by the erosion and by the active sliding. The most popular soils are chernozem and the brown soils; concerning the distribution of the land there are: arable 47.2 %, pasture 26.78 % and forest 16.8%.

The choice for this hydrographic basin is motivated also by the fact that there was the possibility of the validation of the results obtained by the simulation, comparing them with the measurements of the alluvial deposits in the Antohesti accumulation (situated at the exit of the receiving basin).

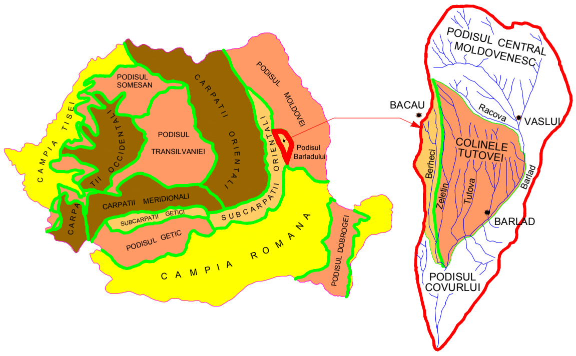


Fig. 1 – Research locations: hydrological basin of Antohesti
(in the superior basin of Berheci River in Bacau County).

3. The Structure of the GIS Process

In our project, the geo-characteristic dates are represented as layers. This facilitated the analysis of the spatial variables and the distribution of the objects on the surfaces studied and the overall analysis of the information obtained, that supposes the simultaneous approach of more layers could be realized using the "overlay" technique.

The general chart of all the steps covered in this project [2] (for the theme mentioned above) is presented in Fig. 2.

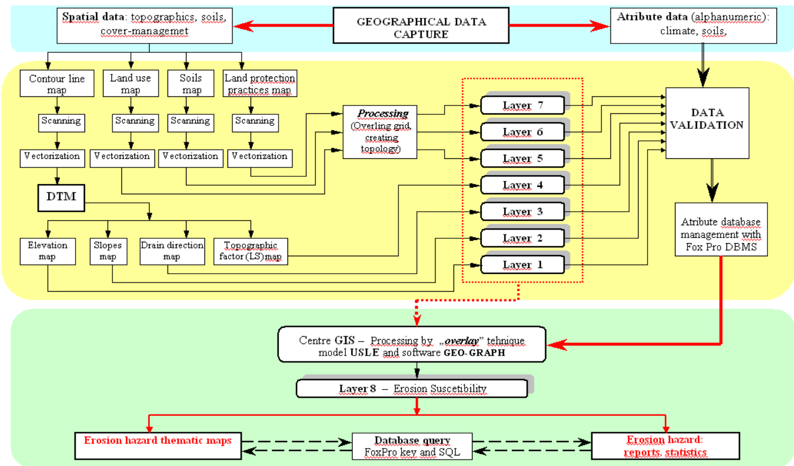


Fig. 2 – Data hide tide in GIS project from reality situation to erosion hazard.

Along the application we used a software type GIS Romanian GEO-GRAPH specialized for the operations with digital maps and for the interogations of the databases. The mathematical model used to determine the damage of the soil is based on the USLE (Universal Soil Loss Ecuation) equation under the usual form from Romania.

In order to set up the geo-characteristic database included in the equation already mentioned above, we utilized the raster process defined as the superposition over the documentation of the maps of a rectangular chart of squared cells calculated 25 x 25 m (figure 3). In this way the calculation of the water erosion in the basin already studied was made on approximately 190,000 cells. In a first stage we've created the informational layers regarding the relief of the territory because the information about the relief is essential for the formational process of erosion for the slopes.

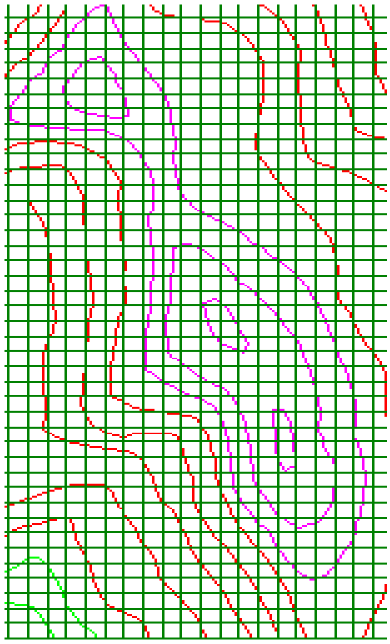


Fig. 3 – Detail of the overlapping grid over vectorial (numeric) plan.

