**Water resources and wetlands**, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan*
Conference Proceedings, 14-16 September 2012, Tulcea - Romania
ISBN: 978-606-605-038-8

# APPLICATION OF DRASTIC MODEL AND GIS FOR EVALUATION OF AQUIFER VULNERABILITY: STUDY CASE BARLAD CITY AREA

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**Abstract**
The aims of this study is to determinate the aquifer vulnerability using the DRASTIC method and the correlations that can be establish between this and the nitrate level present in Barlad city and surrounding villages' wells. The main objective is to determine susceptible zone for groundwater pollution by integrating hydrogeological layers in GIS environment. The methodology consisted in a documentations stage, followed by a field phase consisting in collecting 94 groundwater samples from the study area, analyzed in the laboratory for physico – chemical parameters. The layers such as depth to water table, recharge rate, aquifer media, soil permeability, topography, impact of the vadose zone, and hydraulic conductivity are incorporated in the DRASTIC model using GIS techniques. The aquifer analysis has highlighted the following: the vulnerability varies between 120÷160, being predominant the moderate and moderately-high values (160÷183) while the nitrates concentration is between 0.1 to 788 mg/l. The statistical analysis puts into evidence a powerful positive correlation between vulnerability and concentration of the nitrates in the groundwater. High nitrate concentration are present in high pollution areas as well as in moderate pollution areas. The present model can be used for assessment and management of groundwater.

**Keywords**: GIS, DRASTIC model, aquifer, nitrate, vulnerability

## 1 INTRODUCTION

The groundwater are a major source of water for a wide range of beneficial uses, being the most significant freshwater resource on the planet Earth. All human activities can negatively impact water quality in aquifers, these impacts can result in the temporary or permanent loss of the resource, significant costs to remediate the aquifer and /or to remove the harmful materials from the water prior to use. The aquifers vulnerability at one moment represent a problem of both industrial but also of developing countries, where industry or agriculture grow fast at the same time with the urbanization process (Secunda, S. & al 1998).

Groundwater vulnerability to contamination is defined as the tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer (National Research Council, 1993).

The general concept of groundwater vulnerability is based on the assumption that the physical environment may provide some degree of protection to groundwater against natural impacts, especially with regard to contaminants entering the subsurface environment, making some land areas more vulnerable to groundwater contamination than others. Another goal of vulnerability maps is a subdivision of the area into several units which have different levels of vulnerability (Napolitano P., 1996).

One of the tools created in order to protect the groundwater in the United States is a methodology knew as "DRASTIC," created through in partnership by National Water Well Association (NWWA) and the U.S. Environmental Protection Agency (EPA). The main objective of this methodology was to assure a new and systematic tool of groundwater -pollution potential in any hydrogeologic setting. This method wasn't completely accepted in the past, presenting two main inconveniences: subjectivity as well as the difficulty to asses some important hydrogeological characteristics ore some specific properties of contaminants. Today the DRASTIC method, is a standardized system for evaluating groundwater pollution potential. DRASTIC has been widely used in many countries because the inputs required for its application are generally available or easy to obtain from public agencies (Jovanovici N.Z. & al, 2006). The main nitrate sources in groundwater are fertilizer applications on cultivated land, manure from livestock, and factory and domestic wastewater.

The aims of this study is to determinate the aquifer vulnerability using the DRASTIC method and the correlations that can be establish between this and the nitrate concentrations level present in Barlad city and surrounding villages' wells.

