

ADAPTATION AND APPLICATION OF THE PAN-EUROPEAN APPROACH TO GROUNDWATER VULNERABILITY MAPPING TO THE SON LA KARST AREA, VIETNAM

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Abstract. A groundwater vulnerability map was prepared for the Son La karst area, Vietnam, using an approach developed by the European COST action 620 on 'vulnerability and risk mapping for the protection of carbonate (karst) areas'. It was necessary to adapt this approach to the local hydrogeological, climatic and economic conditions. The modified (simplified) method is proposed for vulnerability mapping in other Vietnamese karst areas.

Keywords: vulnerability, groundwater, Vietnam.

1 Introduction

In Vietnam, there are a variety of tropical karst landscapes, which cover almost 20 % of the land surface. The karst area in NW Vietnam is 8190 km² large and holds important groundwater resources that are crucial for the economic development of the region (Tuyet, 1998).

Karst aquifers are particularly vulnerable to contamination. Due to thin soils and swallow holes, contaminants can easily reach the aquifer, where they are transported rapidly over large distances. Karst groundwater thus needs special protection. However, it is not practical to demand maximum protection for large areas, as the resulting land-use restrictions would not be acceptable. Groundwater vulnerability maps may help to find a balance between groundwater protection and socio-economic aspects.

The European COST Action 620 proposed an approach to vulnerability and risk mapping for the protection of karst aquifers (Zwahlen, 2004). This approach was developed by European scientists having in mind the hydrogeological conditions and data availability in their countries. In order to apply this approach to Vietnamese karst areas, it was necessary to adapt it to the local conditions. This paper outlines the conceptual framework of groundwater vulnerability mapping, and

describes how it was adapted and applied to the Son La karst area.

2 The Son La karst area

The test site is the catchment of the Tham Ta Toong spring, which contributes 50 % to the drinking water supply of Son La town, NW Vietnam (Fig.1). The area is 68 km² large and 600 to 1700 m high. Karst landforms comprise chains of peak-clusters, dolines, dry valleys and caves. The mean annual precipitation is 1413 mm, with a rainy season in summer, and the mean air temperature is 21 °C (Nguyet, 2000). Late Precambrian to Triassic rocks outcrop in the area, including three limestone formations (Dong Giao, Ban Pap, Chieng Pac), claystone, sandstone, basalt and tuff (Tuyet, 1998). Quaternary deposits cover the valleys.

The limestones are covered by shallow soils and drain underground, while surface flow frequently occurs on non-karst formations. Surface streams often sink underground via swallow holes and caves, some of which were explored within the framework of the Vietnamese-Belgian Karst Project (Dusaar *et al.*, 1994). Speleological data suggest connection between the swallow holes and the spring, which has not yet been proved by means of tracer tests.

3 Groundwater vulnerability mapping

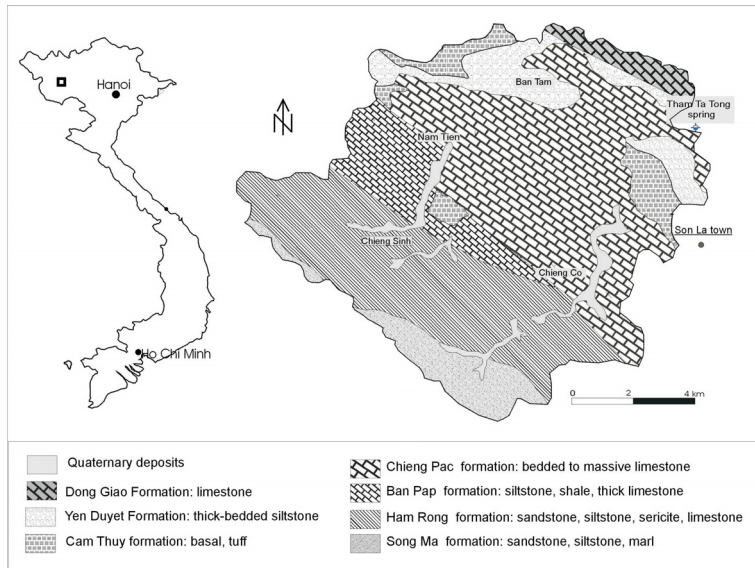


Fig. 1: Location (black rectangle), geology and hydrology of the Son La test site.

