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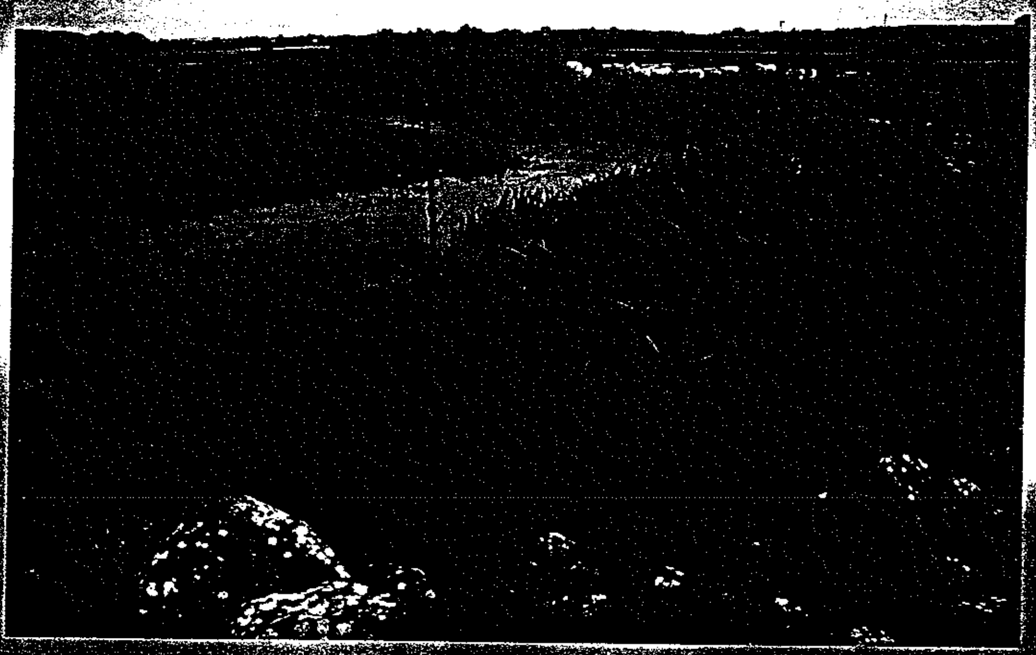
Environment

Vulnerability and risk mapping for the protection of carbonate (karst) aquifers



Final report

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boundaries as to match the local minima of the histogram. Although such a proceeding would render the results of different studies incomparable, it should be discussed as an alternative classification approach. In the present study, the histogram suggests class boundaries at PI = 1.2, 2.0, and 2.6 (Fig. 92).

There are many uncertainties associated with the results, some of which are due to the local conditions, while others are methodical. Despite the regression approach, the protective function of the Cretaceous sediments still remains an important factor of uncertainty. Some of the dry valley troughs have sinks, which makes it difficult to delineate the ponor catchments. Since the vulnerability concept is not based on physical-mathematical process descriptions, the relative importance of infiltration and surface runoff, as expressed by the choice of an I factor value, cannot easily be justified without hydrologic modeling.

2.7.4 References

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2.8 Néblon basin, Belgium

– Intrinsic vulnerability mapping using the PI method

2.8.1 General

The Néblon basin is located in Belgium in the region of Condroz (Fig. 55). Geologically, it belongs to the part of Devonian Carboniferous pleats formations of the eastern edge of the Dinant synclinorium that crosses Belgium from West to East. This region is characterised by typical alternation of shales and sandstones anticline crests (Upper Devonien or Famennian) and calcareous syncline depressions (Lower Carboniferous or Dinatien) (Fig. 93). The geological formations are made of terrigeneous detrical facies of Famennian age, carbonated rocks of carboniferous and terrigeneous detrical sediments of Namurian age. Locally, ancient paleokarsts are filled by Tertiary sandy clay sediments. The region is also covered with loess formation.

