University of West Hungary
Faculty of Geoinformatics

Theses of doctoral (PhD) dissertation

USING GIS METHODS IN WATER MANAGEMENT

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Székesfehérvár
2012

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Background and Objectives

In the research of hydrology and land use changes always arises the spatial behaviour of problems. Both fields can look for answers using traditional statistical methods or analysing paper maps, but the extended information and the complexity of problems have required another analysis technique where the technological development have enabled the application of GIS methods for an efficient and intelligent management of spatial data.

The hydrological modeling is one of the most complex task of GIS because of many model parameters which are difficult to determine. Within the catchment area the quantitative determination of runoff dynamics effected by the urbanization-induced changes, such as land use and land cover change in a broader sense, isa special field of interest for hydrologists (especially in the international literature). There is a novel approach analysing landscape ecological functions, including runoff control functions, which gives an exact numerical result for the relationship between land cover and runoff. In the dissertation this function have been examined for a sample area with the use of GIS tools.

In the doctoral thesis the author undertook to show the important role of GIS in the development of territorial information-based methodology regarding hydrology and land use change associated with hydrological processes presented in an own case study. The thesis has sought to answer the following questions:

- How can we use GIS tools for hydrological tasks, and how does GIS help hydrology?
- What are the typical questions that may arise in the context of land use and its analysis?
- How can be supported a specific question/problem of water managers by GIS tools, the modeling of runoff?
- What connections can be set up regarding an important issue of land consolidation: between the change in cultivation and the change in runoff control function ?
- How can it be modelled in a case study?
- What kind of inland and foreign experiences, references can be found to answer tothis question?

The thesis aims at discovering the potential use of GIS in water management, in its conditions and methods with respect to land use context.

Data and Methods

The study area, the Rovákja Creek watershed in western Hungary, in Fejér county was chosen by the author. The surface of the surrounding areas is diverse,in the test site there are two small regions (Velence Mountains, Lovasberény-back) , which are different in morphology and land use.

The secondary data collection methods have been used by the author. With these partially spatial, partially attribute data can be gathered. The database of secondary data collection includes topographic map. The terrain model was based on the contour lines from the digital map. The databases used for the research are: CORINE (CLC50, CLC100), LANDSAT satellite images (1986, 2011), DTA-50 and DEM made by the 1:10 000 topographic map, AGROTOPO, soil information data from Fejér County Government Office, Directory of Plant and Soil Protection.

For the hydrological modelling the author used the ArcGIS 9.3 software, with the add-in DEM Surface Tools, the WEAP and SAGA GIS software, for the analyses of land-use changes the IDRISI Taiga software. It was important for the author to introduce the use of free softwares, because as the publication statistics shows 90% of both Hungarian and international literature does not use these. In the study area the GIS analysis of various parameter has been carried out. These parameters are: the mechanical composition of soil, slope, land cover, the available water amount for plants.

The author introduces the application of GIS methods from several aspects:

- tool for visualization: for the presentation of results of WAREMA project managed by the author;
- system of planning process: introducing the WEAP software wherewith scenarios can be made for the future;
- analysing function: testing the runoff control function.

Summary of Results

The author described the relationship between runoff and land-use using GIS tools, reviewed the literature of model-set and methods. During the collective work the knowledge of relevant reference literature was summarized and systematized, supplemented by her individual experiences regarding the whole process of data analysis . Based on the literature the extent of the study area was analysed. Less than 10% of the 59 studies have dealt with medium-sized river basins (50-99 km^2). In hydrological modeling rather the large catchment areas (100 km^2 and over), in the landscape ecological research the smaller samples (0-49 km^2) are preferred. Based on the literature the availability of models has been analysed. It has been noted in this regard that 90% of the tested 61 models mentioned in the literature use commercial software. The author has examined only a small proportion of the literature dealing with free and open source software applicability.

The runoff, one hydrological element, takes place in landscape. Therefore, a more accurate description of the movement of water can only take place with the inclusion oftopography and application of terrain models. The author analysed the derivatives of elevation models from the perspective of how useful they are for hydrological analysis. The amount of runoff depends on the slope magnitude, the length of the slopes, the degree of curvature. With the analysis of these parameters she contributed to the subsequent examination of runoff control function.

