Groundwater protection: contribution from Italian experience

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Introduction

Italian water supply for human activities comes from groundwater in its significative part, especially the portion of it, which is used for civil activities, and just for reason it must have qualitative requirements to be drinkable (Figure 1). In this paper it is shown some information coming from:

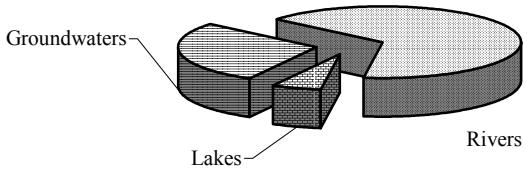

Figure 1

- the italian distribution of water resources;
- examples of large groundwater basin supplying human activities in the central Italy;
- the Italian legislative framework on groundwater protection;
- the most spread in Italy method for the evaluation of groundwater vulnerability with some examples of the application of it.

At the end some considerations are written down to point out the most important results of Italian experience in this field and some indications coming from them.

Water resources in Italy

As it is shown in the attached diagram, groundwater represent the 28% of the whole water resource used in Italy, where the average meteoric precipitation has been estimated to be about $2.96*10^5$ m^3/year (Figure 2).

The whole precipitation is divided in two parts: 44% of it comes back to atmosphere by evaporation, the 56% becomes the natural recharge of groundwater and it is about $1.65*10^{11}$ m^3/year.

Unfortunately only the 60% of this amount can be exploited. Referring to these data in Italy groundwater exploitation by wells involves 115 m^3/s, and it has been increased of 30%[1] (Figure 3). Unfortunately the geographic distribution of this exploitation is very different from the north to the south. As a matter of fact part of Italy suffers of a real over exploitation as it is easily imagined referring to figure 4, where they are represented the exploitations of groundwater resources versus the ones at disposal. The south of Italy is close to the 1 ratio between groundwater

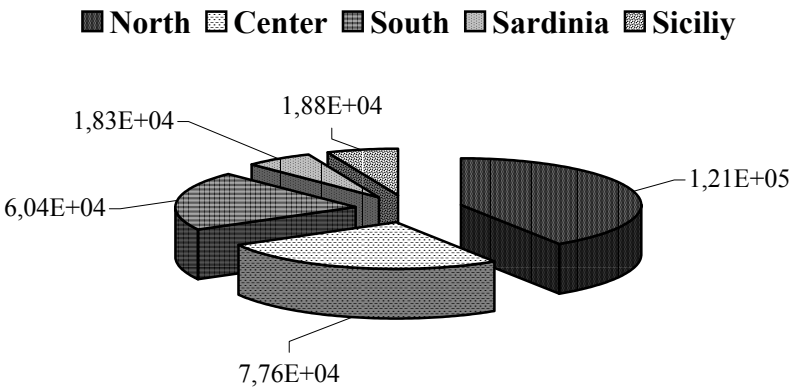

Figure 2. Precipitations (ANPA and CNR IRSA 1999)

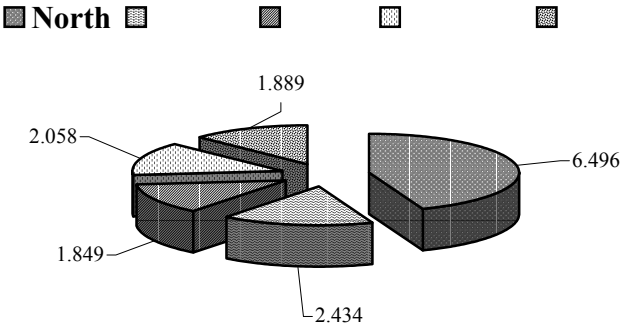

Figure 3. Groundwaters resources (ANPA and CNR IRSA 1999)

[1] Source Ministry of Environment (2001)

resources and exploitations, that it means that some parts of the south of Italy are in a real dewatering situation. As part of south Italian aquifers are coastal aquifers this fact takes to a growing up of seawater intrusion, which is much more difficult to be fighted by artificial recharge techniques.

On the other hand, groundwater feeds about the 75% of drinkable water all over Italy. In fact for instance, some of the most important water supply networks are fed by springs coming out from very large groundwater basin.

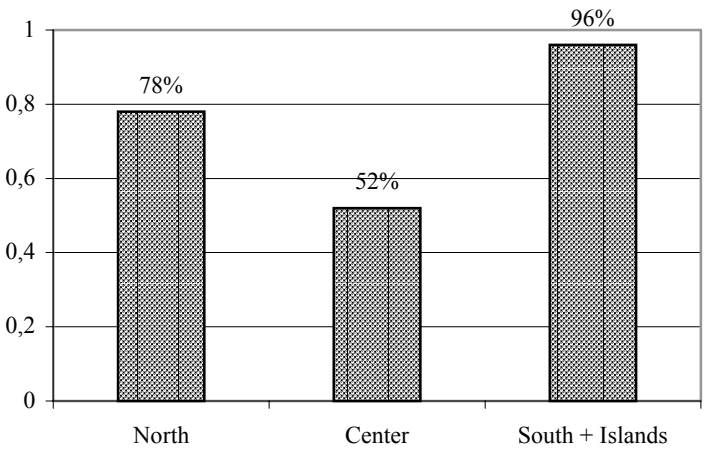

Figure 4. Groundwater resources as water resources

Some examples of significative aquifers in Central Italy

Italian geological framework has aided, in its evolution the outcropping of some important aquifers as in the Alpine chain as in the Appennines one. A s a matter of fact in the following they are presented some details about some Central Italy important aquifers, feeding important water supply networks.