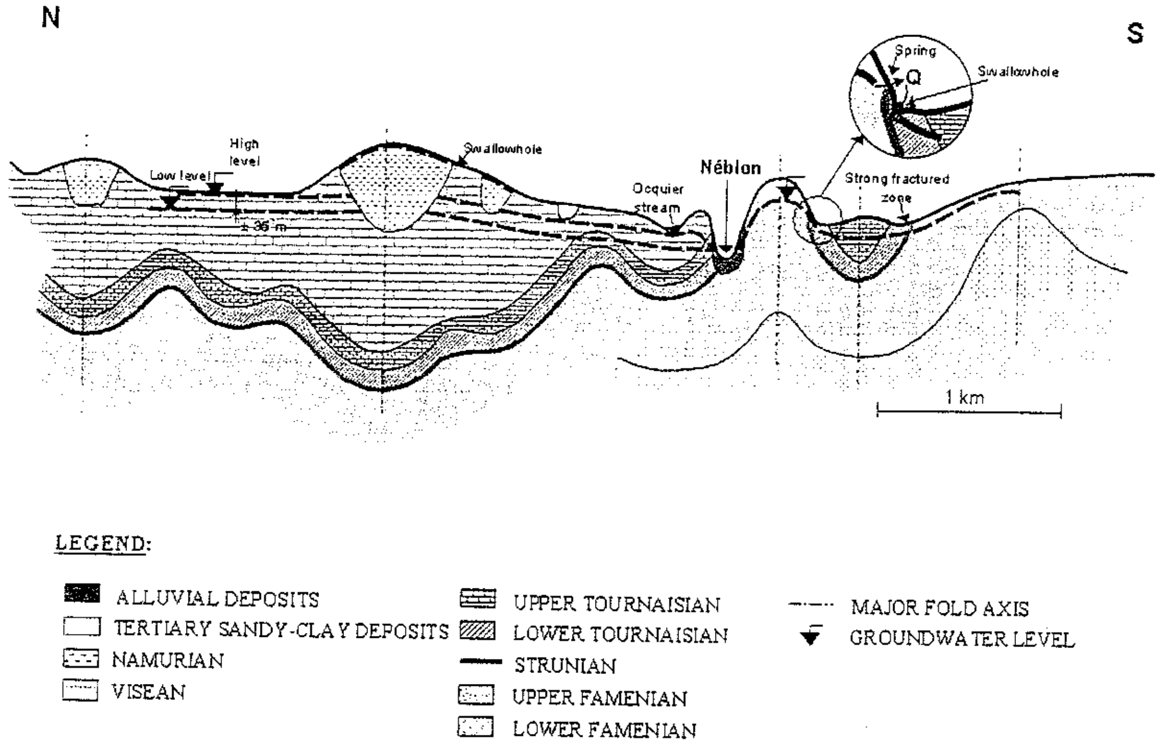

Fig. 93: Schematic N-S geological and hydrogeological cross-section in the Néblon basin (Derouane et al. 1995, Gogu 2000).

2.8.2 Geological characteristics of the investigated area

The region is intensively faulted and the main structural features can be classed in three groups:

- thrust longitudinal faults and fractures, oriented E-W, gently dipping to the S
- transverse faults , oriented NNW-SSE to N-S
- oblique faults, oriented NE-SW.

Some of the intensively faulted zones correspond to dry valleys that are supposed to facilitate groundwater drainage to the Néblon River.

In the southern part, a boundary of the basin consists in shaly formations of a Famennian anticline. The northern, eastern and western limits are located mostly in the Visean limestones. Each of these boundaries corresponds to a groundwater divide between the studied Néblon basin and two other neighbour basins. Consequently, these limits can show large spatial and time variations.

Three aquifers can be distinguished:

- the karstic aquifer in Visean and Tournaisian limestones and dolomites, exploited by the local water company CILE (Compagnie Intercommunale Liègeoise des Eaux);
- the faulted sandstone aquifer in the Upper Famennian;
- locally, the perched aquifer in the Namurian faulted sandstone.

The basin is moderately karstified. Several karstic features can be identified: a couple of dolines, dry valleys, three major swallowholes and a few resurgences (Fig. 94). A few undeveloped karstic caves are also noticed along the cliffs in the Néblon valley as well as some dolines.