4. The results Obtained from the GIS Application

Numerical terrain model (MNT) was obtained by a interpolation (interpolation operation being fundamental to the operation of an information point/discrete).

Starting with the map of contour line the Numerical Model of the Land (MNT) obtained furnished for GIS the main layers as:

Layer 1 - Elevation map (Fig. 4);

Layer 2 - Slopes classes map (Fig. 5).

Mathematically speaking, the slope (tilt to a horizontal surface) and orientation (direction determined in relation to the cardinal points) are properly determined in a point if the surface is described by an analytical function (gradient of the surface); in this case, these two parameters should be redefined for each pixel (cell) basis. The inclination of the land I was calculated from the slope and value (expressed as a percentage %), after his relationship Wischmeier şi Smith, [9]:

(1) $$I = \frac{0{,}17 + 0{,}12i + 0{,}017i^2}{6{,}613}$$

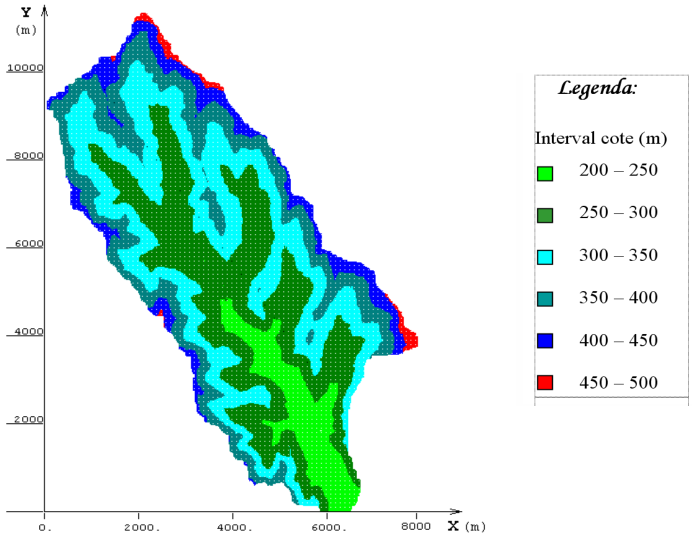


Fig. 4 – Layer 1: Elevation map.

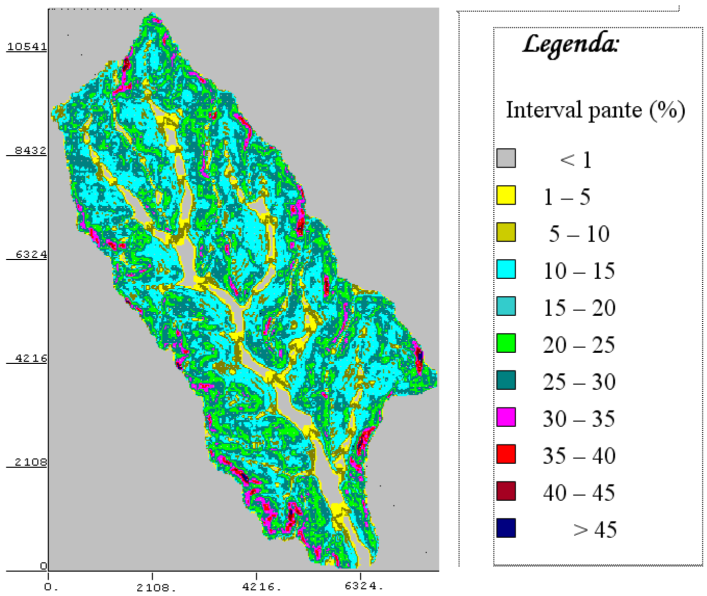
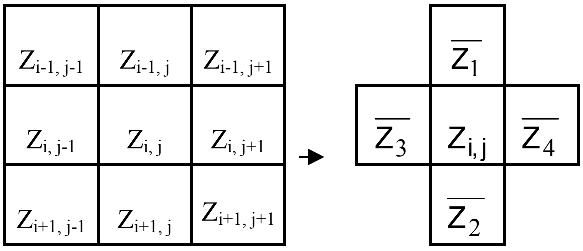


Fig. 5 – Layer 2 - Slopes classes map.