Peschiera springs

The Peschiera springs group, sited in the central Appennines chain, come out at a distance of about 200 km in the north-east of Rome. Their very important groundwater basin is a carbonatic karstic aquifer outcropping at the boundary of Latium region with Abruzzi one. The average outflow of this group of springs is about 13 m^3/s, where the maximum is 16 m^3/s and the minimum is 9 m^3/s. They are the most important water resource for the water supply network of Rome, where they are served about 3.000.000 of inhabitants. The water supply network coming out from these springs feeds also the very popular roman public drinking fountains. In the last few years the groundwater catchment area of these springs have been processed by the aquifer vulnerability assessment method SINTACS, which will be presented in the following pages.

Virgin waters springs

These springs come out from a large volcanic aquifer outcropping at the south-east of the city of Rome. The aquifer has an area of about 112 Km^2, and its importance is related to its history (Figure 5). As a matter of fact since the ancient past these springs have fed the historical centre of Rome and, for instance, also the very famous Trevi fountaine. The total average flow coming out from these springs is about 2 m^3/s. Nowadays just in the aim to protect this groundwater resource it is exploited by wells (Sappa & alii, 1998).

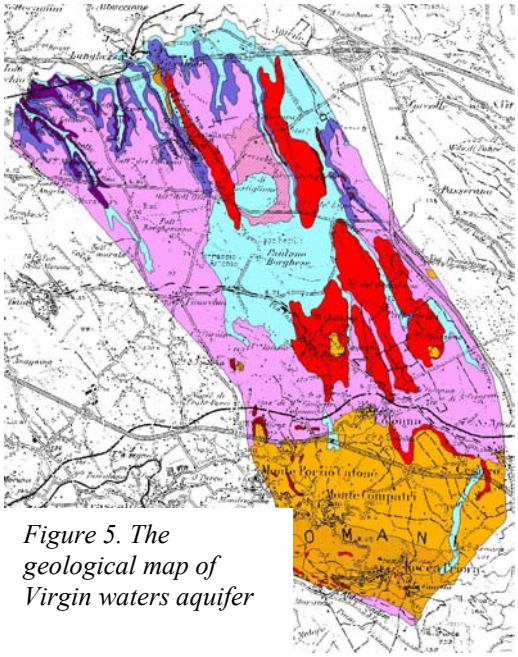

Figure 5. The geological map of Virgin waters aquifer

Sanità spring

On the other hand the Sanità spring, located in the Irpinia region, in the South of Italy, has an average outflow of 4.5 mc/s and it has been since the beginning of the last century (early twenties) the principal water resource for supplying waters in Apulia networks. Both of these groundwater resources belong to carbonatic aquifers, which are the 25% of the whole Italian water supply.

Groundwater protection legislative references

In Italy the importance of groundwater for supporting human activities has been understood from the ancient past, so there have been existed legislative rules about groundwater protection from the beginning of the last century. Actually in the past the concept of groundwater protection was usually taken in account only from a quantitative point of view. And this fact is quite easy to be understood, referring to the situation represented in figure 3. Only in the redent past groundwater protection policy has been carried on also in the target of a qualitative defence. Anyway in the following they are reported some abstracts, dealing with groundwater protection, coming from Italian main legislative rules on water resources management, which are:

- R.D. n. 1775/1933 - Dispositions on the waters and the electric plants
- L. n.129/1963 - Water networks masterplan
- L. n. 183/ 1989 - Rules for the organizational and functional rearrangement of the defense of the ground
- L. n. 36/ 1994- Rules on water resources
- D.L. n.152/ 1999 - Dispositions on the protection of the waters from the pollution and transfer of the directive 91/271/CEE referred to the urban waste waters' treatment and of the directive 91/676/CEE related to the protection of the waters

R.D. 11/12/1933 n.1775

Title II Special Rules On Groundwaters

Art. 92 - For the search, the extraction and the use of the groundwaters, except those thermal mineral and radioactive or however regulated by special laws, the following dispositions are observed as the norms of the title I of the present law are not applicable.

Italian legislation on groundwater protection

Law n.129/63:

Water networks masterplan

Art. 2. The masterplan has：

b) to verify the consistence of the various existing water resources or, correlatively, to point out what groups of water resources are, as a rule, to attribute to determined groups of inhabited areas in base to the criterion of the best correspondence of the first ones to satisfy the water restocking of the seconds;

Law, n. 183/ 1989

Rules for the organizational and functional rearrangement of the defense of the ground.

Art. 1-Targets of the law

1. The present law has for purpose to assure the defense of the ground, the waters' improvement, the fruition and the management of the water patrimony for the uses of rational economic and social development, the protection of the environmental aspects to them connected.

……..

