Climate changes in relation to phreatic aquifers vulnerability assessment. A study case on Bega-Timis region, Romania

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Abstract The concept of vulnerability of aquifers corresponds to the presence of a certain degree of the groundwater natural protection against contamination produced by different man-made activities. The vulnerability maps are useful for different institutions and regulators in their activity of land-use planning and design. These has to be analyzed together with land-use maps, groundwater quality data, and contaminant sources inventories in order to represent the information basis for the groundwater protection programs. Within the ECAVAS research project (Groundwater resources vulnerability assessment and mapping to assure their long-lasting use) the DRASTIC method has been applied for a pilot region focusing the upper aquifer. The region belongs to the Banat plain (Romania) and the traditional activity performed is agriculture. The main vector of the contaminants transport between the soil surface and the groundwater is considered as being the rainfall water that infiltrates and recharges the aquifer. The recharged water mainly depends on the quantity and of the frequency of the rainfalls. Comparisons are shown between the current situation and the vulnerability maps generated for extreme climate conditions represented by excessive precipitations and drought periods.
Keywords groundwater quality; DRASTIC method; vulnerability map; extreme climate conditions

INTRODUCTION

Groundwater represents strategic water resources for most countries. Due to the socio - economic development, which implies an increased requirement for quality water, as well as the climate change situation (extreme hydrometeorological conditions - droughts and floods) the groundwater value increased progressively.

Assessment of vulnerability to pollution of aquifers is necessary for the feasibility and development analysis, planning management, land use decisions (regionalization and protection, development, improvement and monitoring provided by regulations, technical assistance) as well as general education and information.

The term "vulnerability of aquifers to pollution" was first introduced by J. Margat in 1968 and was defined as the property of the aquifer that depends directly on the sensitivity of aquifers to contamination. As definition, "vulnerability is an intrinsic property of the aquifer system that depends on its sensitivity to human impact and / or natural." This formulation of the concept of vulnerability of aquifers has been made by Jaroslav Vrba and Alexander ZAPOROZEC in 1994 and was accepted by the International Association of Hydrogeologists.

Within the ECAVAS project (Groundwater resources vulnerability assessment and mapping to assure their long-lasting use) the DRASTIC method has been applied for a pilot region focusing the upper aquifer (European groundwater body ROBA03). The aquifer is located in the Banat plain (Romania). The traditional activity of this region is agriculture.

STUDY AREA

For the chosen pilot zone, the study focuses on the aquifer vulnerability assessment and mapping procedure for the upper (phreatic) aquifer. Comparisons are made further between the current situation and distinct vulnerability maps generated for extreme climate conditions consisting of excessive precipitations and severe drought periods.

Since the distribution of the observation points (hydrogeological wells belonging to the National Hydrogeological Network for upper (phreatic) groundwater aquifer layers) is relatively irregular for the ROBA03 groundwater body, was decided to reduce the study area to a zone showing a relatively uniform distribution of these information points. This allows a better application of the vulnerability assessment chosen method (Figure 1). The North-East study area limit is beyond the body of water ROBA03, in order to include in the pilot area wells that could provide additional information.

