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The Olt River pollution monitoring, using spatial analysis, analityc hierarchy process and technique for order preference by similarity methods

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ABSTRACT

Environmental pollution is one of the most serious problems of the contemporary world. Chemical industry is one of the major sources of environmental pollutants. Human knowledge and experience is currently focused on the use of assessment methods and techniques before and during the onset of such activities. For instance, it is common to consider the integration of multiple constraining factors and also, taking into account their high complexity and the application of one of the various techniques of Multi-Criteria Decision Making. The purpose of this study is to determine the location of the least and most polluted areas from several sampling points on the Olt River, in Romania. In the investigations carried out, MCDM methods were used: AHP and TOPSIS and spatial analysis performed using GIS software. The first part of the paper presents a quantitative assessment of the pollution in each sampling using AHP method. In the second part, the most polluted and least polluted sampling points among those under consideration were determined by using TOPSIS. At the end of the work performed, a spatial analysis allowed for the development of representative maps of the studied area.

1. Introduction

The MCDM methods are frequently used to solve real-world problems with multiple attributes. Recently, various methods have been developed to support decision-making in various fields. Multi-criteria decision-making (MCDM) is a well-known branch that deals with decision making problems based on a number of criteria. Depending on the type of the MCDM theory applied, the following categories of MCDM methods can be distinguished: relations-upgrading, ordinal regression, multi attribute utility theory, multi attribute values theory (MAUT, MAVT). MAUT (Multi-Attribute Utility Theory) is widely used for the quantification of subjective judgements in various decision making areas (Kim et al., 2007). Multi-Attribute Value Theory, MAVT, is a method used for making decisions in an environment of certainty. It is based on an aggregative model and ranks all options from worst to best (Ferretti et al., 2014). In addition MCDM methods can be classified according to the type of data used (deterministic, stochastic or fuzzy methods) or based on the number of stakeholders involved in the decision process: MCDM methods with a single decision-maker and MCDM with a group of decision makers. The methods belonging to each of the above classes have common characteristics regarding the conflict between criteria and difficulties regarding the selection of alternatives. Therefore, MCDM methods can be successfully applied to obtain realistic solutions to complex problems regarding environmental quality and to help decision makers to consider a variety of ways, in addition to costs for social, and technological issues. In our research we had used the MCDM methods: Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity System (TOPSIS).

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The best known MCDM method had been AHP. It is a compensatory method with a linear additive model, which especially is based on pair wise comparisons on a ratio scale.

TOPSIS, known as one of the classical MCDM methods, was first developed by Hwang and Yoon (1981). It is based on the idea that the chosen alternative should have the shortest distance from the Positive Ideal Solution (PIS) and on the other side the farthest distance from the Negative Ideal Solution (NIS). The Positive Ideal Solution maximizes the benefit criteria and minimizes the cost criteria, whereas the Negative Ideal Solution maximizes the cost criteria and minimizes the benefit criteria (Wang and Elhag, 2006; Wang and Lee, 2007). In the process of applying TOPSIS, the performance ratings and the weights of the criteria were given as exact values. Abo-Sinna and Amer (2005) extended the TOPSIS approach to solve multi-objective nonlinear programming problems. Jahanshahloo et al. (2006) extended the concept of TOPSIS to develop a methodology for solving multi-criteria decision-making problems with interval data.

Determining the best location from a number of alternative locations had been a difficult and complex process. Site selection had been a kind of decision-making process that requires criteria to be weighed and alternatives to be evaluated and ranked. Integration between Multi Criteria Decision Making (MCDM) and GIS was needed to solve the site selection problem as GIS was used to handle the spatial aspect of the problem and MCDM was used to calculate weights of the criteria and ranking of alternatives. These multi-criteria methods could be used in GIS software to view data directly on intelligent maps.

In the literature the research that we had performed it was situated in a relatively less study. For the first time we were able to implement multi-criteria methods in GIS software using its specific entities: query language and scripts.