One of the crucial component of land use modeling is the spatial extension of measurement results. This geographical problem is still not solved. The theoretical problem is that the point objects are discrete in mathematical sense, the geographical phenomena, however, is continuous in space and time. At the GIS implementation of land use and land arrangements one problem is the management. of data varying in space and time The solution for this is a task for the future.

GIS with several tools assists a number of landscape ecology related hydrological modeling approaches: data processing, systems thinking, analysis and visualization. In the case studies they have been shown. The example given to spatial analysis, using WEAP software facilitates the decision-makers, primarily due to the creation of scenarios. The WAREMA project giving specific examples for complex analysis and visual display information demonstrated well the use of numerous tools of GIS, and its role in visualization. The application of elevation models for hydrological modeling is an accepted method. However, it can be a basis for landscape ecological analyses because of numerous functions. By the analysis of elevation models such information can be gained, like the steep of slopes,

length, shape, which affect the work of the surface water drainage, and nevertheless the broader issues of soil conservation are also touched. The results are summarized in table confirming the correctness of my statements.

Name of Software	**Name of Modul**	**Adaptation**	**Parameters**
ArcGIS licenced	Spatial Analyst, DEM Surface Tools	slope, DDM	slope
	Spatial Analyst, DEM Surface Tools		aspect
	Spatial Analyst		runoff direction
	Spatial Analyst, DEM Surface Tools		curvature
SAGA GIS free		slope, DDM	slope
			aspect
			runoff direction
			curvature
			length of slope
		erosion	LS value
			soil moisture value
		simulation	C-cycle
			TOPMODEL
			kinematic wave
			IHACRES

In a medium-sized catchment the change of the runoff control function have been tested by the author in 1980-2011. For the analysis databases and satellite images have been used in GIS programs. The runoff control function is used in the literature in field of geo-ecological mapping. The author has developed evaluation categories which are not included in either the foreign or the Hungarian literature. For the evaluation four different overlays have been examined, they concerned soil characteristics

(mechanical properties, available water amount for plants), the terrain and the land use. Land use changes was analysed by using satellite images and CORINE database. During the analysis raster model was used, so data have been produced for all points of the catchment.

It was found that the effect of land use on surface runoff can occur in two ways: the way of land use and the ratio of land uses. The hydrological balance of the catchment with various branches of farming is determined by the individual cultivation proportions. The runoff control function together with soil erosion tends to examine the agro-ecological potential. Agricultural and urban areas have a higher rate of runoff, than nearly natural areas. This also means that the runoff control function of these two fields occurs to a lesser extent. In the case study it was demonstrated by the author: the wooded/forest areas have the largest rate of runoff regulation.

Theses of the Dissertation

The following new or novel results were determined:

(1)The author have analyzed and evaluated basic databases related to the environmental management and water management which she used in the GIS applications. The most important developments and applications have been collected that are essential for the use of applied research topics. The author also evaluated the largest digital databases: which should be used and in which scale, in spatial planning and delimitation issues. For these databases metadata descriptions were prepared from a research point of view, which is important to facilitate the transparency and availability of the data.

Publication(s) to thesis:

Horoszné Gulyás M., Katona J. (2011): Térinformatika a hidrológia és földhasználat területén. Tudományos Doktorandusz Konferencia, Sopron, pp. 115-118, ISBN 978-963-334-013-4

(2)The author analyzed the relationship between land use and water management, adapted to the runoff control function of the Rovákja Creek catchment. It is included in the fourth and fifth chapter. The author has found that between 1980 and 2011 the value of runoff control function has changed,reached a higher-value , which has been adapted to the evolution of discharges. It was found that the increase in forest area caused these changes.

Publication(s) to thesis:

Horoszné Gulyás M. (2012): Lefolyás-szabályozás a talajvédelem tükrében, GISOPEN2012, Székesfehérvár, 2012.03.12-14.

(3)With catchment level analysis the author created a new opportunity within the landscape ecological studies. Between small-sized (up to 10-50 km^2) and large area (at least 100 to 200 km^2) research the medium-scale analysis is a novel approach. Studies with different scales have been analyzed and found that the high-resolution data is recommended, and hereby recommending itfor future research in this direction.