Art. 3

h) the improvement of the superficial water and groundwater to the purpose to stop their degrade and making them conforming to the normative community and national, to assure their rational use for the demands of the feeding, of the productive uses, of the leisure time, of the recreation and of the tourism, through works of purification of the urban, industrial and agricultural effluentis and the definition of provisions for the transformation of the industrial productive cycles and the rational employment of fertilizers and pesticidi in agriculture;

……..

Art. 12- Authority of basin .....

1. In the basins is founded the Authority of basin, that operates in conformity to the objectives of the present law considering the basins themselves as unitary ecosystems.

2. They are organs of the Authority of basin:

a) the institutional committee;

b) the technical committee;

c) the general secretary and the technical-operational reception office.

Law, n. 36/ 1994- Rules on water resources

Art. 1 - Protection and use of the water resources

3) The uses of the waters are addressed to the saving and the renovation of the resources not to compromise the water patrimony, the suitability for human living and of the environment, the agriculture, the fauna and the flora aquatic, the geomorfological trials and the hydrogeological balance.

…….

Art. 3 - Equilibrium of the water budget
1. The authority of competent basin defines and periodically adjourns the direct water budget to assure the equilibrium between the availabilities of available resources in the area of reference and the requirements for different uses, in the respect of the criterions and the objectives of which to the articles 1 and 2.
2. To assure the equilibrium between resources and requirements, the Authority of competent basin adopts, for how much of competence, the measures for the planning of the in operation water economy of the uses which the resources are destined
……
HEAD II - INTEGRATED WATER SERVICE
Art. 8. - Territorial Organization of the integrated water service
1. The water services are reorganized on the base of optimal territorial circles delimited according to .....

D.L. of the 11/05/1999 n.152
Dispositions on the protection of the waters from the pollution and transfer of the directive 91/271/CEE referred to the urban waste waters' treatment e and of the directive 91/676/CEE related to the protection of the waters
Art. 21 - (Rule of the areas of safeguard of the superficial waters and groundwaters for the human consumption)
1.According to the suggestion of the authorities of circle, the Regions, to maintain and to improve the qualitative characteristics of the superficial and groundwaters for the human consumption …individualize the areas of safeguard lists in zones of absolute protection and zones of respect, as well as, inside the catchment basins and of the areas of recharge of the stratum, the zones of protection.
……
4. The zone of absolute protection is immediately constituted by the surrounding area the catchments or derivations; it has to have an extension, in case of groundwaters and, where possible for the superficial waters, of at least ten meters ray from the point of catchment, it has to adequately be protected and exclusively turned to catchment works or taken and to infrastructures of service.
5. The zone of respect is constituted by the portion of surrounding territory the zone of absolute guardianship to submit to ties and such destinations of use to qualitatively protect and quantitatively the gained water resource and it can be divided in zone of respect clasped and zone of respect widened in relationship to the typology of the work of water taking out .

As it is outlined in the previous rule extracts the protection of the groundwater water resources has been a very important target since the early sixties, when the main task was the quantitative protection of the resource. It looks like being interesting to stress that the fist time when it was introduced a concept of quantitative protection of groundwater, at the beginning of the last century, it happened inside a rule dealing with electric plants and, as a matter of fact, in the aim of protecting groundwater resource for hydroelectric exploitation. In 1963 the national law n. 129 introduced the concept of master plan for water supply, and divided Italy in different water districts, depending on administrative and historical properties, which were expected to set up a water needing and water feeding master plan, referred to each other territory, starting from the natural water resources budget. In the last period, from the ending eighties, the qualitative protection demand is coming up, and the Italian laws, which are referred to water resources and in particular to the protection as qualitative as quantitative of groundwater, are, in the whole, two: the 183/1989 and its modified edition of 1993 and the 152/1999, with its new edition numbered 258/2000. These second ones come directly from the most recent edition of the European Union Directive on Water resources management. It seems to be interesting to point out that one of the attachments to these latter law includes the prescription of processing aquifer vulnerability evaluation method to protect groundwater.

Groundwater protection: the aquifer vulnerability assessment

In the light of the Italian legislative recommendations, a project, addressed to study vulnerability of Aquifers, developed within the Research Line 4 of the Research Group for Defence against Hydrogeologic Disasters of the Italian National Research Council (CNR). The research activities carried out by the RL4 GNDCI-CNR began in 1987. The term of groundwater vulnerability to contamination draws its origin from the definition introduced in France by Margat & Albinet (1970): *Intrinsic vulnerability is defined as the likelihood of infiltration and spreading capacity of pollutants in aquifers, based on the type of surface geological deposits and hydrogeological conditions present* (Margat & Albinet, 1970). A definition of aquifer vulnerability proposed by Civita (1987) is the following: *Intrinsic or natural aquifer vulnerability is defined as the sensitivity of aquifer systems, in their different components and in the several, geometric and hydrodinamic settings, to swallow and spread , also mitigating the effects, a fluid or watertransported pollutant, in such a way to produce impact on the groundwater quality in space and time.*
The use of vulnerability cartography has been introduced with great success in territorial planning. Many Italian regions and provinces have carried out o are carrying out vulnerability maps.
Up till today, there are 135.000 km^2 of Italian surface covered with vulnerability maps at applicative scale. For this reason in the following it is briefly presented the most spreadfully Italian method, which is SINTACS.