3.1 The pan-European approach (COST 620)

The terms ‘vulnerability of groundwater to contamination’ and ‘natural protection against contamination’ can be used alternatively (low protection = high vulnerability). Intrinsic vulnerability takes into account the hydrogeological characteristics of an area, but is independent of the nature of the contaminants; specific vulnerability additionally considers contaminant properties. There are two general approaches to groundwater protection: Resource and source protection. Vulnerability assessment is based on an origin-pathway-target model. The origin is the location of potential contaminant release. The pathway includes the passage from the origin to the target. Resource vulnerability maps take the groundwater surface as the target, and the pathway consists of the passage through the unsaturated zone. For source vulnerability mapping, the well or spring is the target. Two main aspects are to be considered when assessing vulnerability: travel time and attenuation. The pan-European approach to intrinsic vulnerability mapping uses four factors that influence travel time and attenuation: overlying layers (O), flow concentration (C), karst network development (K), and precipitation regime (P) (Fig. 2) (Goldscheider and Popescu, 2004).

The overlying layers consist of four types of layers: topsoil, subsoil, non-karst rock, and unsaturated karst rock. These layers provide some degree of natural protection, dependent

on their thickness and properties. Concentration of flow in the catchment of sinking streams may bypass the overlying layers. Groundwater resource vulnerability maps can be created by a combination of the O and C factor. The P factor is relevant when comparing different climatic zones, and the K factor applies for source vulnerability mapping.

3.2 Local adaptation of the method

The modified method of intrinsic resource vulnerability mapping uses two factors: overlying layers (O) and flow concentration (C) (Fig. 3). The assessment scheme for the O factor is simple: A low protective function is

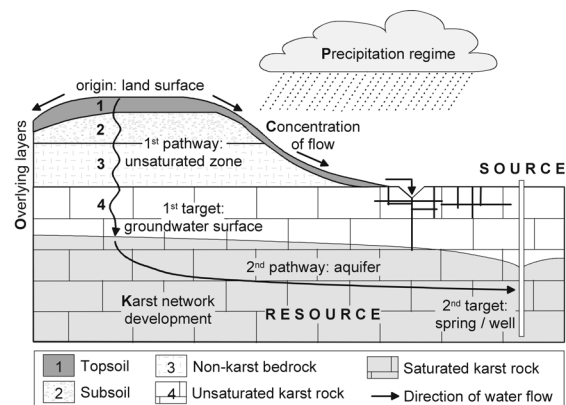


Fig. 2: The COST 620 methodology is based on an origin-pathway-target model. For resource protection, the groundwater surface is the target. Vulnerability assessment uses up to four factors: Precipitation regime, Overlying layers, Concentration of flow, Karst network development (Goldscheider and Popescu, 2004).