Calculation of slopes (gradients) and guidelines to do after 8 directions (Fig. 6), starting from an average altitude of the pixel, both parameters were estimated by using a window of 3 x 3 pixels. For example, the direction of lines and columns that have used the relations from next figure:



Gradient column $= \dfrac{\overline{z_3} - \overline{z_4}}{3\Delta x}$

Gradient line $= \dfrac{\overline{z_1} - \overline{z_2}}{3\Delta x}$

Fig. 6 – Calculation of slopes using a window of 3 x 3 pixels.

(2) $$\overline{z_1} = \frac{1}{3}\left(z_{i-1,\,j-1} + z_{i-1,\,j} + z_{i-1,\,j+1}\right)$$

(3) $$\overline{z_2} = \frac{1}{3}\left(z_{i-1,\,j-1} + z_{i-1,\,j} + z_{i-1,\,j+1}\right)$$

(4) $$\overline{z_3} = \frac{1}{3}\left(z_{i-1,\,j-1} + z_{i-1,\,j} + z_{i-1,\,j+1}\right)$$

(5) $$\overline{z_4} = \frac{1}{3}\left(z_{i-1,\,j-1} + z_{i-1,\,j} + z_{i-1,\,j+1}\right)$$

The raster representation, the current pixel can be drained after one of the 8 possible directions, depending on the position of a neighboring pixel with the lowest altitude (Fig. 7).

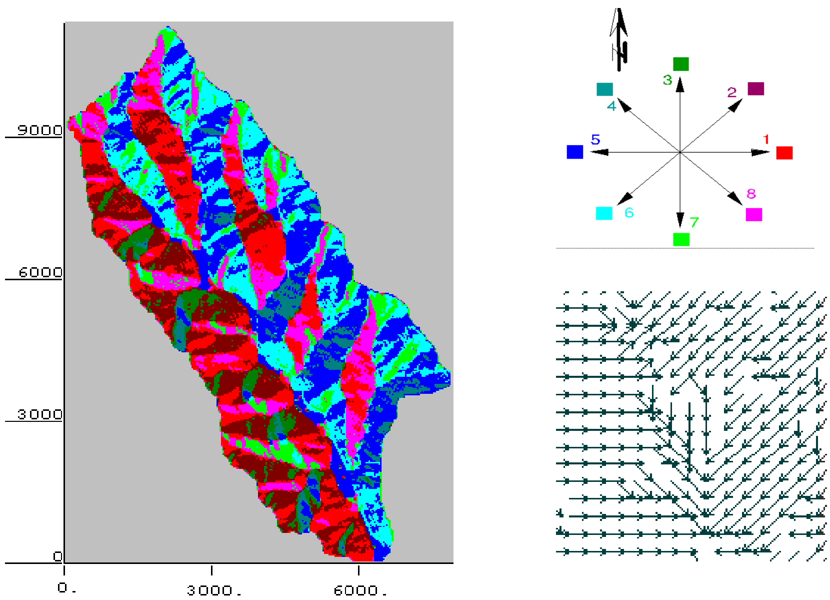


Fig. 7 – Layer 3: Drain direction map.

The analysis of the central pixel neighborhoods to determine the direction of drainage, the altitudes of the diagonal are reviewed to maintain the same distance from reference pixel.

This algorithm was published in the language is Fortran Power Station under Windows, called "MNT.exe" and is part of their calculation modules applied in GIS project. A fourth layer information resulting from the application of MNT is the topographic factor: *Layer 4* - product of slope and length factors ($L^m \cdot i^n$).

Starting with the plans of distribution of the slopes and of the soils using rules of spatial topology there had been created the following informational layers:

Layer 5 – Cover – managemnet Factor
Layer 6 – Soil erodability Factor
Layer 7 - Support Practical Factor

