



Methodological approach to assessment of groundwater contamination risk in an agricultural area



Anna Matzeu*, Romina Secci, Gabriele Uras

Università degli Studi di Cagliari, DICAAR, Settore di Geologia Applicata, Via Marengo 3, 09123 Cagliari, Italy

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ABSTRACT

Water contamination by nitrates of agricultural origin is a major problem in Sardinia (Italy) where Nitrate Vulnerable Zones (NVZs) has been identified in the Arborea reclamation area (W. Sardinia), where intensive agriculture and farming are the mainstays of the local economy. Agricultural practices have seen an increase in the use of animal and chemical fertilizers for enhancing soil productivity. This, accompanied by the intensive use of groundwater resources for irrigation has led to the deterioration of groundwater quality, in areas particularly vulnerable to nitrate contamination. In the test area, the intrinsic nitrate contamination risk from agricultural sources has been evaluated through the combined application of the parametric methods, SINTACS, SI and IPNOA. Risk assessment, using vulnerability and hazard mapping, is considered a fundamental aspect of sustainable groundwater management. All parameters used in this risk assessment were prepared, classified, weighted and integrated in a GIS environment. Results show that nitrate concentrations are located in those areas where agricultural and livestock farming are concentrated. These results could, consequently, be interesting for future development and long term planning of groundwater protection management. The risk methods adopted, verified by comparing the distribution of nitrates in the groundwater with the different vulnerability classes, proved to be a valid tool. In fact the areas with nitrate concentration of more than 100 mg/l coincide well with those at high risk identified by the model and the areas with nitrate concentration of less than 25 mg/l closely match those areas with low and moderate risk.

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1. Introduction

Groundwater represents an important resource exploited both for human consumption and agricultural and industrial use (Hamza et al., 2007). Excess nitrogen in soil, aquatic and atmospheric environments is becoming a global problem (Tedd et al., 2014). The assessment of the vulnerability, susceptibility and potential risk of pollution of aquifers is a key instrument for assisting government agencies in planning for resource protection. The European Water Framework Directive (WFD) established a framework for action on water management, targeted mainly at protection, setting 2021 as the target date for achieving good status for both surface and groundwater (Directive 2000/60/EC, 2000). that the directive suggests that an accurate and current map of groundwater quality is of paramount importance in the management of water resources (Chica-Olmo et al., 2014). This study carries out an

analysis of nitrate-only pollution in order to provide a tool for governmental authorities to develop plans for reducing this pollutant in compliance with the European Directive.

A common form of groundwater pollution which affects industrialized countries and areas under agriculture is nitrate contamination. This environmental problem occurs in Sardinia (Italy) particularly in the Arborea reclamation area (W. Sardinia).

One of the most common ways to assess the vulnerability of an aquifer to pollutants is to apply the methods of scores and weights. Many researchers throughout the world have applied these methods to assess the vulnerability of aquifers to nitrate pollution (Pacheco and Sanches Fernandes, 2013; Wang et al., 2012; Antonakos and Lambrakis, 2007). A number of studies have adopted the DRASTIC (Aller et al., 1987) method from which the SINTACS method (applied in this study) was derived.

These parametric models of scores and weights have become essential decision-making support tools in vulnerability assessment. The groundwater vulnerability indexes such as DRASTIC and SI (Ribeiro, 2005) are often used to assess groundwater vulnerability for non-point source nitrate pollution from agricultural areas (Rodriguez-Galiano et al., 2014).

* Corresponding author.

E-mail addresses: annamatzeu@libero.it (A. Matzeu), romysecci@gmail.com (R. Secci), urasg@unica.it (G. Uras).

Another parametric index named IPNOA (Padovani and Trevisan, 2002) designed to assess the hazard of nitrates from agricultural sources (Padovani and Trevisan, 2002) has been applied here. This method has been tested in the Cuneo district of Piedmont (North Italy) (Civita and Fiorucci, 2003) and in an area of Sardinia (Ghiglieri et al., 2009). Other methods based on GIS technology have been developed to locate critical source areas of diffuse nitrate pollution (Orlikowski et al., 2011).

The objective of this study was to perform comparative evaluations, using parametric models, to determine the potential risk of anthropogenic nitrate pollution in aquifers, to analyze the quality of groundwater used for agriculture – livestock farming in the Arborea reclamation area (W. Sardinia) and to recommend solutions for such fragile areas.

2. Material and methods

2.1. Study area

The study area, the Arborea reclamation area [folios 528 and 538 IGM Cartography (Geographic Military Institute) scale 1:50.000], extends over roughly 70 Km² and is part of the coastal flood plain near the Gulf of Oristano in Western Sardinia.

The area has a population of about 4.050, with just over half living in the town center, the remainder scattered across the countryside (ISTAT data – population census 2011). This area is bound to the North by the S'Ena Arrubia marsh, to the West by the sea, to

the South West by San Giovanni marsh and to the East and South East by the Acque Medie canal and the Rio Mogoro river (Fig. 1). The Acque Medie canal bed and the Rio Mogoro river bed have been paved, making them impervious to water. There are no natural watercourses in this area that recharge the aquifer, which are primarily replenished by rainfall and irrigation waters and by lateral recharge (Barrocu et al., 2004).