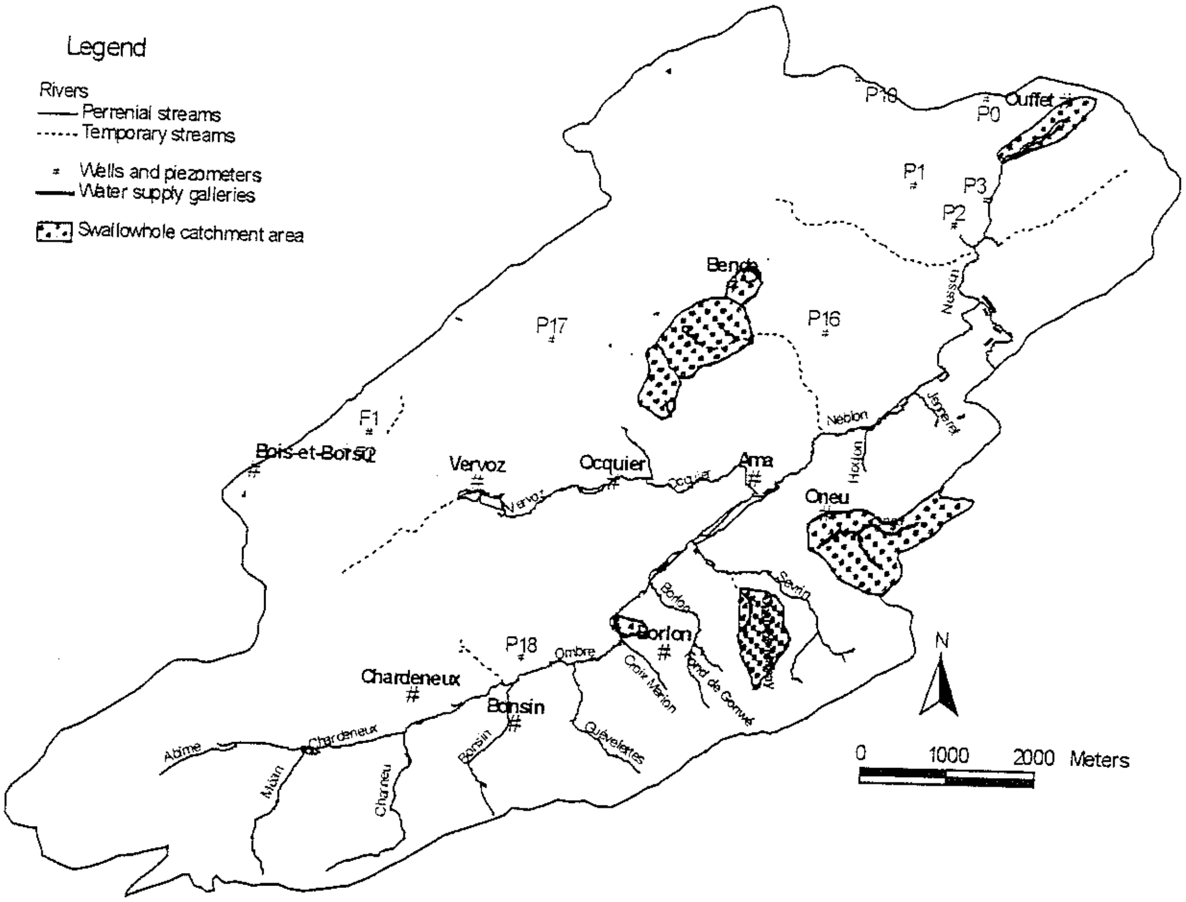

Fig. 94. Map of the basin, hydrologic network, piezometers, swallow holes and sub-basins feeding the swallow holes (Gogu 2000).

2.8.3 Vulnerability mapping using the PI method

2.8.3.1 Determination of the P parameter

Topsoil – T: The different types of soil are clayed silts, silty clays, silts, silty loams, sandy loams, silty sands, silty loamy sands, and sandy silts. In PI, the topsoil parameter must be quantified taking account the effective field capacity (mm/dm). In Germany, this parameter can be derived using the standard tables of the German Pedological Handbook (AG Bodenkunde, 1982). Then the effective field capacity is multiplied by the thickness of the soil horizon. The far more detailed Belgian soil map was used here and correspondences with the German classification had to be studied accurately. The result parameter is almost constant on the area except where the soil is significantly less thick.