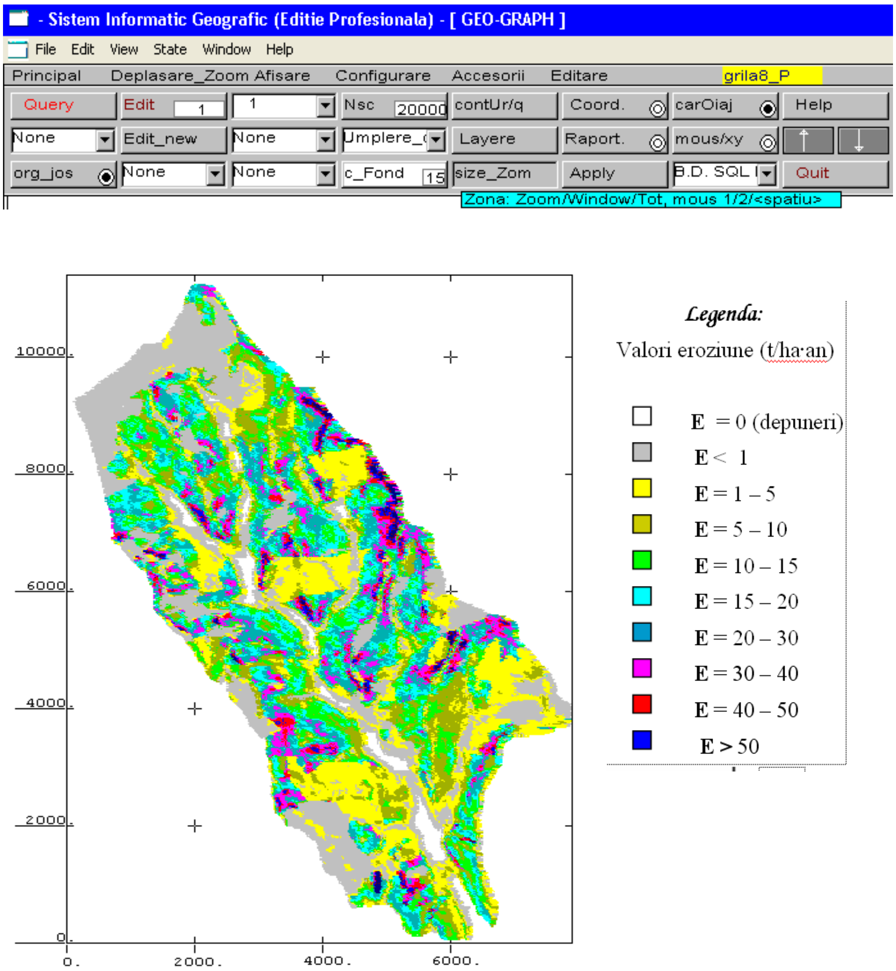


Fig. 8 - Layer 8: Hazard erosion map - effective risc (tonne/ hectares · year).

Including the 7 layers mentioned above in the USLE equation with the software GEO GRAPH it's been obtained the informational layer of the erosion hazard (*Layer 8*) in 2 ways of simulation: effective risk, determined by the combined action of all the parameters from the equation USLE (Fig. 8) and the potential risk (in which the factors could be controlled in the basin of reception (Fig. 9): layer 5 and layer 7 would not be considered).