From a geological point of view, the outcropping formations are mainly variously cemented dune sands, largely Wurmian (qd). Present and recent beach sands can be found along the coast (s), while silty-clayey marshy or brackish deposits (a) are located near the coastal ponds and in some other marshy internal areas (Barrocu and Soddu, 2006) (Fig. 2).

The territory has a flat morphology, with an average ground surface elevation of 7 m above sea level (m a.s.l.). The series of marsh depressions, previously mentioned, have an average depth of 2 m a.s.l. To the east of Sassu, the marsh relief grows with wavy morphology and with a maximum ground surface elevation of about 15 m a.s.l (Muzzu, 2005). In its classification work “Characterization, Objectives and Monitoring of Groundwater Bodies in Sardinia” (2010), the Sardinian Hydrographic Agency places the test site within the detrital, alluvial water body of Arborea Hydrogeological Complex, in the Campidano area, dating from the plioQuaternary period. The depth of groundwater wells, stratigraphy of the deposits, piezometric surface and salt content, all suggest that two underground aquifers are present in the Arborea zone. These largely overlapping aquifers, one near the surface, the other

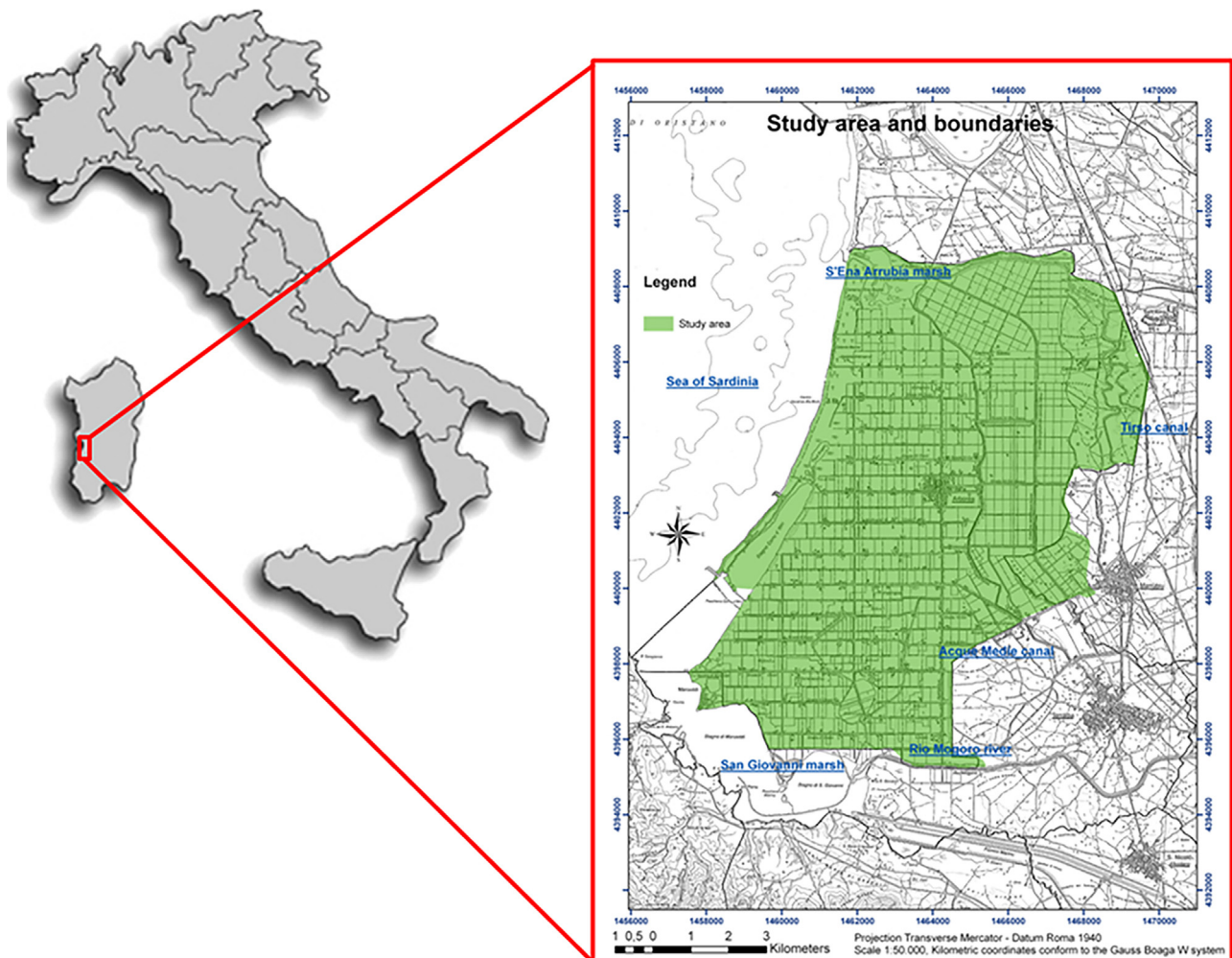


Fig. 1. Study area and boundaries.

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