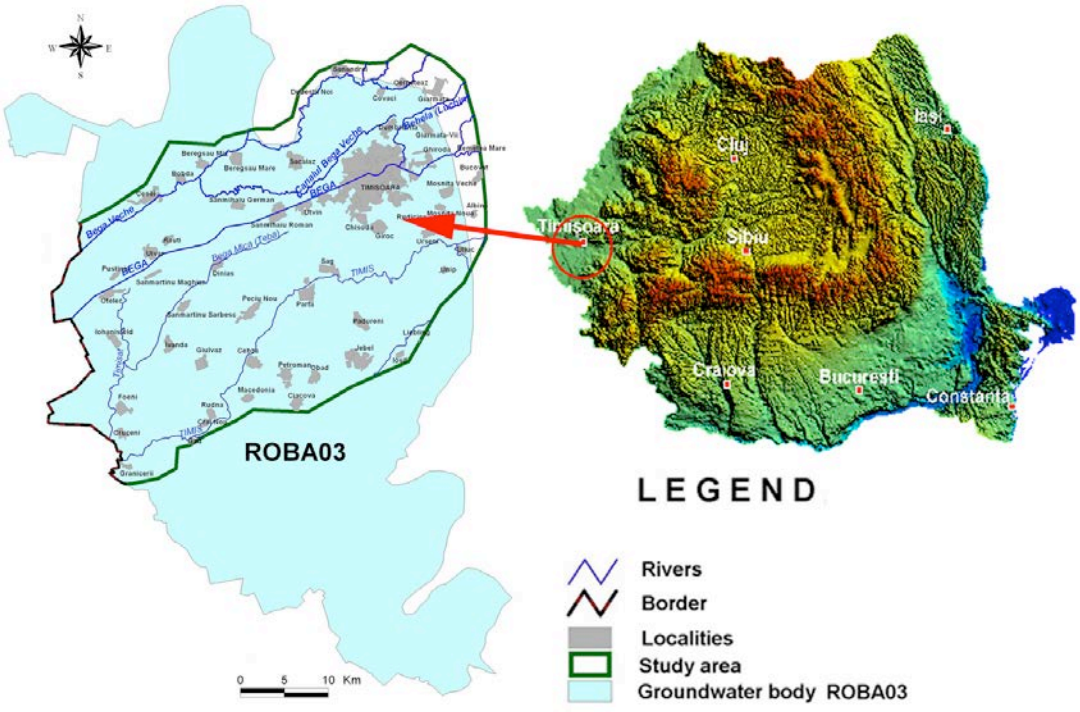

Figure 1 Study area location

General characteristics of the study area

In terms of geomorphology, the study area belongs to the Banat plain. From the morphogenetic point of view, this is a recent subsidence alluvial plain with shallow valleys (2-4 m), strong meanders, deserted floodplains and buried terraces. It is partially covered with proluvial-deluvial deposists. Main rivers in the region are Timis river, Bega Veche river and Bega Channel, whose main flow direction is from North – South to East - West.Geologically, the studied area belongs to the South East part of the Pannonian Basin. Its foundation is composed of Higher Precambrian crystalline. Over these strata are disposed discordant sediment deposits belonging to Cretaceous (Senonian), Cenozoic and Quaternary ages.

From the lithologica point of view, the Pannonian basin is composed of an alternation of sand, loamy sand, marl and clay, and subsidiary gravel and sandstone. Quaternary unit consists of sands and gravels, sandy clays with intercalations of silt. In addition to these, there are "red clays" from the Upper Pleistocene and loess deposits from Upper Pleistocene- Low Holocene. From the hydrogeological point of view, the free level aquifer (upper), which is the subject of this paper, is developed in the alluvial deposits of the floodplain as well as in the terraces and in interfluve areas. These belong to the Upper Pleistocene-Holocene age.

The analysis of geological cross-sections shows that the porous-permeable deposists, containing the phreatic aquifer, consist mainly of fine, medium and medium to coarse sands, common clay and/or silts. Also sand with small gravel pockets can be observed (Figure 2). These layers alternate with clays, sandy clays and/or silts and/or calcareous concretions.