The study had consisted of five sections. The first section the introduction and the purpose of the paper. The second section described the proposed approach and gave information about AHP and TOPSIS methods. In Section 3, we presented our research on the environmental process for the river studied. In Section 4 we presented the results of the study and the spatial analysis in GIS software for AHP method. The paper ended with conclusions, remarks and discussions. One of the most important objectives of this paper was to demonstrate that the algorithms of multi-criteria analysis could be implemented in GIS software.

2. Materials and methods

The studied area was located in the middle of the Olt River, which is one of the most important rivers in Romania. It springs from Hăşmaşu Mare Mountains, situated in the Oriental Carpathians. The Olt River Basin is situated in the central and south part of the country with a surface of 24,050 km^2. Near the main course, the Olt River Basin has many important tributaries such as the Negru River ($S = 2349$ km^2; $L = 88$ km), the Cibin River ($S = 2194$ km^2; $L = 82$ km), the Lotru River ($S = 990$ km^2; $L = 83$ km), the Olt River ($S = 2663$ km^2; $L = 185$ km). The Olt River has a compensatory and well-balanced hydrological regime due to its sources of supply. The average altitude is between 750 m in the upper area and 18 m in the confluence area. The physico-geografical unit, very diverse due to the existence of several areas with specific characters. For example, there are depressions (Ciucului Depression, Brasovului Depression, and Făgăraşului Depression), mountains (it flows through the Oriental Carpathians, the Southern Carpathians and the Sub-Carpathians), the plateau and plain area (the Romanian Plain and Getic Plateau). It influences the process of formation of the Olt River's hydrological regime and its tributaries, Fig. 1

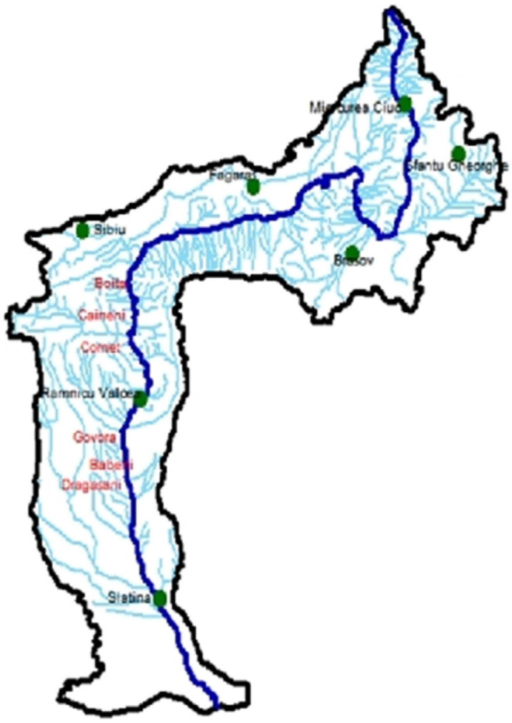

Fig. 1 – The drainage basin Olt–GIS representation.

The various industrial factories had a major impact on the hydrographic network. One of these factories was dealing with the manufacturing of organic and inorganic chemical products being thus the main polluter of the Olt River, by polluting it with alkaline waters, organic substances, suspended matters and filtered residues. Other factories had polluted the Olt River with alkaline and strongly mineralised waters.

Most of the wastewater treatment stations had contributed to a smaller or larger extent to polluting the surface rivers of the county's hydrographic network with many organic substances, nitrogen and phosphorus compounds and suspended matter, that surpassed the limits set in the field-specific standards.

Furthermore, the food industry had a minor but of a great importance impact, producing untreated organic residues in biological wastewater treatment plants, thus affecting the microfauna and the microflora of the Olt River.

2.1. *The AHP (analytical hierarchy process) method*

Algorithm of AHP method for multi-criteria decision problem: n decision criteria $C_1, C_2, \ldots, C_n$ are considered leaf nodes of a simple hierarchy, representing the decomposition of a requirement (of an objective).

The AHP method (algorithm) has three steps:

1. Pairwise comparison of decision alternatives according to each decision criterion, to arrange them in a hierarchy in relation with the corresponding factor;