Description of SINTACS

The acronym SINTACS comes from the names of the parameters taken into consideration (Civita & De Maio,1997), in intrinsic vulnerability assessment, which are presented in the following.

S*oggiacence - Depth to water* – It is the distance between the ground surface and the groundwater table level and it is very important in vulnerability assessment as its value, together with the unsaturated zone properties, influences the travel time of solid or fluid contaminants, which could be transported by water and the length of the attenuation process inside the unsaturated thickness (Figure 6).

I*nfiltration* - The effective infiltration plays a very significant role in aquifer vulnerability assessment, because of its dragging down surface pollutants and, on the other hand, their diluition at first during the travelling through the unsaturated zone and after within the saturated zone. Direct infiltration is the only, or widely prevalent component of net recharge in all the areas where there are no interflow aquifers linking to the surface water bodies and no irrigation practices, using large water volumes, are carried out (Figure 7).

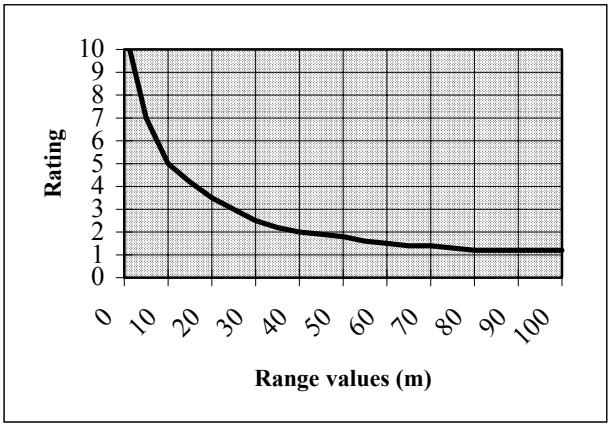

Figure 6. Range values and ratings of depth to water

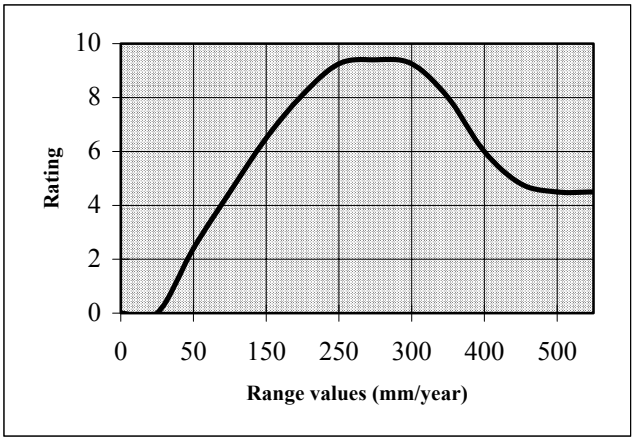

Figure 7. Infiltration range values and ratings

Attenuation effect of the ***N****on saturated zone* - It is the second layer of the hydrogeological system, which opposites itself to contaminants penetration in groundwater. Inside the unsaturated thickness, a four dimensions process takes place, as physical and chemical actions are involved in promoting the contaminant attenuation. The unsaturated zone attenuation capacity is assessed starting from the hydrolithologic features