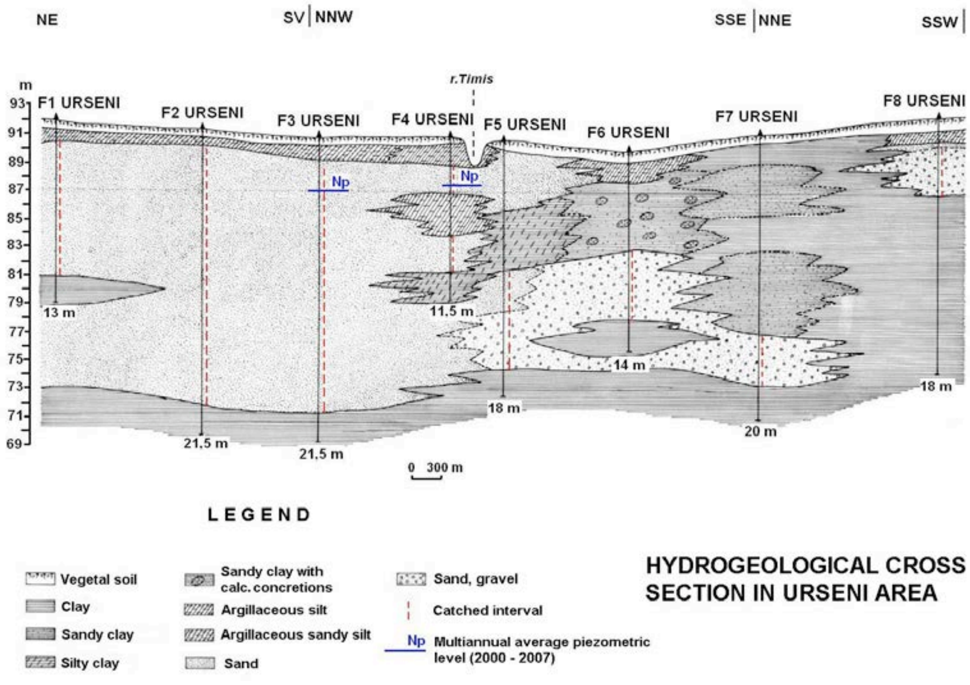

Figure 2 - Hydrogeological cross-section in the South East part of the study area (Urseni)

The presence of a relatively high proportion of silt fraction is observed and the absence other the coarse fraction, respectively the boulders, can be noted. The deposit granulometry decreases in the study area from North – East to South - West, as the transport potential of the surface water flow decreases. A characteristic to these deposits is the lateral facies variation, reflected by the horizontal and the vertical transition to deposits with different thickness and granulometry.

The facies variation is graduated (from fine sand - to medium or coarse sand, with rare elements of small gravel at the beginning) or abrupt (the occurrence of loamy sand levels and silt and sandy clay and silt). Locally sandy levels lenses can occur showing a low development, isolated in clay and silt deposits (Figure 3). The facies variations are due to the deposit river - lake environment. This formed these deposits of alluvial or prolluvial type. Processes that have characterized recently the subsidence of the area can be observed.