## 2. METHODOLOGY

The study area is situated in the eastern part of the country, in the Moldova Plateau, lies in the contact area between Falciu hills at east and Tutova hills at west. The annual average temperature is 9,8°C. The maximum average temperature is in July, 21,4°C, and the minimum of -3,6°C is in January. The average annual precipitation recorded at the Bârlad weather station is 472,2 mm, being the lowest recorded rainfall in the Bârlad river basin. The maximum rainfall was 712,8 mm in 1968, while the minimum of 388 was recorded in 1967. Bârlad is located at the contact of two geotecture areas in the north the Moldavian Platform and in south the Bârlad Platform. These structural units shows two levels: foundation (crystalline and folded) and sedimentary consisting of Paleozoic, Mesozoic, and Neozoic formations (Mutihac V. & Ionesi V. 1974). The border between the two structural units is merely conventional (the Bârlad-Pogonesti-Murgeni line), because has no counterpart in the present relief (Frugina E., & al 1975). Groundwater aquifers are located in structures belonging to the Quaternary formations. Pleistocene deposits consist of rough sand with gravel in the base, sheltering underground terrace aquifers and Holocene alluvial deposits shelter floodplain aquifers (Macaleț R.& Dragusin D. 2008, Pancescu M., 2004 ).

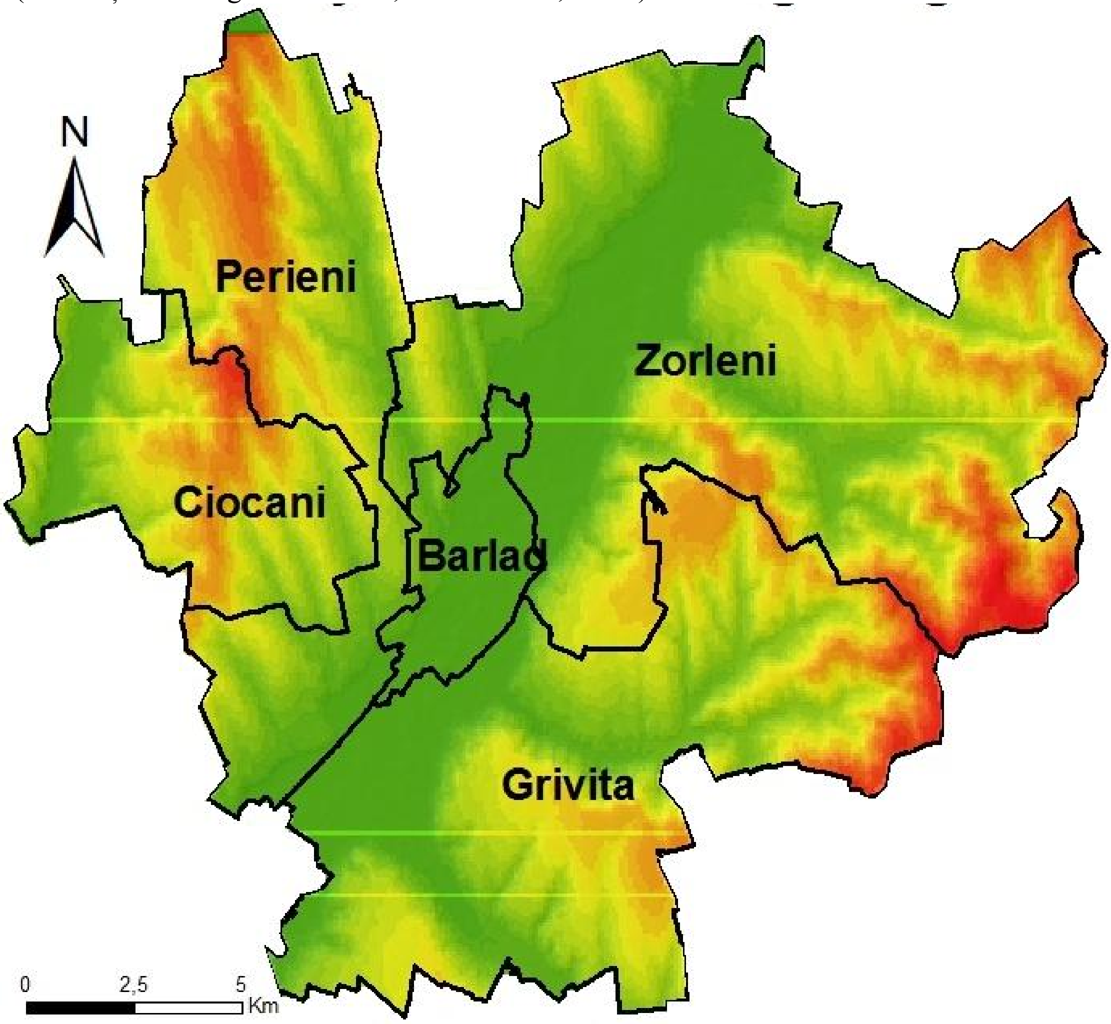


**Figure 1. Study area**

Almost 92% of the study area is non irrigated arable land. Growth in population during communist regime and agricultural activities tends to result in groundwater pollution in rural area (Dragusin D., 2005). One of the contaminates with high health risks is the nitrates which occurs in drinking water from many sources: naturally, runoff or leachates from manure or fertilized agricultural lands, municipal and industrial waste waters, refuse dumps, animal feed lots, septic systems as well as power plants and cars.

One of the most widely used models to assess wide range of potential contaminants is DRASTIC index (Aller et al. 1987). This method use some hydrogeological factors of an area in order to determine the relative groundwater vulnerability to contaminants. DRASTIC is an acronym created of the first letters of features used to create the map. There are 7 included features: Depth to the groundwater (**D**), Recharge net