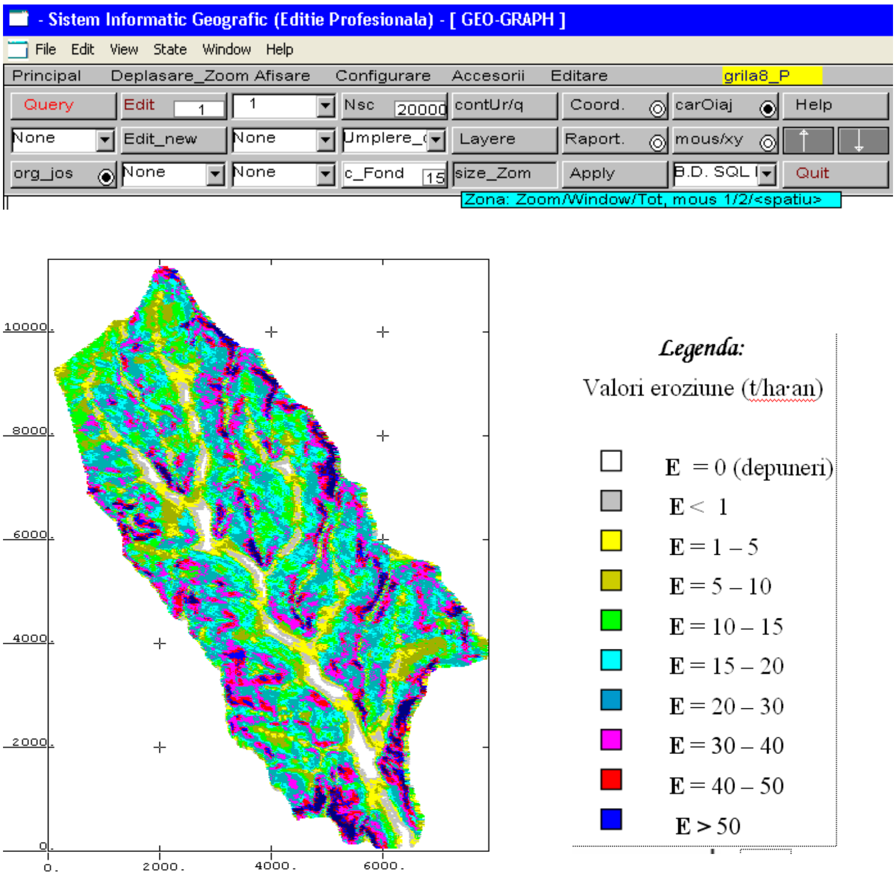


Fig. 9 - Layer 8: Hazard erosion map - potential risc
(soil loss in tonne/ hectares · year).

5. Conclusions

By implementing these techniques we can performed an integrated environmental monitoring, which the authorized personal permanently can monitor the status of natural resources in general environmental factors and human impact, based on parameters and indices of spatial and temporal coverage, to provide the information necessary strategy and tactics to prevent the consequences of environmental factors and human activities, of preparing the of forecasts and exercise operational control on measures of recovery (improvement) of the ecological situation.

In the context of natural and socio-economic conditions in Romania, using Geographical Information Systems (GIS) to monitor the space-time evolution of land degradation through erosion and associated processes is a requirement for high current, justified primarily by economical reasons and the speed with which to obtain necessary information in real time making the most appropriate decisions to improve the situation.

Increase accuracy while the research activities on land degradation by erosion using GIS techniques can be achieved by diversifying the methods of data acquisition (including photogrammetry and remote sensing), development and updating of databases, but also by using mathematical models to simulate erosional processes, like WEPP, EPIC, GRASS, AGPNS.

In this context, application of Geographical Information Systems technology for the purpose set out in our country, it is necessary and justified not for only economic reasons, but also the safety and speed of which can be obtained in a "real time" information you want.

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APLICATII ALE TEHNICII GIS IN EVALUAREA PROCESULUI DE EROZIUNE PE TERENURILE IN PANTA.

(Rezumat)

In aceasta lucrare este prezentata o aplicatie GIS in prognoza si evolutia procesului de degradare a terenurilor prin eroziune. Prin rezultatele obtinute in urma cercetarii se arata avantajele folosirii acestor technici GIS si se argumenteaza importanta aplicarii in acest domeniu al ingineriei mediului.

Utilizarea tehnicii Sistemelor Informaţionale Geografice pentru gestionarea unor parametri referitori la mediu a devenit astăzi un fapt obişnuit. Aceste tehnici pot fi utilizate atât pentru studiile întreprinse pe suprafeţe mici (de ordinul a câtorva hectare), cât şi pentru studii de impact la nivel regional sau chiar naţional.

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DRYLAND SALINITY AND IRRIGATION WATER QUALITY

BY

FLORIAN STĂTESCU and *DORIN COTIUŞCĂ-ZAUCĂ

Abstract. Soil salinity represents a factor that must be taken into account to characterize the conditions of plants development. In this context, the research presented in this work reveal a number of issues regarding: the conceptual of dryland salinity (causes, impact, remedial actions and crop salt tolerance), irrigation water quality and its influence on the regime of saline soils, such as the irrigation systems supplied from the Siret and Buzău rivers.

Key words: soil; dryland salinity; electrical conductivity; irrigation; root zone salinity.

1. Causes of Dryland Salinity

Dryland salinity occurs where removal or loss of native vegetation, and its replacement with crops and pastures that have shallower roots. This results in more water reaching the groundwater system. The groundwater rises to near the surface in low-lying areas. It carries dissolved salts from the soil and bedrock material through which it travels. As saline groundwater comes close to the soil surface (within 2 m), salt enters the plant root zone. Even where the groundwater does not bring much salt with it, the water logging of the plant root zone alone can damage or kill vegetation.