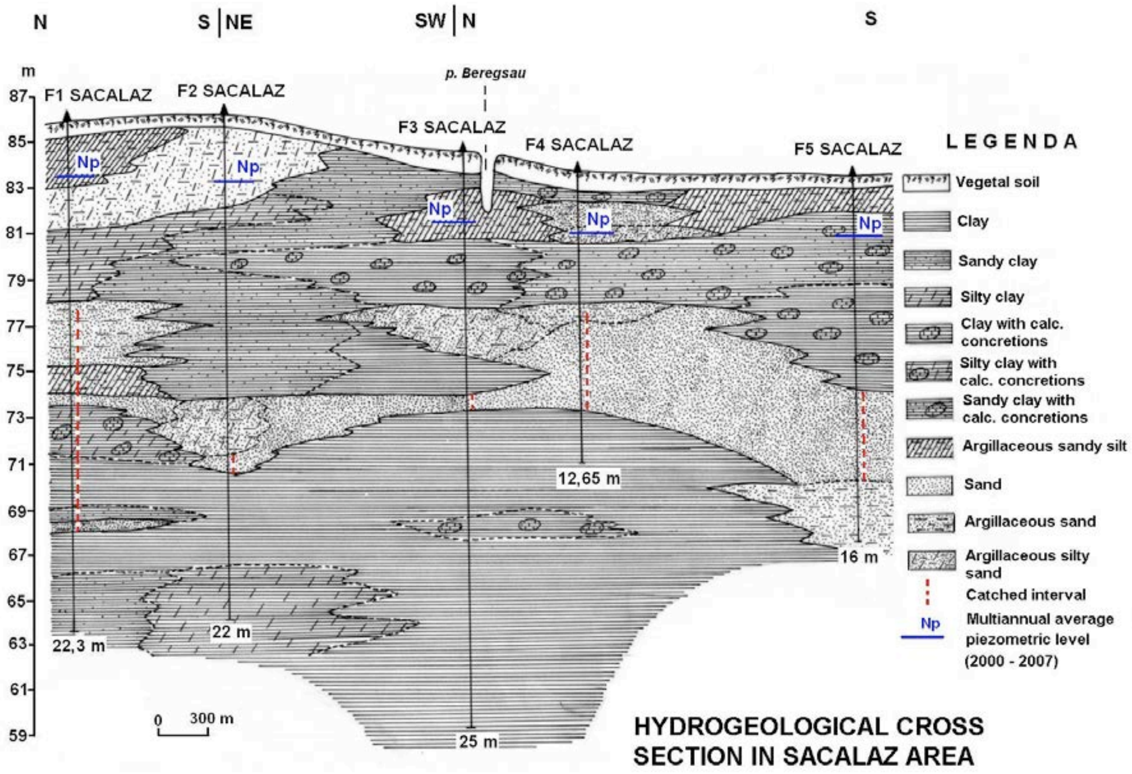

Figure 3 – Lithofacies variation of the alluvial – prolluvial deposits in the study area (Sacalaz area)

AQUIFERS ASSESSMENT VULNERABILITY TO POLLUTION USING THE DRASTIC METHOD

The DRASTIC method, developed by Aller et al. for the Environmental Protection Agency U.S. (EPA) in 1985 is a Point Count System Model, used to assess the groundwater vulnerability. The seven parameters used by this method to assess the intrinsic vulnerability are (their initials, in English, form the method name):

1. **D** (Depth to water)
2. **R** (net Recharge)
3. **A** (Aquifer)
4. **S** (Soil media)
5. **T** (Topography)

6. **I** (Impact of vadose zone)
7. **C** (hydraulic Conductivity)

The DRASTIC method assigns weights and rates to each of these parameters and calculates an overall index of vulnerability. The index of vulnerability is computed by applying the formula:

$DRASTIC_{index}$ = Dr*Dw + Rr*Rw+Ar*Aw+Sr*Sw+Tr*Tw+Ir*Iw+Cr*Cw (1)

- where r is the score of each parameter, and w is the weight value of each parameter.

To each parameter a value of r (rate) of 1 to 10 is assigned. The value of 1 corresponds to the low vulnerability and of 10 to the highest vulnerability. The rating values are multiplied by a string of weighing values of 1 to 5. The parameter with the highest influence will have the weight equal to 5 and the one showing the lowest influence will take the value of 1.

Using the DRASTIC index, distinct areas can be identified that are more susceptible to contamination than others. The maximum value of the index represents the highest vulnerability. To assess DRASTIC parameters, a raster format map showing each parameter contribution was created. In the subsequent step, each parameter was reclassified according to the standardized description of the DRASTIC method.

THE VULNERABILITY MAP

The vulnerability was calculated using the formula (1). The vulnerability values for the DRASTIC index are between 101 and 169.

After computing the vulnerability index (Figure 4), this layer was reclassified in three classes. The final map contains tree classes:

- Low vulnerability (index ranges between 101 and 107)
- Medium vulnerability (index ranges between 108 and 148)
- High vulnerability (index ranges between 149 and 169).

The distribution of the intrinsic aquifer vulnerability classes on the final vulnerability map is shown by Figure 4.