Subsoil – S: The parameter is quantified taking account of the lithology of the subsoil horizon. In our case, the non-consolidated lithology is made of alluvial sediments, loess and sand-clay sediments. The thickness of these sediments is estimated on basis of precedents studies (Di Clemente and Laurent, 1986, CILE – LGIH - INIEX Report, 1986, Hallet et al, 2000).

Lithology – L: Most of the different lithologies are foreseen in the method tables. For few geological units, the indexation must be adapted. The thickness of the different units take the topographic elevation and the position of the piezometric heads into account. The thickness is reduced in the perched Namurian aquifer.

Fracturation – F: In the limestones, several zones were distinguished:

- limestones with strongly developed epikarst and showing swallowholes and dolines;
- limestones strongly fractured or strongly karstified (e.g. dry valleys);
- limestones moderately fractured or karstified

Other lithologies were supposed to have a "slightly jointed" structure

Recharge – R: The parameter was quantified on the basis of previous balance studies. Different zones can be distinguished with the recharge respectively estimated as entering into three classes: 300-400mm/y, 200-300 mm/y, 100-200 mm/y.

The P parameter is obtained combining the previous described parameters (Goldscheider et al. 2000 and chapter on the PI method in this report). The map (Fig. 95) shows that the protection is higher on the Famennian and Strunian shales and sandstones while the limestones have mostly a moderate protection.