2. The Impact of Dryland Salinity

Dryland salinity has many environmental, economic and social impacts [1],…,[3], [9], [10]. The costs associated with salinity are potentially enormous and are borne not only by the rural community, but also ultimately by the whole country and its environment. The effects of dryland salinity may impact on: 1° agriculture, 2° water quality, 3° public infrastructure and urban households, 4° biodiversity and the environment.

1° *Agricultural impacts*. The impacts of dryland salinity on soil have adversely affected agriculture. The consequences include

a) Significant losses of productivity in agriculture, with some land entirely out of production. With increasing soil salinity, plants always find it more difficult to extract water from the altered soils. Most normal crop and pasture plants are not highly salt-tolerant and will eventually die out under saline conditions.

b) Damaged soil structure and increasing content of toxic substances that may be limiting to plant growth.

c) More serious soil erosion, both by wind and by water, due to worsening soil structure and reducing vegetation cover.

2° *Impacts on water usage.* Dryland salinity may increase salt concentrations in streams and rivers, and has a significant impact on a wide range of uses, including:

a) Declining suitability for drinking by humans and livestock, and for irrigation.

b) Increasing costs for water treatment.

c) Corroding water pipes, concrete channels, similar infrastructure, and of various machines and household appliances.

d) Affecting industrial and domestic uses such as washing and food processing.

3° *Impacts on public infrastructure, buildings and houses.* Dryland salinity also affects rural towns. Apart from land clearing, salinity there is partly caused by human activities such as over watering of gardens and sports grounds. It has potential effects on infrastructure, buildings and domestic houses. The impacts include

a) Damage to houses, buildings and other structures caused by the deterioration of brick, mortar and concrete due to saline water crystallizing in brickwork.

b) Corrosion of metal buried in the ground or set in structural concrete may also occur.

c) Shifting or sinking of foundations may result in structural cracking, damage or collapse. Damage to heritage buildings may be of particular concern and land values may be degraded by salinity.

d) Salt damage to roads and highways includes the breakdown of concrete, bitumen and asphalt with associated pot holing, cracking and crumbling of the road base.

e) Damage to underground pipes, cables and other infrastructure due to the breakdown of unprotected metal, cement and other materials.

f) Loss of amenity in recreational areas such as gardens and sports fields due to the appearance of bare, exposed patches where grass and other plants cannot grow.

g) Failure of septic tanks caused by high water tables. This often leads to other environmental and health problems.

4° *Impacts on biodiversity and the environment.* Rising water tables and increasing salinity have serious impacts on native vegetation, in the same way as they do for crops and pastures. Remnant vegetation may be threatened and with this, a variety of animal species and their habitats.

3. Remedial Actions

Remedial actions can be preventive and aimed at eventually stopping further loss of resource (land and/or water) to salinity, or ameliorative and attempt to reclaim the resource. Preventive measures aim to stabilize the depth to the water table, while for amelioration there must be a lowering of the water table.

The remediation strategies can be split into two broad themes: (i) an agronomic approach and (ii) an engineering approach. The agronomic approach relies on reducing the amount of recharge to a level commensurable with, or less than the discharge (a causal approach). Engineering solutions rely on the ability to cost effectively remove salt from the zone of interest and dispose of, or store, in a minimal impact way (a symptomatic approach).

(i) *Agronomic solutions* include

a) *Revegetation with woody perennials*. Trees and shrubs on recharge areas can reduce recharge, maintain or lower water tables and thus prevent or ameliorate salinity. However, unless there is: (α) an economic value (or an economic value can be assigned by society, for instance, in terms of carbon sequestration) in the trees or shrubs themselves and (β) a recognition of the spatial extent of the recharge zone and the magnitude of the reduction in the absolute amount of recharge, implementation on a broad scale is unlikely.