Publication(s) to thesis:

Horoszné Gulyás M. (2007): Vízgazdálkodás-Természetvédelem-Földhasználat. Acta Agraria Kaposvariensis Vol. 11 No. 2, pp. 53-66, ISSN 1418-1789

(4)The author presented and analyzed the hydrological processes with various types of GIS software, so the effects of slope, curvature, exposure have been evaluated in case of water management processes. The author analysed and evaluated the possibilities of the open source and commercial software. Their advantages and disadvantages have been listed, thus providing support for water management studies.

Publication(s) to thesis:

Horoszné Gulyás M., Katonáné Gombás K. (2010): Ökológiai szemléletű vízgazdálkodás-tervezés. 4. Magyar Tájökológia Konferencia, Kerekegyháza-Kunpuszta, 2010.05.13-15.

(5)The author summarized those GIS procedures which can be applied for the different types of water management decisions, so the author developed a certain methodology. The specific examination of spatial analysis and display of information will help to better manage future water management problems.

Publication(s) to thesis:

Horoszné Gulyás M., Katonáné Gombás K. (2010): Vízgazdálkodás-tervezés. VIII. Alkalmazott Informatika Konferencia, Kaposvár, 2010.01.22.

(6)The thesis comprehensively reviewed the scientific literature of the frontiers of knowledge.

Publication(s) to thesis:

Horoszné Gulyás M. – Katona J. (2010): Tájökológiai kutatások módszerei. Corvinus Regionális Tanulmányok, 2010. I. évfolyam/2-3. szám, pp. 43-50., ISSN 2061-8638

M. Horoszné Gulyás – J. Katona (2010): The methods of landscape ecology researches. Corvinus Regional Studies, 2010. I. volume/2-3. issue, pp. 43-50, ISSN 2061-8646

K. Katona-Gombás, M. Horosz-Gulyás (2010): Microregions agricultural aptitude test methodology. Geographia Technica No. 1/2010, pp. 11-16., ISSN 2065-4421

Practical applicability of results

The future impact of agricultural policies on land use, through the drainage conditions is not known, yet. The land cover maps and models are known, but land use maps and models regarding land use intensity affecting the runoff the most are unknown, especially in certain resolutions. Until today the mapping practise is to produce comprehensive information about a large area in low-resolution models. The models used in landscape ecology on the contrary, provide useful information at high resolution.

The presented analyses in the thesis – combined with the results of the hydrological and land use modeling, topographic and geographic conditions – can serve as a useful tool for national, regional, watershed-based hydrological modeling. They have an important role in the estate planning process , inthe preparation of the plans and in the process to be made public. The intermediate (medium) scale of the processes of research promotes a complex way of view, thus opening up a new dimension in landscape ecology and in the study of water management processes.

The National Rural Strategic Concept-2020 is a national strategic program in which the water has priority, which is essential from the natural resources. In seven National Strategic Plans water is included(Flood Protection Program, Water Resources and Water Quality Protection Program, Regional Water Management Program, Green Danube Program, Drinking Water Program, Wastewater Program, Urban water management), and it is a component in a number of other programs associated with land management and land arrangements. Analyzes described in this paper, as the further developed geo-ecological mapping can be integrated into the concept for several programs, helping to ensure their effective implementation.

The Good Agricultural and Environmental Condition requirements which is an essential element of cross-compliance also include water-related fields of the environment protection. The cross-compliance system influences the support of farmers, so the more efficient (and also ecologically appropriate) land use analysis can assist in Good Agricultural and Environmental Condition creation.

The novelty of the medium-scale watershed modeling and the provided information can be a step forward in the decision-making. The value of the model is that it combines landscape ecology and hydrologic modeling using GIS, in river basin level. In the future, relevant catchment scale modeling methodology on the principles of the WFD can be helpful in landscape ecology, in hydrology and agriculture research professionals. The expansion of runoff control function (eg. urban ecological research) promotes drainage (water management) operations, activities, in order to increase the precision.

By the surface and sub-surface drainage works is very useful to use this function, because the various parameters help to improve the accuracy of engineering. With the land cover change modes scenarios can be made, which makes easier the decision-making process and allow the settlement of agricultural land (land consolidation), or even local level planning as well.

The application of DEM in hydrological process prevails widely in the field of water management. Through the terrain analysis information related to other disciplines can be obtained. eg. analysis of the shape of slopes for soil conservation, flood protection. It has also an important role in the complex analysis of landscape ecology and an essential element in the multi-use decision support systems of integrated, landscape ecological approached water management.

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