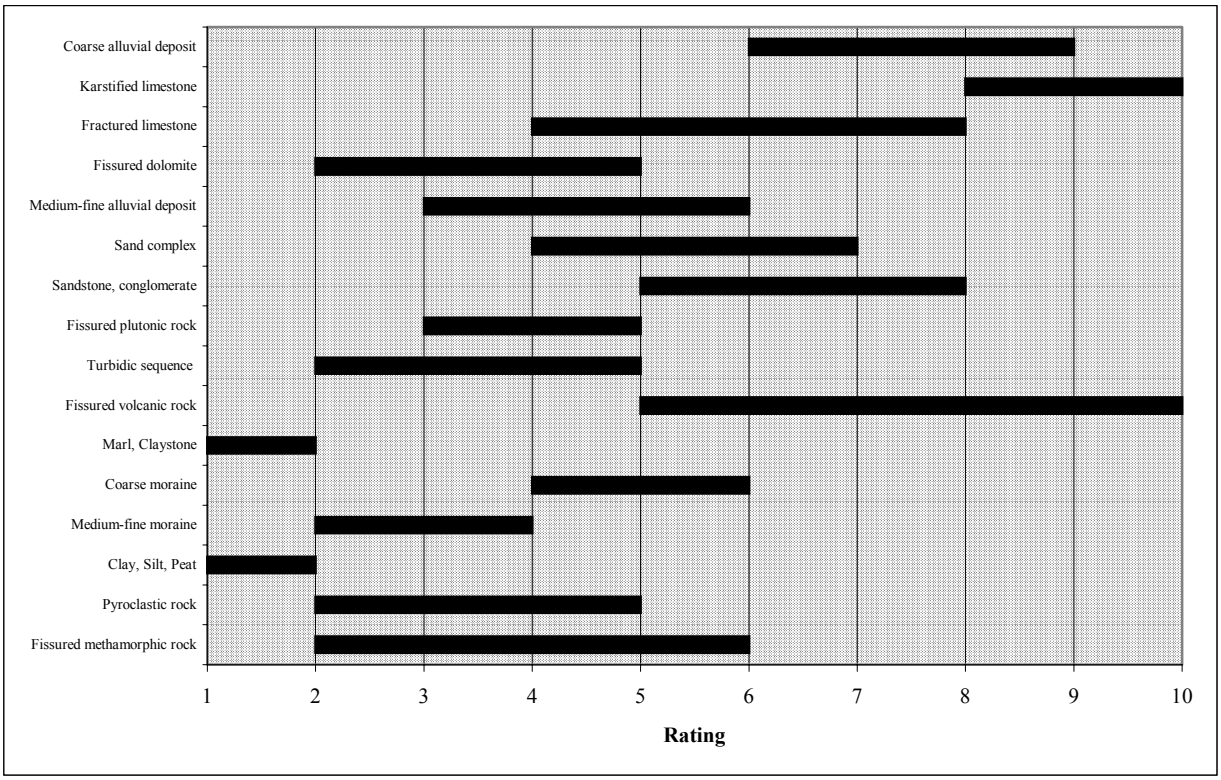

Figure 8. Unsaturated zone attenuation capacity

(texture, mineral composition, grain size, fracturing, karst development) (Figure 8).

***T**ypology of overburden* - Soil is the first defence line of the hydrogeologic system: several important processes take place inside the soil layer, which make up the attenuation capacity (Figure 9).

*Hydrogeological characteristics of the **A**quifer*- In vulnerability assessment methods the aquifers properties describe the process that take place below the piezometric level when a contaminant becomes mixed with groundwater after having lost a small or more relevant part of its original concentration while travelling through the soil and unsaturated thickness. These processes are basically: molecular and kinematic dispersion, dilution, sorption and chemical reactions between the rock and contaminants (Figure 10).

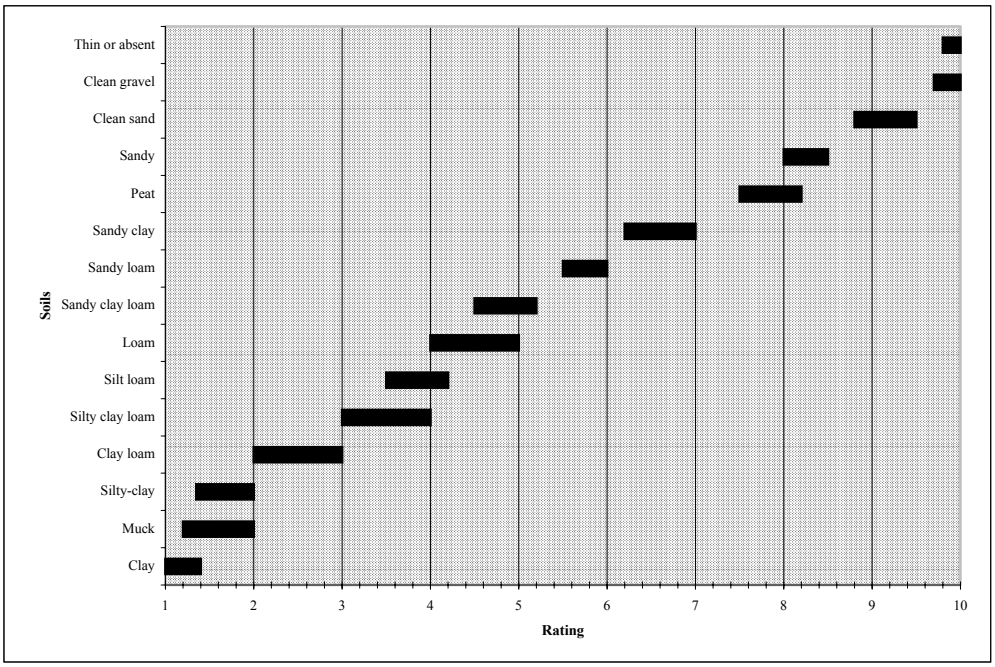

Figure 9. Overburden attenuation capacity

*Hydraulic **C**onductivity* – This parameter represents the groundwater mobility capacity inside a saturated media, thus the potential mobility of hydrocarried contaminant which has a density and viscosity that is almost the same as the groundwater. In the SINTACS assessment context, this parameter rules the hydraulic gradient and the groundwater flow cross sections being equal, the aquifer unit yield and flow velocity towards the outflowing and tapping works which give up exposition of risk targets (Figure 11).