With plantings closer to, or on discharge areas, the range of species is limited to those that are salt tolerant and, with the exception of halophytes, their longevity is questionable.

b) *Perennial pastures*. Perennial pastures, such as lucerne, can control water table rise. The advantage of perennial pastures is that potentially they can be grown on large areas. The current economics of the animal industries predicate against widespread adoption. In high rainfall areas the effectiveness of this treatment is dubious.

c) *Phase cropping*. With the prospect of a significant proportion of cropping land being lost to salt (as high as 30% in some regions) the use of deep rooted perennials as part of a longer cropping rotation offers some opportunity for water table control.

d) *Productive use of saline land*. Salt tolerant shrubs (*e.g. Atriplex*) and grasses (*e.g. Puccinellia, Agropyron*) can grow well on saline land. They have been shown to lower water tables *in situ* and the limited leaching this allows permits the invasion or establishment of less salt tolerant species. The resulting species mix can be a productive fodder source. However, this type of treatment is only localized in terms of the extent of its applicability.

(ii) *Engineering options* include: drainage, aquifer pumping. Drainage (with drains to 1.5…2 m) and aquifer pumping can be effective at controlling water tables. The area of effect away from the drains or pump depends on the transmissive properties of the aquifer. Disposal of the effluent can present legal and environmental problems.

Integrated approach include catchments water management.

Rarely will a single treatment be sufficient or applicable, even within small catchments. In most cases the water balance of a catchment can only be manipulated by invoking a treatment or treatments appropriate to the land unit, its underlying hydrology and the major land use, and with due recognition of potential off-site impacts.

Technically salinity is reversible, with massive revegetation, drainage and pumping. However, in practice, and recognizing the need for farmers to continue to make a dollar, we contend that it is only reversible on a local scale. In large catchments the time constants for reversal are very long (hundreds of years) and there needs to accept that what is now saline will remain saline. Thus the aim must be to reduce the rate of spread and learn to live with salinity by getting production from the saline land and the saline water – salt land agronomy.

4. Crop Salt Tolerance

Crop salt tolerance also needs to be taken into account when assessing the suitability of water and soil for irrigation [4],..,[6]. The salt content of the soil water in the crop's root zone, referred to as the average root zone salinity (EC_{se}), is important in assessing which crops are suitable for growing in particular soils.

The average EC_{se} can be calculated using the measured EC_i of irrigation water [8]. This requires estimation of the average root zone leaching fraction (LF) of the soil under irrigation, *i.e.* the proportion of applied water moving below the root zone. This is shown in Fig. 1.

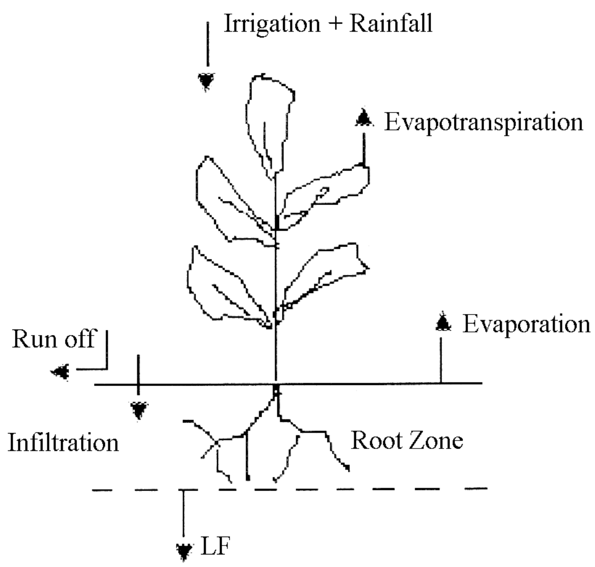

Fig. 1 – Diagram of the leaching fraction (LF) concept.

Average root zone leaching fraction, for four soil types, are listed in Table 1.

Table 1

Soil Type and Average Root Zone Leaching Fraction

Soil type	Average root zone leaching fraction (LF)
Sand	0.6
Loam	0.33
Light clay	0.33
Heavy clay	0.2

Average root zone salinity can then be calculated using the following relation

$$\mathrm{EC_{se}} = \frac{\mathrm{EC}_i}{2.2\mathrm{LF}}, \tag{1}$$

where: $\mathrm{EC_{se}}$ is average root zone salinity, [dS/m]; EC_i – electrical conductivity of irrigation water, [dS/m]; LF – average root zone leaching fraction.

The calculated $\mathrm{EC_{se}}$ can then compared against the $\mathrm{EC_{se}}$ values in Table 2 to asses the general level of salinity tolerance required of the preferred crop in the particular irrigation situation.