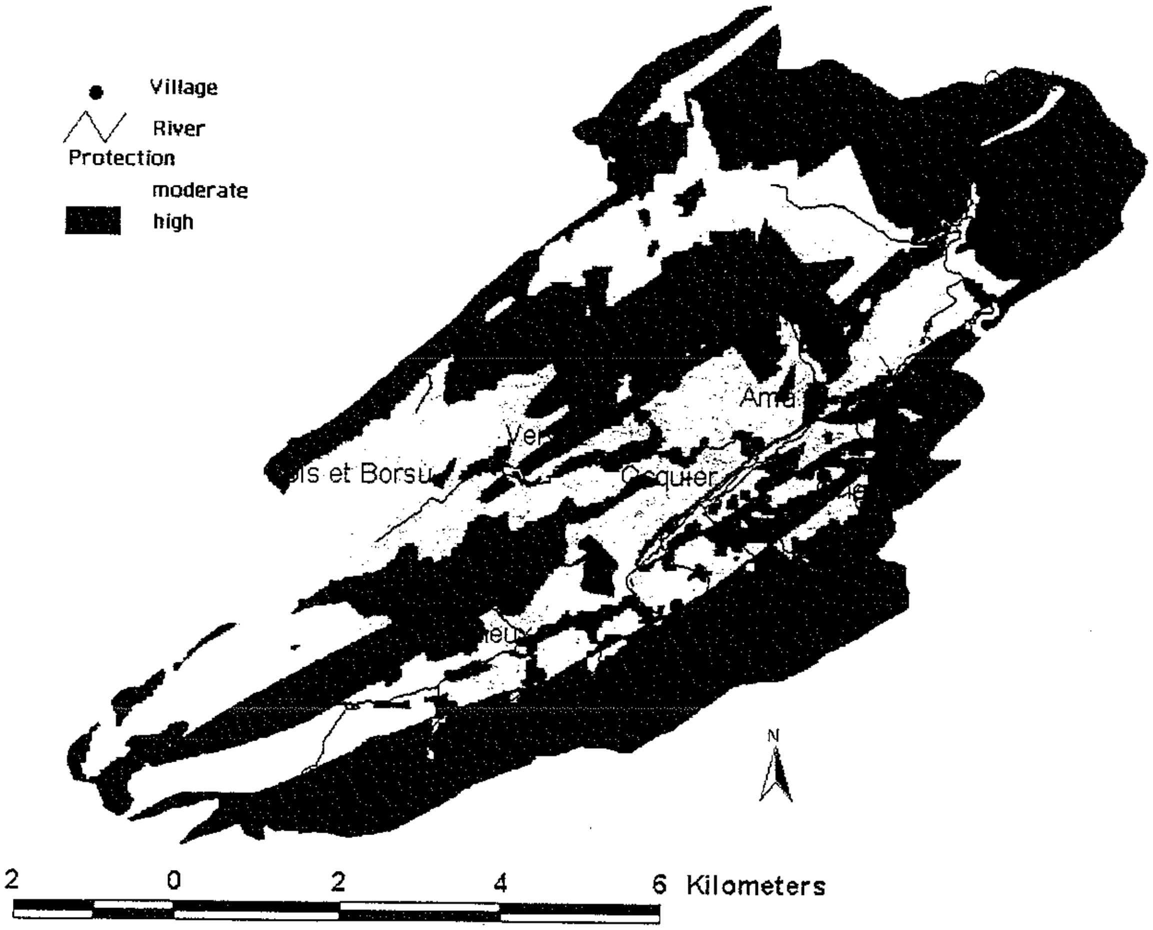

Fig. 95: Map of the parameter P of the PI method.

2.8.3.2 Determination of the I parameter

The dominant flow process is assessed on the basis of the topsoil permeability and the presence of low permeability layers. Permeability of the topsoil has been estimated on the basis of saturated hydraulic conductivity tables as proposed by Mermoud (1998).

The I' parameter is assessed by intersecting the coverages of dominant flow process, the vegetation and the slope gradient. On the basis of the landuse map, it can be noticed that ~24% of the area is covered with forest, while almost 76% represent fields,meadows and pastures. The slope gradient is calculated on the basis of a DTM with 30m pixels. The more important gradient corresponds to cliffs along the Néblon river. The lowest gradient is generally situated in the northern and eastern part of the basin.

The I map (Fig. 96) is obtained by intersecting the I' map and the surface catchment map. This one is created on the basis on a digital map containing all the swallowholes and the sinking streams. The 10 m and 100 m "buffer zones" around these features are introduced. The map shows that flow components which bypass the protective cover have to be expected in the catchment areas of the swallow-holes and sinking streams and mostly in the central zone, while protective cover is not likely to be bypassed in the N-W part of the investigated area. A large impact of the slopes must be noticed: the map is parcelled out according to this factor.