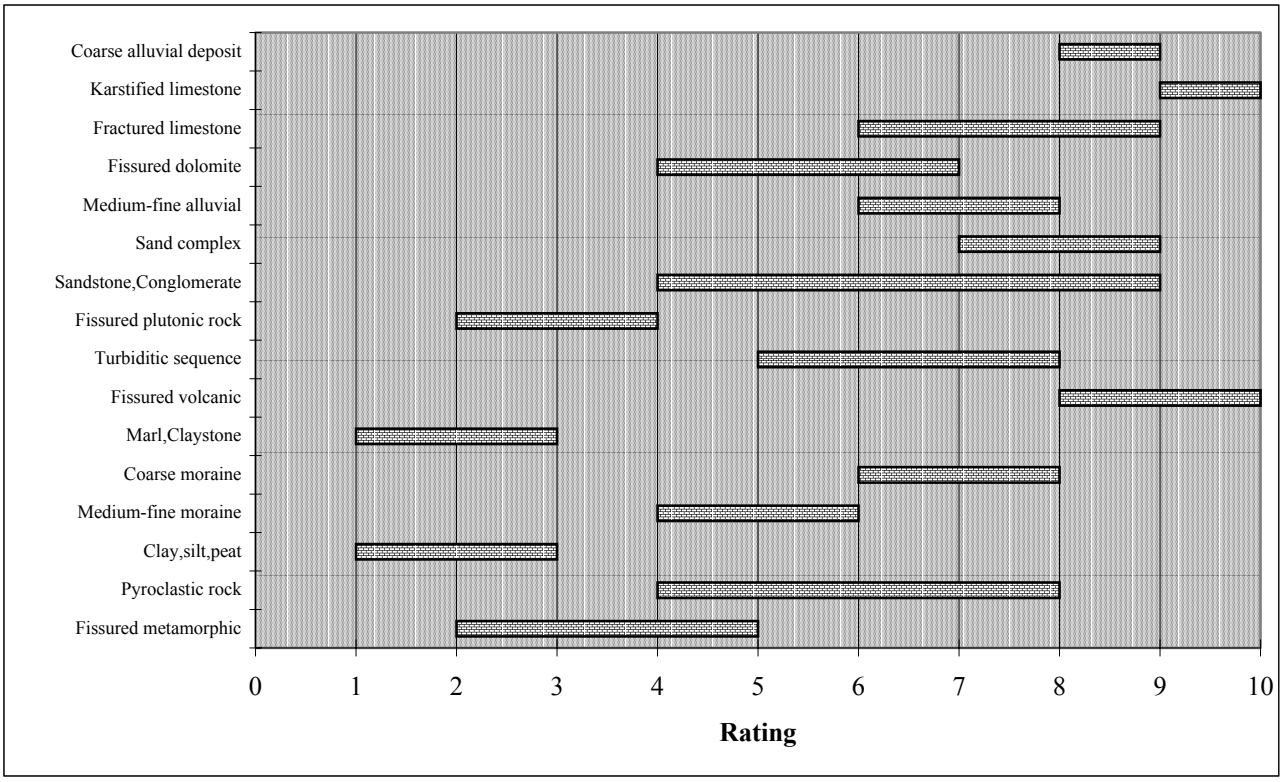

Figure 10. Hydrogeological characteristics of the aquifer

***S**lope of the topographic Surfaces* - It rules the amount of surface runoff produced, the precipitation rate and displacement velocity of the water over an equal surface. In practise, high rating is assigned to slight slope i.e. to surface zones where a contaminant may be less displaced under gravity action o slope or stop in the place of the outlet, supporting percolation. (Figure 12). Moreover the slope may be a genetic factor of the soil type and thickness that indirectly rules the attenuation potential of the hydrogeologic system (Civita & De Maio, 2000).
Each parameter is given a score, ranging from 1 and 10, according to the lithological, morphological, hydraulic, natural and biological characteristics of the area as well as the rock massives involved.

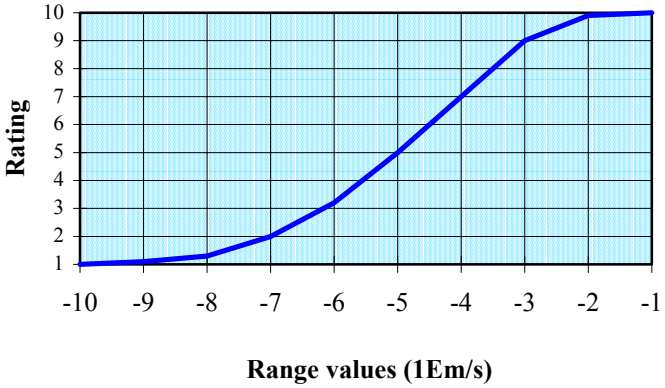

Figure 11. Hydraulic conductivity ratings

Figure 12. Slope ranges and ratings

The rating and its distribution outcome from the method validation, made on a few hundred test sites. The attribution of points is a function of the various situations present.
The area, under study, has to be divided into finite square elements (EFQ) of 250 to 1000 m per side. In order to represent the different influence each parameter covers in the various hydrogeological situations, SINTACS proposes five different strings, or rather, five different impact situations: each one matches a different hydrogeological scenarios (Figure 13).
The vulnerability index is given by the rating the seven parameters have in each cell multiplied for the choosen weights string. In fact one of the five described scenarios has to be identified and related string is assumed. According to this equation:

