Aquifer vulnerability to soil pesticide leaching at regional scale in Lombardy - North Italy

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1.   Abstract

The agricultural use of pesticides, in particular herbicides, has often led to groundwater pollution; the interaction of these substances with soil plays a major role in determining the occurrence and the extent of groundwater contamination.

Knowledge of soil properties and evaluation of soil functions, such as sensitivity or vulnerability, are essential in providing guidelines to support sustainable land management and decision making at the different scales. This paper deals with aquifer vulnerability to pesticide leaching, evaluated at regional scale (1:250,000) in an intensively cultivated landscape of alluvial plain (Lombardy - North Italy). The work has been performed in the frame of the program "European Soil Database at scale 1:250,000". For this purpose the flow diagram for the derivation of Aquifer Vulnerability Classes proposed by Hollis (1991, 1993) has been applied to the regional soil database allowing the identification of areas at different risk of pesticide leaching. The methodology has been adapted to characteristics of the Lombardy soil cover and to soil database structure. In the study area 14 soil/groundwater pesticide leaching potential classes have been identified and represented, using a Geographic Information System (GIS) for integrating alphanumeric data related to the digitized soil polygons.

This work is a preliminary step, aimed to define programs for the sustainable development of agricultural practices.

2.   Introduction

The agricultural use of pesticides, in particular herbicides, has often led to groundwater pollution; the interaction of these substances with soil, plays a major role in determining the occurrence and the extent of groundwater contamination.

Knowledge of soil properties and evaluation of soil functions, such as soil sensitivity or vulnerability, is essential for providing guidelines to support sustainable land management and decision making at various scales.

This paper deals with aquifer vulnerability to pesticide leaching, evaluated at regional scale (1:250,000) in an intensively cultivated alluvial plain (Lombardy - North Italy). The soil interpretation performed in this study will be included in the land evaluation models, selected for the Pilot Zone "Pianura Padano-Veneta" of the program "European Soil Database at scale 1:250,000". It is aimed to define an integrated framework for sustainable management of soil resources, according to the EU agro-environmental policy and the "Regional Plan for Pesticide Safety" adopted by the Region of Lombardy.

To this purpose the flow diagram for the derivation of Aquifer Vulnerability Classes proposed by Hollis (1991, 1993) has been applied to the regional soil database allowing the identification of areas at different risk of pesticide leaching.

3.   Material and Methods

The study area is 14,000 km^2 wide, encompasses several hundred municipalities and has about 7,000,000 inhabitants.

Following soil-landscape relationships, three scenarios can be identified in the study area:
- the main level of the plain, characterized by alluvial and glacio-fluvial Pleistocenic deposits; soils occurring in this area are generally Alfisols and Inceptisols, fine to coarse textured;
- the main river valleys landscapes, characterized by alluvial Holocenic deposits; soils are formed on alluvial parent materials, where flooding and water table control the genetic process. Soils occurring in this area are generally Entisols and Inceptisols, characterized by high amount of gravel;
- the foot-hill landscape including Pleistocene moraines and their glacio-fluvial terraces generally characterized by weakly developed soils.

Organic matter content of the topsoil is normally low (1 - 3 %); higher contents can be found only in restricted landscapes (Histosols and Mollisols).

The specific soil moisture regime is Ustic in the eastern and southern part of the region becoming Xeric in soils with low available water capacity (AWC). An aquic moisture regime is prevalent in soils where the groundwater is very close to the surface. The rest of the region is characterized by an Udic regime.
Groundwater is the primary source of drinking water supply. Water table depth ranges from 0 to 20 m somewhat till 50 m below the glacial drift.

The described landscapes are intensively cultivated and often irrigated; maize, rice (southwest of the region), barley and wheat are the prevalent crops.

The flow diagram developed by Hollis 1991) has been selected to evaluate the aquifer vulnerability to pesticide leaching at regional scale (1:250,000).

In this methodology soils are rated on the basis of their pesticides leaching potential, groundwater depth and travel time to groundwater surface.

The soil properties taken into account are: particle size, organic matter content, type of hydraulic flow and occurrence of redoximorphic features. These properties affect soil attenuation capacity, water leaching and soil permeability.

The method describes 17 different risk factor combinations occurring within the territory; it does not provide a rank of identified risk aquifer vulnerability classes.