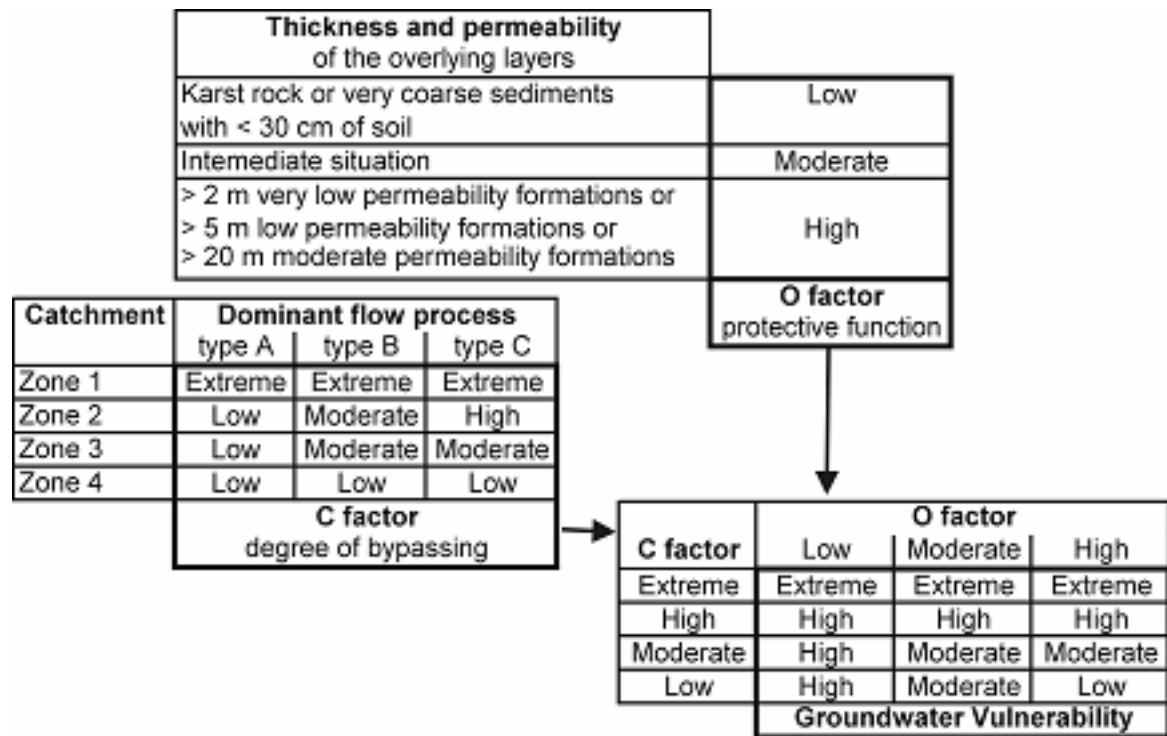


Fig. 3: Proposed simple method of groundwater resource vulnerability mapping for Vietnamese karst areas.

assigned to karst rock covered by less than 30 cm of soil. Sufficiently thick layers of limited permeability provide high natural protection. Moderate protection is assigned to intermediate situations, e.g. 1 m of soil overlying karst.

The C factor expresses the degree to which the overlying layers are bypassed by flow concentration in the catchments of swallow holes. The first step is to determine the dominant flow process (after Goldscheider, 2002):

- Type A: Direct infiltration and percolation takes place on high permeability formations.
- Type B: Intermediate situations.
- Type C: Frequent surface runoff takes place on low permeability formations.

The second step is to determine if this type of flow occurs within the surface catchment of a sinking stream. Four zones can be distinguished (after Goldscheider, 2002):

- Zone 1: Swallow hole, surface stream up to 1 km upstream from the swallow hole, 20 m buffer zones on both sides of the stream.
- Zone 2: The rest of the catchment areas of the sinking stream.
- Zone 3: Areas outside the catchment of sinking streams but inside the karst catchment.
- Zone 4: Areas that drain laterally out of the karst catchment.

The C map is obtained by combining the dominant flow type and the surface catchment map. Combining the O and C maps then allows creating the vulnerability map. Four vulnerability classes are symbolised by colours from red (extreme vulnerability) to blue (low vulnerability).

3.3 Application to the test site

The O factor was determined on the basis of the geological map and field observations, directly using the table in Fig. 3. The C factor was assessed in two steps. First, the dominant flow process was determined using the geological map and field observations. Direct infiltration (A) takes place on limestone formations with shallow soils; frequent surface flow (C) occurs on Quaternary deposits and clayey formations; an intermediate situation (B) was assigned to all other settings. The swallow holes were mapped during fieldwork; their catchments were delineated based on a topographic map.