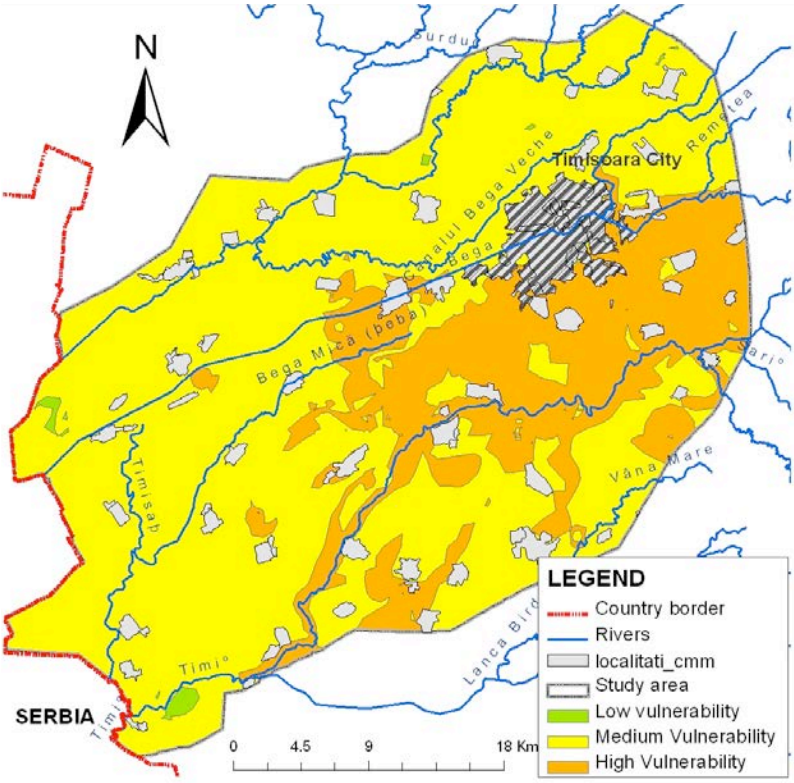

Fig.4 - Map of intrinsic vulnerability of groundwater

ASPECT OF CLIMATE CHANGE IMPACT ANALYSIS IN RELATION TO GROUNDWATER VULNERABILITY ASSESSMENT

The regional climatic conditions in terms of precipitation and temperature variation play a significant role for the groundwater. This may determine the rising of effective value of vulnerability due of the existing amount of precipitation that reaches the aquifer.

The influence of the climatic factors on the evaluation of the intrinsic vulnerability of the aquifer can be reflected in DRASTIC method by using the Net Recharge parameter (R).

Under a period of time showing drought, the aquifer recharge decreases. This may produce a decrease in vulnerability to contamination due to the fact that the possibility of penetration of potentially polluting substances in the aquifer area is lower. During periods showing an increased amount of rainfall, the aquifer vulnerability increases because of the amount of water that feeds the aquifer.

The DRASTIC vulnerability maps developed for different climate scenarios can highlight the distribution and the evolution of the areas showing different degrees of vulnerability depending on the chosen scenario.

Figure 4 shows the DRASTIC vulnerability map of the study area obtained when the *Net recharge* (R) parameter was considered for multi-annual rainfall of 580 mm in average. This produces an effective infiltration of about 80 mm, which corresponds to a period in terms of normal climate conditions.

To highlight the variation of vulnerability, a DRASTIC map was created (Figure 5) corresponding to a period of deficient rainfall (as for the year 2000) where the amount of annual rainfall is 280 mm. This corresponds to about 24.5 mm effective infiltration.

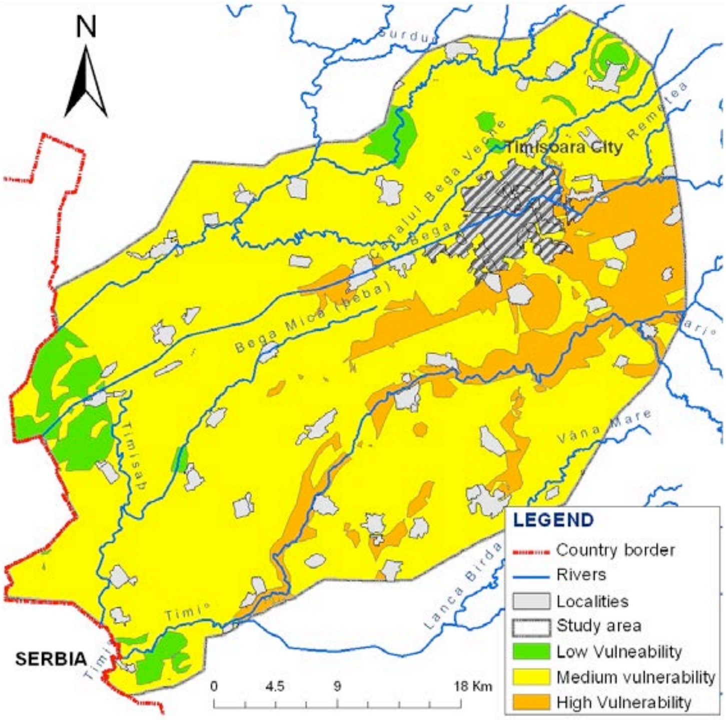

Figure 5 - Map of intrinsic vulnerability of groundwater when considering the rainfall deficit

The DRASTIC vulnerability map presented in Figure 6 corresponds to a period of excess rainfall (as for the year 2005). In this case the total annual precipitation rate is about 675 mm and corresponds to about 117.7 mm effective infiltration.