(**R**), Aquifer media (**A)**, Soil media (**S**), Topography (**T**), Impact of vadose zone (**I**) and Conductivity of the aquifer (**C**). These are then weighted and ranked, and then are combined to obtain a final ranking value using an groundwater vulnerability algorithm (Neukum, C. & al 2008), There are three significant part: weight, ranges and ratings. Each DRASTIC features has assigned a weight relative to each other in order of importance from 1 to 5, the least significant is allocated one and five for the most significant. For each features have been establishh ranges (significant media types) based on its impact on pollution potential. The ratings for each features has assigned value between 1-10, providing a relative assesement between ranges in each feature. (Martínez-Bastida J. & al 2010) To build and manage the database was used Microsoft access, meanwhile for spatial distribution and other GIS analysis was used Arc Gis map 9.3. (ESRI) The DRASTIC vulnerability map referrred as a composite description of all results from the intersection of thematic maps parameter and were combined by overlaying according to the index equation (Newton P. & Gilchrist A. 2010). In order to calibrate the DRASTIC model, nitrate concentration was selected as the primary contamination parameter. Ninety-four agricultural wells were selected for sampling and analysis. Two sets of samples in august 2011 and January 2012 were taken, the exact position of each well was determined using GPS techniques. For nitrates a spectrophotometric method were utilized, with sodium salicylate, optical density of the solutions being measured by Shimadzu UV 1601 spectrophotometer

The DRASTIC index is calculated according to the following equation:

$$\mathbf{DRASTIC}\ \text{index} = \mathbf{D}r*\mathbf{D}w + \mathbf{R}r*\mathbf{R}w + \mathbf{A}r*\mathbf{A}w + \mathbf{S}r*\mathbf{S}w + \mathbf{T}r*\mathbf{T}w + \mathbf{I}r*\mathbf{I}w + \mathbf{C}r*\mathbf{C}w$$

Where,

Dw-Relative weight of the depth to the water table
Dr-Rating of the depth to the water table
Rw-Relative weight of the net aquifer recharge
Rr-Rating of the net aquifer recharge
Aw-Relative weight of the aquifer media
Ar-Rating of the aquifer media
Sw-Relative weight of the soil media
Sr-Rating of the soil media
Tw-Relative weight of the topography slope
Tr-Rating of the topography slope
Iw -Relative weight of the impact of the vadose zone
Ir -Rating of the impact of the vadose zone
Cw- Relative weight of the hydraulic conductivity
Cr -Rating of the hydraulic conductivity

The DRASTIC index ranges from 23 to 230 and to describe the relative assessment of the groundwater vulnerability to contamination, have been established five classes of vulnerability: low, moderately low, moderate, moderately high and high (Piscopo, 2001).