Table 2

Soil and Water Salinity Criteria Based on Plant Salt Tolerance Groupings

Plants salt tolerance grouping	Water or soil salinity rating	Average root zone salinity $\mathrm{EC_{se}}$, [dS/m]
Sensitive crops	Very low	< 0.95
Moderately sensitive crops	Low	0.95…1.9
Moderately tolerant crops	Medium	1.9…4.5
Tolerant crops	High	4.5…7.7
Very tolerant crops	Very high	7.7…12.2
Generally too saline	Extreme	> 12.2

Common crop and pasture species are listed in Table 3 in order of salt tolerance determined by average root zone salinity at the threshold level causing yield reduction. Electrical conductivity of irrigation water at the threshold level for a range of soil types is also shown and can be used as a general guide for selecting suitable crops for the particular irrigation situation.

Table 3
Tolerance of Plants to Salinity in Irrigation (*Field Crops*)

Scientific name	EC_{se} average root zone salinity threshold for yield reduction, [dS/m]	EC_i threshold for yield reduction for crops growing, [dS/m]		
		Sand	Loam	Clay
Sorghum almun	8.3	11.6	6.6	3.9
Hordeum vulgare	8.0	12.6	7.2	4.2
Gossypium hirsutum	7.7	12.1	6.9	4.0
Beta vulgaris	7.0	11.0	6.3	3.7
Sorghum bicolor	6.8	9.4	5.3	3.1
Carthamus tinctorius	6.5	8.2	4.7	2.7
Triticum aestivum	6.0	9.4	5.3	3.1
Triticum turgidum	5.7	9.6	5.5	3.2
Helianthus annual app.	5.5	7.5	4.3	2.5
Avena sativa	5.0	7.0	4.0	2.3
Glycine max	5.0	7.0	4.0	2.3
Arachis hypogala	3.2	4.4	2.5	1.5
Oryza sativa	3.0	4.8	2.7	1.6
Vigna unguiculata var. Caloona	2.0	3.7	2.1	1.2
Zea mays	1.7	3.2	1.8	1.1
Vinum usitatissimum	1.7	3.2	1.8	1.1
Saccharum officinarum	1.7	4.3	2.5	1.4
Vigna uncuiculata	1.6	3.4	2.0	1.1
Macroptilium lathyroides	0.8	2.7	1.5	0.9

5. Case Study

The water of Siret River and Buzău River, used as water sources for eastern Romania irrigation systems [7] has the electrical conductivity (EC_i) presented in Table 4. The averages root zone salinity (EC_{se}) were calculated with relation (1), form sand, loam, light clay and heavy clay.

Table 4

The Averages of EC_i and EC_{se}

River	EC_i , [dS/m]	EC_{se} , [dS/m]			
		Sand	Loam	Light clay	Heavy clay
Siret	1.30	0.98	1.79	1.79	2,95
Buzău	2.03	1.53	2.79	2.79	4,61
Plants salt tolerance grouping		Moderately sensitive crops	Moderately tolerant crops	Moderately tolerant crops	Moderately tolerant crops

6. Conclusions

A detailed knowing of the soil salinity, of the quality of irrigation water and the of the salinity tolerance in plants represents a very important component of management of irrigated lands.

Dryland salinity has many environmental, economic and social impacts. The remediation strategies can be split into two broad themes: an agronomic approach and an engineering approach.

Supplementing the volume of water in the soil by irrigation can lead to changes in the soil salinity, making it saline or alkaline if management is inadequate. Therefore, control of irrigation water quality, especially in arid areas, is a mandatory requirement.

Where there is uncertainty regarding the effect of irrigation water quality on soil structure stability or crop salt tolerance, it is recommended that soil samples from the surface and subsoil of representative profiles of the soil under irrigation be submitted for laboratory analysis.

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DESALINIZAREA TERENULUI ŞI CALITATEA APEI DE IRIGAŢIE

(Rezumat)

Salinizarea solului constituie un factor de care trebuie să se ţină seama la caracterizarea condiţiilor de dezvoltare a plantelor. În acest context, cercetările prezentate în lucrare se referă la o serie de aspecte ca: desalinizarea terenului (cauze ale salinizării, impact, acţiuni de remediere, toleranţa culturilor la săruri) calitatea apei de irigaţie şi influenţa sa asupra regimului salin al solului, cu exemplificare pentru sistemele de irigaţie alimentate din râurile Siret şi Buzău.