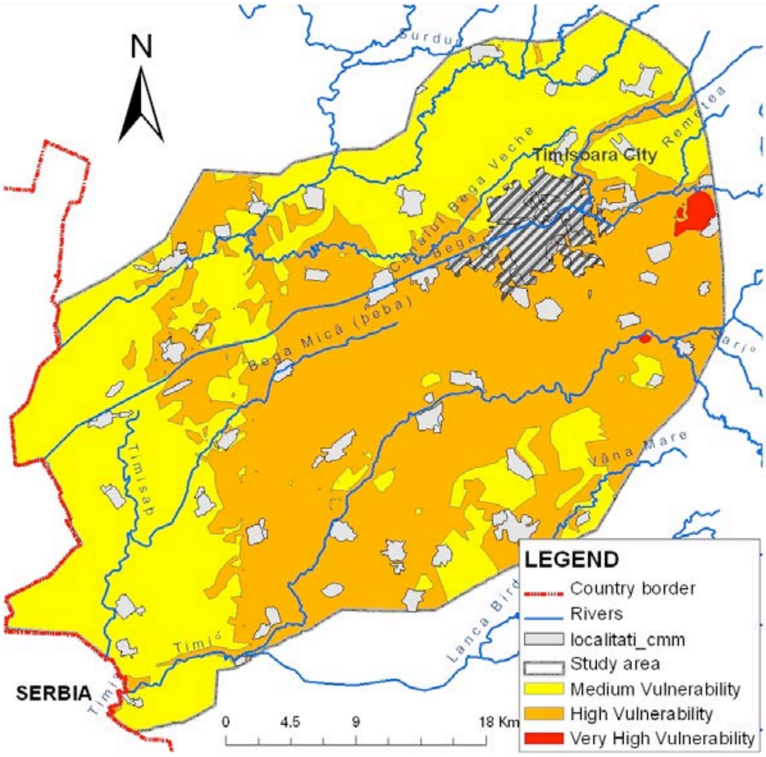

Fig.6 - Map of intrinsic vulnerability of groundwater corresponding to conditions of excess rainfall

From the analysis of the DRASTIC vulnerability maps reflecting distinct climatic conditions (as shown by Figures 4,5, and 6), the following observations can be made:

- during a period of low rainfall intensity (Figure 6), the vulnerability classes of the aquifer study area takes values of "low", "medium" and "high";
- the areas of "low" vulnerability show a relatively small percentage (4.7%). They are located in the extreme North, West and South-Western parts of the study area;
- the medium vulnerability shows a large extension with an average of about 85.4%;
- areas with high vulnerability, with a take about 13.9% and they are located in the central and south east part of the analyzed region. In the south part are located meadow and terraces of the Timis river;
- in conditions of a normal rainfall conditions (Figure 4), the vulnerability map maintained the same classes of vulnerability, however the vulnerability classes "low" (0.4%) and “moderate” (74.4%) decreases their expansion, in favor of the "high" vulnerability class (25.5%);
- the area of "high" vulnerability is extended to the west and to the north, occupying almost all the space between the Bega (north) and the Timis (south) rivers;
- during the periods showing excess rainfall (Figure 7), the areas of "low" vulnerability disappear and zones showing "very high" vulnerability appear in the eastern area. These last take an extension of 0.4% of the studied area.;

- in this last case (excess rainfall amount), the "medium" vulnerability area is reduced substantially to about 46.3% and the "high" vulnerability extends to 53.2%;