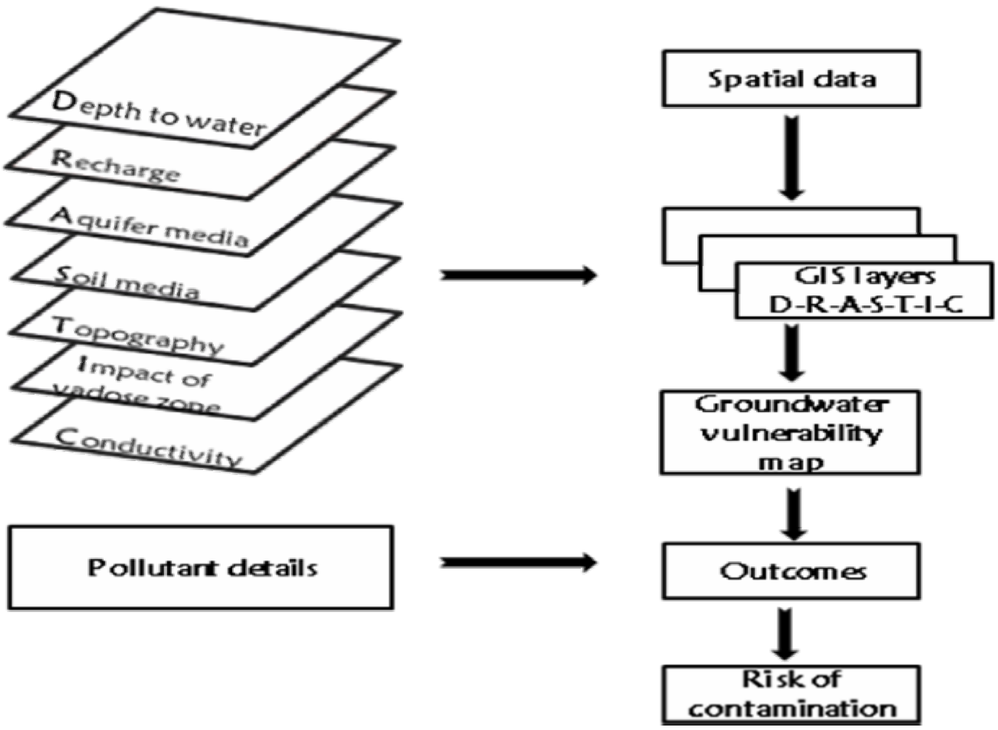


**Figure 2. Methodology flowchart for groundwater vulnerability analysis using DRASTIC model in GIS**

**Table 1 Weight, ranges and ratings of the seven DRASTIC parameters (Aleer, 1987, modified Piscopo, 2001)**

| **Depth to water table** | **w= 5** |
|---|---|
| **Range** | **Rating** |
| 0-1.5 | 10 |
| (1.5-4.6) | 9 |
| 4.6-9.1 | 7 |
| 9.1-15.2 | 5 |
| 15.2-22.8 | 3 |
| 22.8-30.4 | 2 |
| >30.4 | 1 |

| **Recharge** | **w= 4** |
|---|---|
| **Range** | **Rating** |
| >254 | 9 |
| 177.8-254 | 8 |
| 101.6-177.8 | 6 |
| 50.8-101.6 | 3 |
| 0-50.8 | 1 |

| **Aquifer media** | **w= 3** |
|---|---|
| Range | **Rating** |
| Gravel | 9 |
| Sand and gravel | 8 |
| Limestone, gravel, sand and clay | 7 |
| Sandy clay | 6 |
| Clay | 5 |