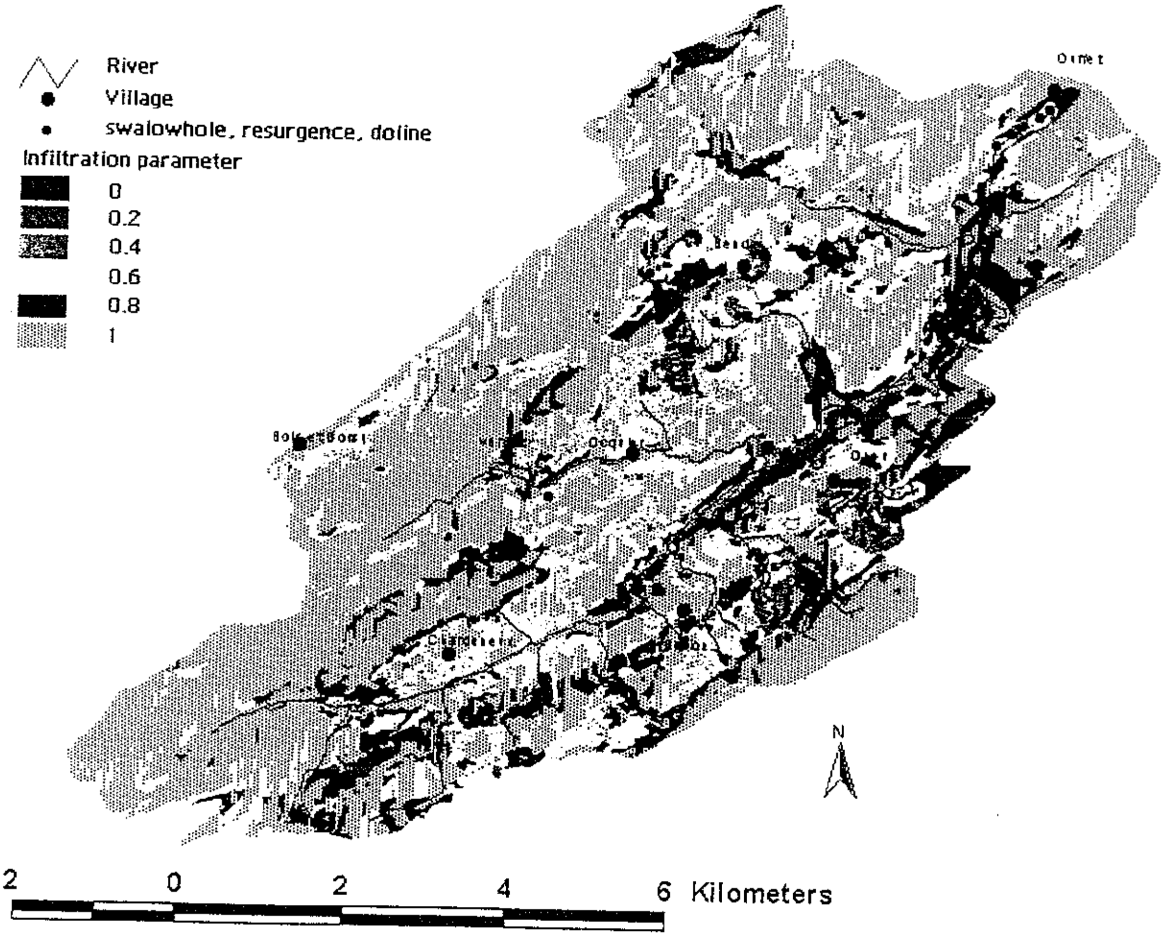

Fig. 96: Map of the parameter I of the PI method.

2.8.3.3 The PI vulnerability map

The PI vulnerability map (Fig. 97) is obtained by intersecting the P map with the I map. The most vulnerable zones are located near the swallow-holes (100 m). The slope impact must be noticed: for geological formations with the same characteristics, the greater the slopes gradient, the more vulnerable the formation appears. The vulnerability of geological formations classed as strongly fractured is moderate to high. The dolines are mapped in the more vulnerable zones. The PI map is so parcelled out that its application for land-use management seems to be questionable.

A sensitivity analysis was performed showing the importance of having a good knowledge of topography, with a detailed DTM. In a gently hilly country as the Néblon basin, the parcelling out seems inevitable. These observations are valid only if the slope computation accuracy is acceptable. This reliability depends on the DTM uncertainty and the size of the pixels. In this case, the level error between two successive pixels is estimated at 1 m maximum.