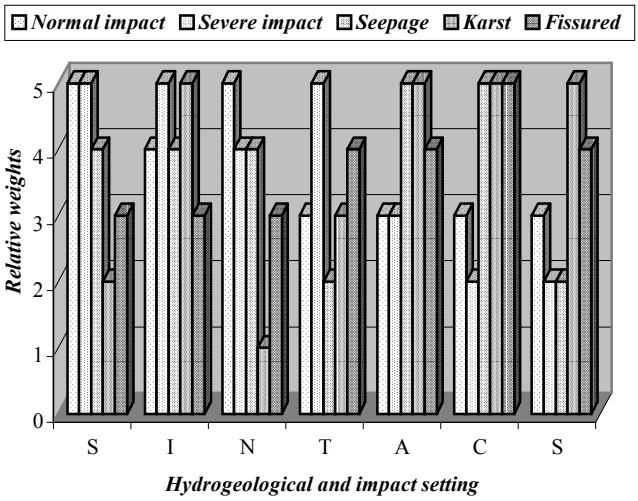

Figure 13. Hydrogeological scenarios

$$I_{SINTACS} = \sum_{J=1}^{7} P_J W_J$$

where P_j is the rating of each parameter and Wj is the weight of the choosen hydrogeological scenario. For every cell it is given in such way a final score ranging from 26 to 260.
The normalized diagram of the intrinsic vulnerability

degrees, is represented in the following (Figure 14).

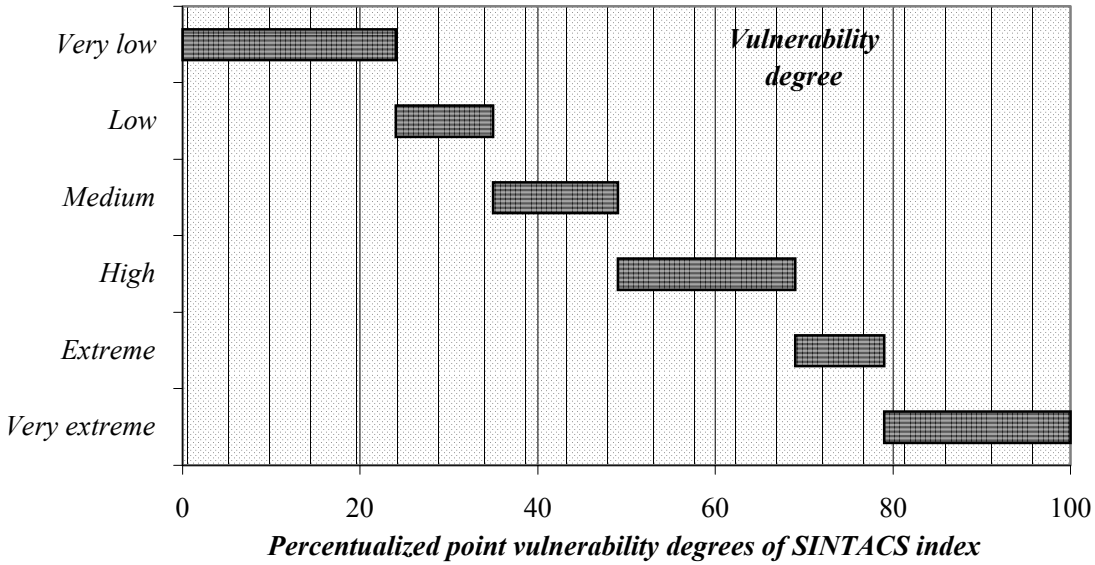

Figure 14

Examples

In the following they are presented two case-studies of aquifer vulnerability assessment carried on in groundwater basins in central Italy, which belong to carbonatic karstc aquifers. Their importance comes from their being protected by law, as they feed quite large civil water networks.

Maiella aquifer

The Maiella carbonate massif, situated in Central Italy, more exactly in the Abruzzi Apennines, covers a surface of 416 square km (Tulipano & alii, 2002). It represents an important groundwater basin in Italy, with the particular and distinctive features of a karst aquifer. In the following it is shown the vulnerability map, coming out from the SINTACS application (Figure 15).