| **Soil media** | **w= 2** |
|---|---|
| **Range** | **Rating** |
| Thin or absent | 10 |
| Gravel | 10 |
| Sand | 9 |
| Peat | 8 |
| Aggregated clay | 7 |
| Sandy loam | 6 |
| Loam | 5 |
| Silty Loam | 4 |
| Clay loam | 3 |
| Muck | 2 |
| Nonaggregated clay | 1 |

| **Topography (Slope)** | **w= 1** |
|---|---|
| **Range** | **Rating** |
| 0-2 | 10 |
| 2-6 | 9 |
| 6-12 | 5 |
| 12-18 | 3 |
| >18 | 1 |

| **Impact of vadose zone** | **w= 5** |
|---|---|
| **Range** | **Rating** |
| Karst | 10 |
| Basalt | 9 |
| Sand and gravel | 8 |
| Sandstone | 6 |
| Limestone/Sandstone | 6 |
| Sand, gravel and alluvium | 6 |
| Clay/Alluvium | 3 |
| Calcareous | 3 |
| Confined aquifer | 1 |

| **Hydraulic conductivity** | **w= 3** |
|---|---|
| **Range** | **Rating** |
| >82 | 10 |
| 41-82 | 8 |
| 28.7-41 | 6 |
| 12.3-28.7 | 4 |
| 4.1-12.3 | 2 |
| 0.4-4.1 | 1 |

## 3. RESULTS AND DISCUSSIONS

The map obtained evidence the potential and sensitivity of the aquifer for contamination, especially to nitrate. The DRASTIC aquifer vulnerability map (figure 3) shows the predominant of moderately vulnerability class (shades of yellow) on the both side of Barlad watershed follow by the moderately high vulnerability class (orange shades). This situation is caused by small depth to water potentiated by the presence of sandstone, marl and alluvial rocks, all of which help to increase the infiltration water into the aquifer as well as increase agricultural activity and location of wastewater disposal in this region which helps to groundwater pollution.

The nitrate concentration in groundwater in north of study area was more than 150 mg/l during January 2012 while the maximum acceptable nitrate concentration for human health is 50 mg/l and 45 mg/l according to the World Health Organization it is well know that if nitrate concentration is higher than 10 mg/l in groundwater, it indicates anthropogenic contamination. Nitrate concentration increases about the wastewater disposal location in Zorleni and Grivita. This area is a moderately vulnerable area due to increase of nitrate in groundwater due to both ancient input of fertilizers and nowadays manure infiltration in the aquifer.