The methodology, adapted to the characteristics of the Lombardy soil cover (Fig. 1) and to the soil ERSAL database structure, has been customized:
- to distinguish between soils developed over till that forms moraines and over alluvial and glacio-fluvial deposits;
- to point out the hydrologic behaviour of rice cultivated soils showing anthraquic conditions;
- to use data stored in the soil database linked to 166 soil mapping units (SMU) identified at scale 1:250,000.
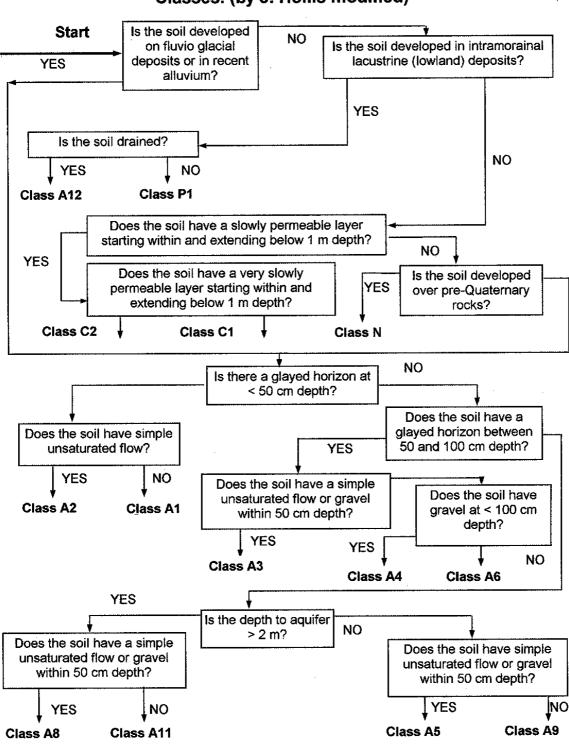
Fig. 1: Flow Diagram for the derivation of Aquifer Vulnerability Classes. (by J. Hollis modified)
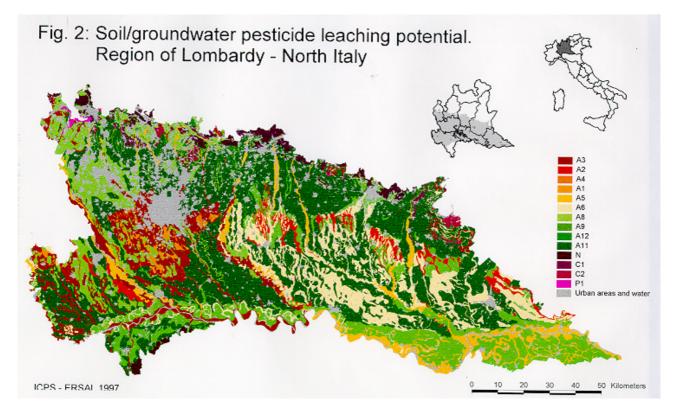
Tab. 1: Soil/Groundwater pesticide leaching potential classes.

Class	Pesticide Leaching Potential	Aquifer
A1	soils with an intermediate pesticide leaching potential	very shallow
A2	soils with an moderately high pesticide leaching potential	very shallow
A3	soils with an high pesticide leaching potential	shallow
A4	soils with an moderately high pesticide leaching potential	shallow
A5	soils with an high pesticide leaching potential	moderately deep
A6	soils with an intermediate pesticide leaching potential	shallow
A8	soils with an high pesticide leaching potential	deep
A9	soils with an intermediate pesticide leaching potential	moderately deep
A11	soils with an intermediate pesticide leaching potential	deep
A12	lowland soils developed on intramorainal lacustrine deposits, drained or partially drained, with a low pesticide leaching potential	shallow
C1	soils with an intermediate pesticide leaching potential	non-aquifer or very deep aquifer that may conceal groundwater-bearing strata
C2	soils with an low pesticide leaching potential	non-aquifer or very deep aquifer that may conceal groundwater-bearing strata
N	upland soils developed on pre-Quaternary rocks with an intermediate or high pesticide leaching potential	
P1	undrained and peaty soils with an high pesticide leaching potential, developed on intramorainal lacustrine deposits	

4.   Results and Discussion

A map showing the soil/aquifer vulnerability classes has been obtained (Fig. 2).
The most represented class is A11 characterized by deep aquifers; in the western part of the region soils with high pesticide leaching potential (class A8) are dominant. A considerable part of the territory belongs to classes defined by shallow aquifers and soils with high pesticide leaching potential (classes A3, A2).

Fig. 2: Soil/groundwater pesticide leaching potential.
Region of Lombardy - North Italy

The methodology used in this paper and the obtained maps are a preliminary step, aimed to define programs for the sustainable development of agricultural practices. Findings might be considered sufficiently reliable for a macro evaluation of vulnerable areas to the pesticide leaching. A questionable point might be the use of the soil interpretation developed in a North European soil landscape (Soil Survey of England and Wales, 1977). In fact the methodology does not provide distinctions between coarse loamy and sandy soils, present in North Italian alluvial soils, often showing different drainage and permeability, according to their pedogenic development. More, the methodology does not differentiate between soils occurring on Middle Pleistocene surfaces, characterised by slowly permeable layers where runoff is prevailing, and soils occurring on Late Pleistocene, characterised by high amount of gravel where leaching is dominant.

To define programs for the sustainable development of agricultural practices and identification of aquifer vulnerability to pesticide leaching, further work is planned:
- to integrate the Hollis methodology with different models addressed to evaluate the soil attenuation capacity with respect to pollution phenomena;
- to integrate the use of information on climate, land use, soil and hydrologic properties, physico-chemical properties of pesticides and deterministic models in a GIS environment.

5.   References

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