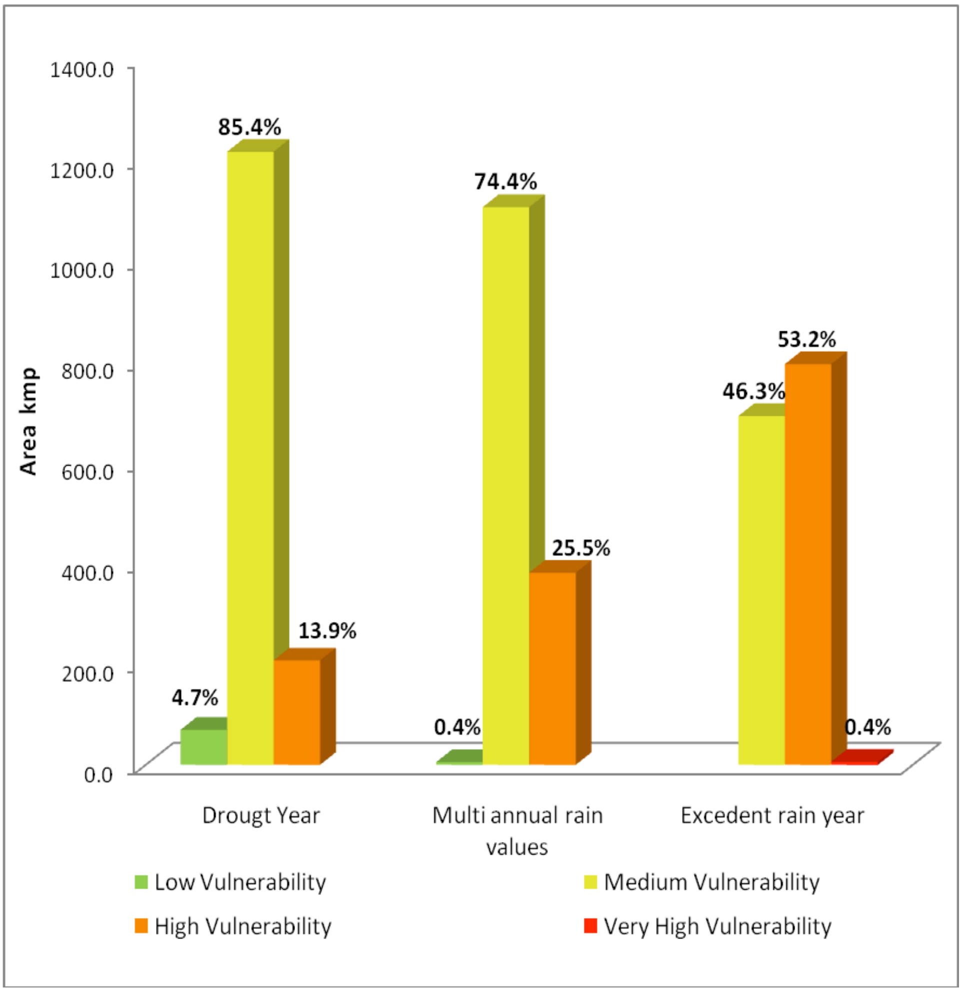

Figure 7 – Vulnerability classes for different types of climate conditions

The graph of Figure 7 shows the areas with different degrees of vulnerability depending on the above mentioned climate scenarios.

CONCLUSIONS

The DRASTIC method is a Point Count System Model. It uses seven parameters that are : **D** (Depth to water), **R** (net Recharge), **A** (Aquifer), **S** (Soil media), **T** (Topography), **I** (Impact of vadose zone) and **C** (hydraulic Conductivity).Within the ECAVAS project (Groundwater resources vulnerability assessment and mapping to assure their long-lasting use) the DRASTIC method has been applied for a pilot region focusing the upper aquifer (European groundwater body ROBA03).

To highlight the impact of the climate change on the groundwater vulnerability maps were made for different climatic conditions: normal conditions (medium annual rainfall), lack of rainfall and excess of rainfall. As rainfall amount has a direct influence on the aquifer recharge, the Net Recharge (R) parameter of the DRASTIC method has been used to simulate the influence on the aquifer vulnerability. Comparative analysis of the resulted maps is shown for the study area. The distribution of the different classes of vulnerability areas changes function off the weather conditions.

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