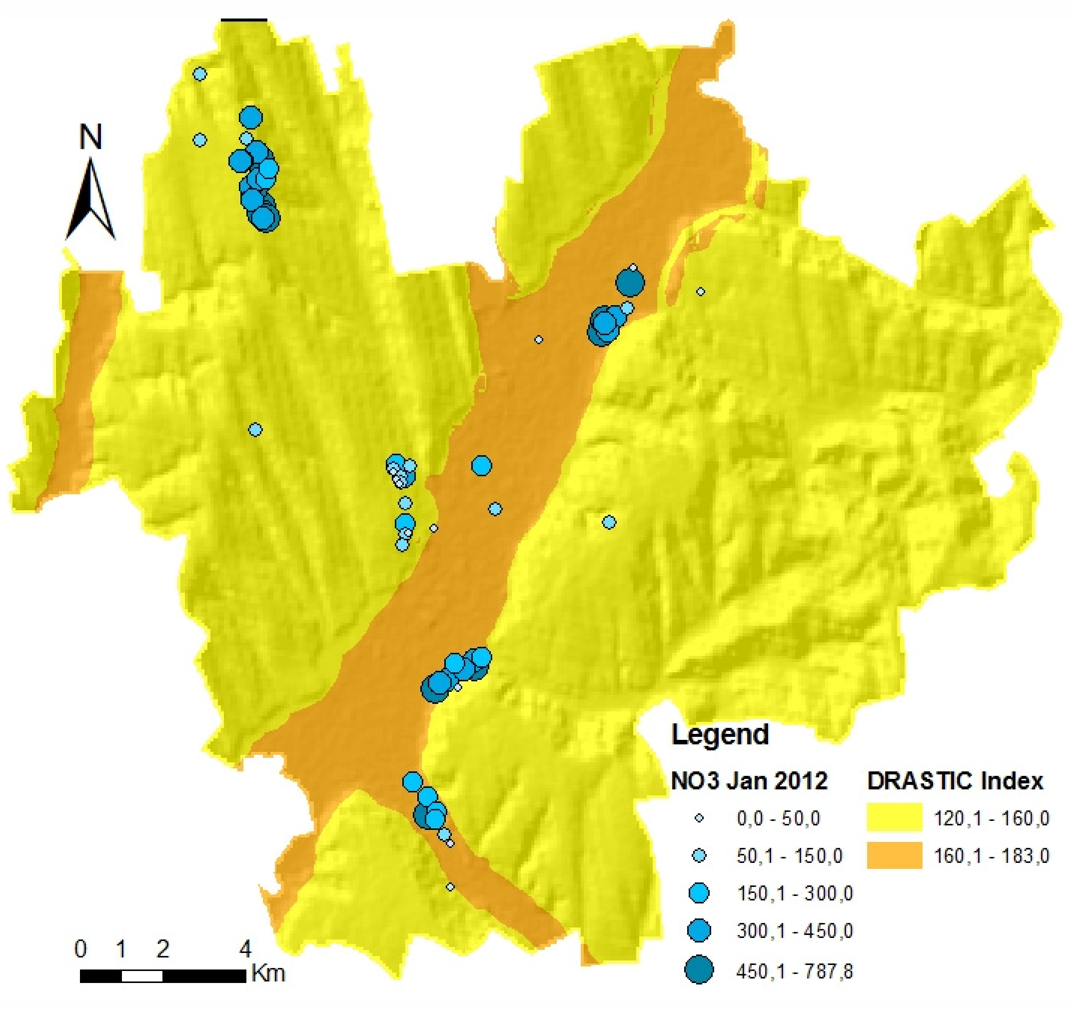


**Figure 3 Spatial distribution of groundwater vulnerability score**

## 4. CONCLUSIONS

The results of this study confirm the utility of intrinsic vulnerability indexes (DRASTIC) and specific vulnerability to nitrate pollution indexes for evaluating the vulnerability of the groundwater in the area of Barlad city.

This model, which was proposed as an adaptation based on the DRASTIC index has been developed with the objective of achieving greater accuracy in the estimation of specific vulnerability to nitrate pollution. It is based on a multiplicative model that integrates the risk of groundwater pollution by nitrate related to different land uses and considers both the negative impacts, over time, of some of these uses on aquifer media and also the protective effects of others.

In some parts of the map there are polluted areas that are not consistent with the degree of vulnerability assigned to it by any of the vulnerability maps. This result could be explained by incomplete land use information for this area or by movements of nitrate due to groundwater flows from the areas of highest risk to stagnant zones. In this respect, the DRASTIC and intrinsic vulnerability indexes show certain limitations that should be improved, related to a lack of parameters that consider the effects of groundwater flow direction on the distribution of vulnerable zones. The results of this study provides a basis for considering the shalow aquifer in the area of the Barlad city as possible nitrate vulnerable zones, as defined by EU Directive 91/676/EE.

The DRASTIC method is very simple and effective way of characterizing groundwater vulnerability to contamination91/676/EEC. The importance and nature of groundwater resources call for mankind to act at global, regional, and local levels.

**Acknowledgements**

This work was supported by both: the European Social Fund in Romania, POSCCE-A2-O2.2.1-2009-4, ID 901, SMIS 13984, No 257 / 28.09.2010, “CERNESIM”, and Geography Department from University „Al.I.Cuza” Iaşi.

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