Overlaying the O and C map then created the vulnerability map (Fig. 4). Only three classes of vulnerability are present in the test site: extreme, high and moderate. Extreme vulnerability is restricted to small zones near sinking streams. High vulnerability is present both on karst limestone (low protection of the

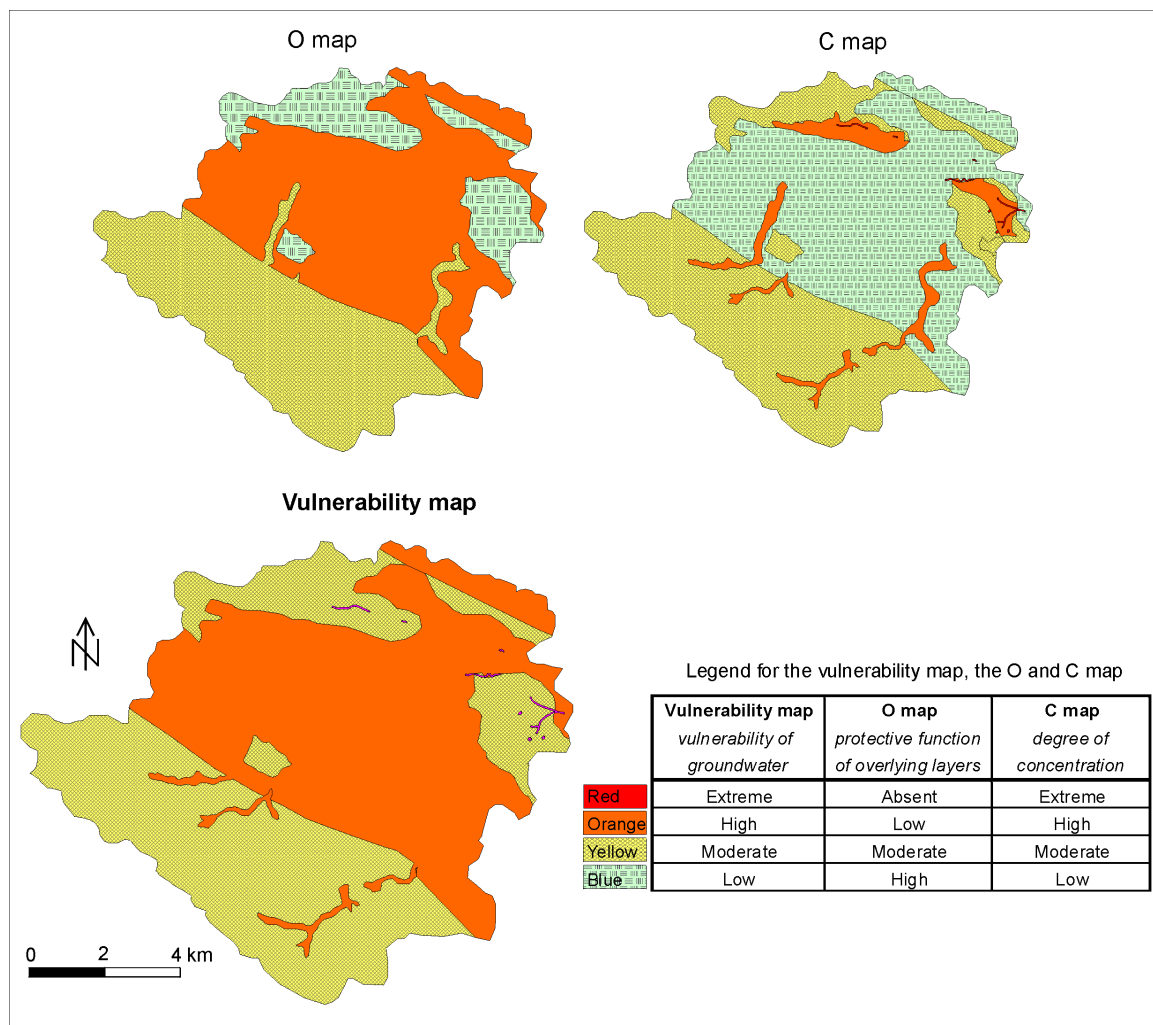


Fig. 4: O map, C map and vulnerability map of the Son La karst area, and legend for the three maps.

overlying layers) and on Quaternary deposit (surface flow near sinking streams). The rest of the area was classified as moderately vulnerability. These results are reasonable in terms of karst hydrogeology, and at the same time applicable, as strict land use restrictions will only be required on relatively small zones.

4 Acknowledgement

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