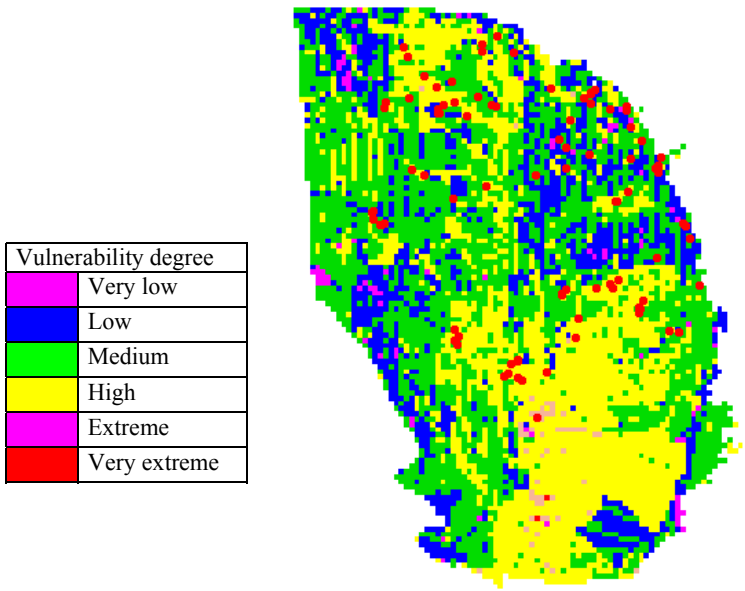

Figure 15. Maiella Intrinsic Vulnerability Map

Posta Fibreno Aquifer

It is one of the most important karst aquifers of the Central Italy, which occupies a south - eastern area of the "Alto Bacino del Liri" (Latium) (Coviello, 2001). This basin takes on a large scientific interest for its structural and hydrogeological complexity and, at the same time, it represents a strategical resource as it satisfies the drinking supply of a large area of the southern Latium, thanks to the remarkable recharge of its springs (Q > 500 l/sec) (Figure 16).

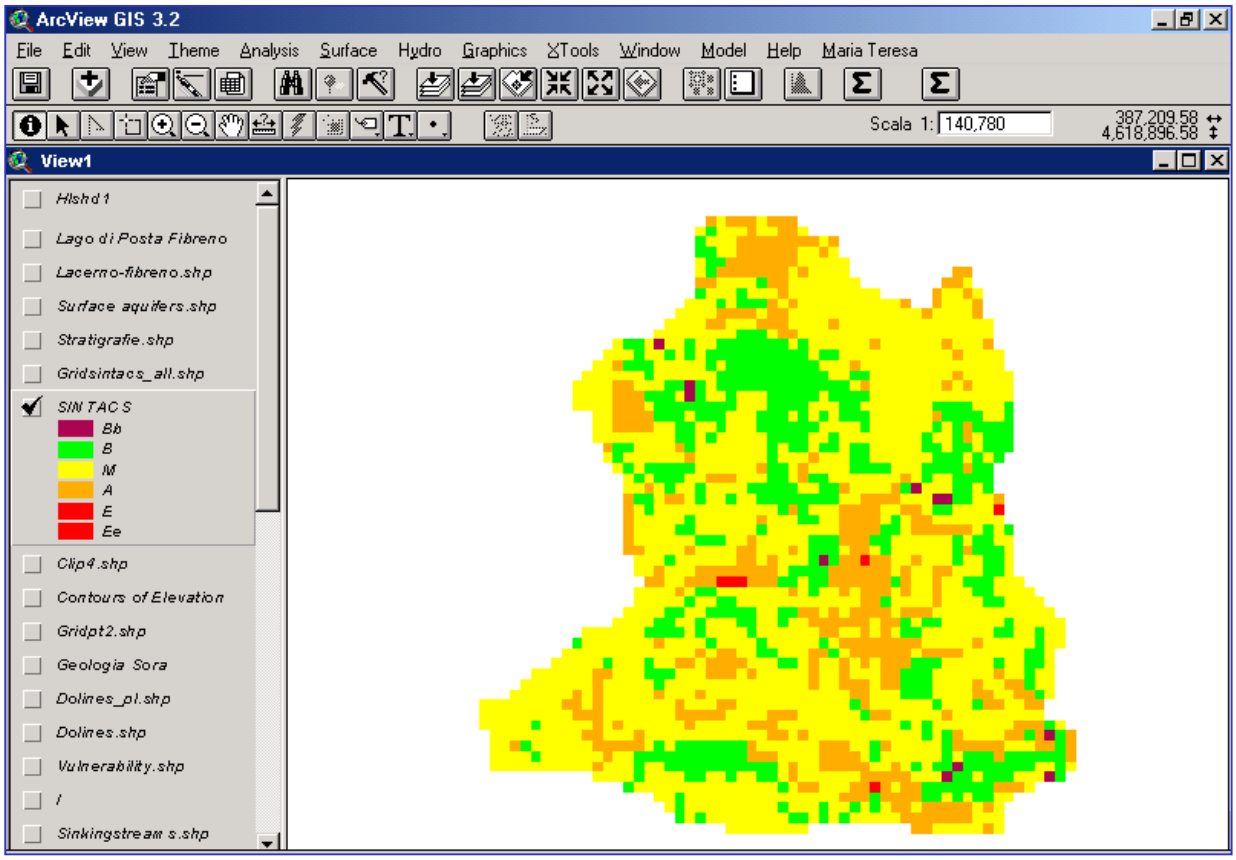

Figure 16. Posta Fibreno Intrinsic Vulnerability Map

Conclusions

The aquifer vulnerability assessment in Italy has been carried out with a large research programme as it has been referred to in the previous pages. In comparison with other european and american methods, SINTACS looks like a quite useful instrument for the groundwater and territory management. As a matter of fact it is not perfect and neither absolutely objective, but during these years it has been resulted as a tool with a good rate of confidence, as it has been tested on more than 200 sites. Looking at our experience, SINTACS looks like being very suitable to the land use planning as it makes it possible to compare different situations, belonging to different kinds of aquifer. Sometimes it seems to need too many pieces of information to be applied, and the job, we are doing to improve it, has the target to simplify the parameters involved in vulnerability evaluation of the aquifers, but it is not sure that, finally, we will succeed. This is the task of the team which is trying to set up the European approach.

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