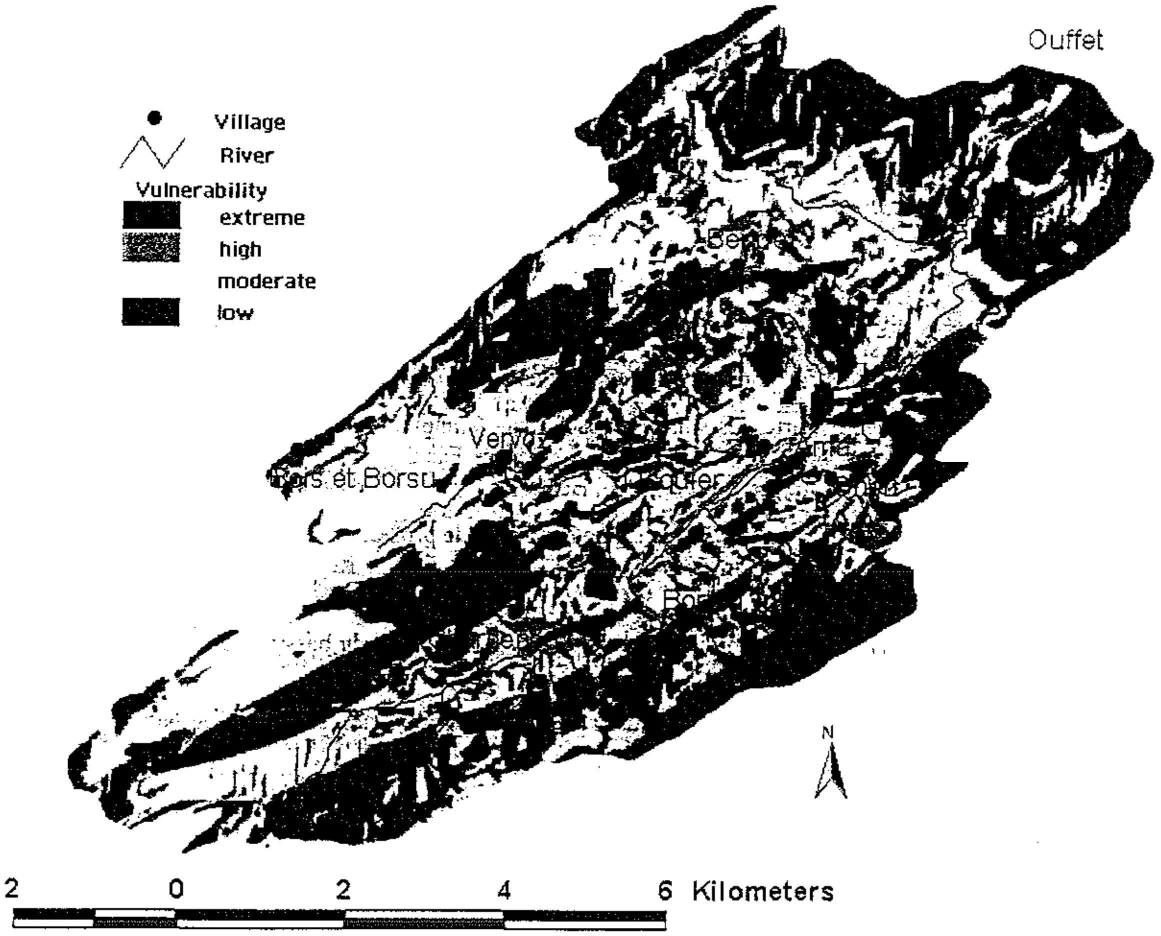

Fig. 97: Vulnerability map according to the PI method.

Five methods were applied on Néblon before applying the PI method: Gaule (1998) applied EPIK and Gogu (2000) applied GOD, ISIS, DRASTIC, EPIK and the German method and compared the results (Gogu & Dassargues, 2001).

For the limestone aquifer, results of Intrinsic Vulnerability as assessed by different methods can be summarized as follows:

- high or very high vulnerable according to GOD, ISIS and the German method;

- moderate to high vulnerable according to PI
- moderate vulnerable according to DRASTIC and EPIK;

As presented before, in the Néblon basin the limestone aquifer is in connexion with other aquifers (sandstone, silty-sandstone), there are also Tertiary and Quaternary deposits. As the PI method is applicable for all types of aquifers, but with special consideration of karst, despite of a real validation possibility, the obtained map seems to better reflect the conditions of the Néblon basin.

The results show that all those tested vulnerability methods, including PI method, remain highly subjective. They can be used as rough screening tools but unfortunately they cannot be validated, as the combination of their parameters is still empirical. In the future, a more physical point of view (see Brouyère, this report) must be adopted for obtaining "physically consistent" results.

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2.9 The Albiztur Karst Unit, Basque Country, Spain

– Comparative application of the European Approach (in this case the PI method) and the EPIK method of intrinsic vulnerability mapping –

2.9.1 General

The Albiztur Karst Unit (27 km^2) is formed by Urgonian limestones (Salubita System, 21 km^2) and by Jurassic carbonate rocks (location see Fig. 55). The Salubita spring is the main point of discharge and its mean yearly discharge is 670 l/s. The intrinsic resource vulnerability has been estimated using two methods: EPIK and the European Approach. Only the factors O (overlying layers) and C (concentration of flow) were taken into consideration. The European Approach is a conceptual model for vulnerability mapping but does not prescribe detailed assessment schemes. Thus, the tables from the PI method (Goldscheider et al., 2000) were used to determining the factors O and C (which are called P and I in the PI method).

2.9.2 Geology and geomorphology of the survey area

Most of the pervious rocks in the catchment are Urgonian, represented by sandy and massive limestones with a maximum depth of 700 m. In the southern part, sandy and clayey materials appear and they are in contact with an important fault (Azkoitia, Fig. 98). The Errezil Fault is the northern limit of the catchment. On the carbonate rocks, very important karstic depressions are present (Fig. 98), some of wich are filled with Quaternary detritic materials.