THE ASSESSMMENT OF NITRATES FLUX TO THE GROUNDWATER, USING GIS, AT A CATCHMENT AND NUTS4 SCALE

Sorina Dumitru[1], Ioana Nilca[1], Victoria Mocanu[1], Valentina Coteț[1], C. Simota[1]

ABSTRACT

The presence of the high nitrogen concentrations in soils is a high potential risk for the groundwater and, implicitly, for human and animal health , because the ground water is the main source of the drinking water in many areas abroad. One of the main risk factor for nitrates pollution is the agricultural activity.

The aim of the paper is to describe the nitrates pollution evaluation procedures at the scale of a catchment and at NUTS4 level, using data from the Geographic Information System SIGSTAR – ICPA, available weather data from statistical yearbooks, as well the pedotransfer functions from the methodes and models database. In order to compute the nitrates flux to the groundwater, a simulation model ROIMPEL, developed in the frame of an international cooperation, is used. The computed values are compared with the maximum nitrates flux that can be removed out by the groundwater and translated in the terms of maximum number of the livestock without affecting the groundwater.

La presence dans le sol de concentration elevée de nitrates c'est un risque potential pour l'eau souterraine et pour santé humaine et animal, parce que l'eau souterraine est la principale source d'eau potable dans beaucoup des regions. Un factor de risque de certain importance pour la nitrate pollution c'est l'activité agricole.

L'objectif de cette papier est cel de présenter le methode d'estimer la pollution avec nitrates a l'échelle de bassin versant et a NUTS4 niveau, en utilisent des données de System d'Information Geographique SIGSTAR – ICPA, des données climatiques disponibles de l'Annuaries Statistiques, et aussi des functions de pedotransfer provenant de la base de données de methodes et modeles. Pour calculer le flux de nitrates dans l'eau souterraine, on a utilisé un model de simulation ROIMPEL developée dans un projet international. Les valeurs obtenues sont comparé avel le maximum flux de nitrates quel a été lavé dans l'eau souterraine et traduit en terms de nombre maximum des animaux sans affecté l'eau souterraine.

Key words: Geographic Information System, nitrates pollution, nitrates flux, animal units.

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[1] *The National Research-Development Institute for Soil Science, Agrochemistry and Environment Protection,Bucharest, Romania*

INTRODUCTION

The presence of the high nitrogen concentrations, exceeding the admissible maxim limits, may have a negative impact on the environment through the possible losses in the ground and surface waters and/or atmosphere. Generally, the nitrogen behaviour is determined by a lot of physical, chemical and environmental factors, such as: climate, relief, soil type and its properties. It is the main constituent of the leaf chlorophyle, of all amino-acides and other essential components for crop growing and development, but besides these, inadequate nitrogen quantities affect negatively the main environmental resources.

The agricultural activities are the main nitrogen supply in soil, through application of the mineral and organic fertilizers doses, sometimes in inadequate fertilizers rates determining the accumulation of high quantities of nitrogen in soil. In the last decades, worldwide there was an increasing tendency of for using nitrogen based fertilizers, because the nitrogen represents an essential nutrient for conservation and/or amelioration the soil fertility state and for agricultural production, which has to satisfy the needs of increasing population. The intensive agriculture applied a long time, the uncontrolled organic and mineral fertilizers application in inappropriate moments are some of the elements that determined important nitrogen quantities accumulation, which represented a major source of nitrates in the ground and surface waters from urban and rural zones. The organic and mineral fertilizers use determines surface water eutrophication and nitrates accumulation in the drinking water. The nitrates ground water pollution determines potential adverse effects for human and animal health, the groundwater being the main source of the drinking water in many areas. This is why it is necessary to apply suitable practices according to an agricultural system that should optimize the crop production in order to avoid the environmental contamination with nitrates. As a consequence, the Nitrates Directive became a basic component of communitary agricultural policies and a condition for the EU candidates.

In order to promote a sustainable agriculture based on suitable agricultural practices application for environmental protection, in our country a Code of Good Practices was elaborated (Dumitru et al., 2003). This represents a group of technical and scientific knowledge available for agricultural farmers in order to be implemented in practise. The Code has to be harmonized with the European Nitrates Directive regulations regarding to water protection against the nitrates pollution from agricultural activities and consists of specific recommendations for our country. The scientific Romanian community tried through different studies and succeeded successfully to elaborate some information systems, which evaluated and monitored the potential vulnerable zones to nitrates, using pre-established indicators. An important objective is to create an interface between the outputs of these systems and the stakeholders, especially that's are located in vulnerable zones to nitrates pollution, in order to self-evaluate and monitoring the risk of environmental deterioration and to implement agricultural technological plans for protection and/or amelioration of the environment.

The aim of this paper is to develop an easy-to-use system for characterising the potential vulnerability to nitrates pollution of a vulnerable area to nitrate pollution.

DATA SOURCES

The available databases are: the soil map of Romania (at the scale 1:1 000 000), the soil map at the subtype level (1:200 000), the soil profile database (PROFISOL), the spatial distribution (at NUTS4 level) of the average value of cumulated precipitation deficit (Potential Evapotranspiration– Precipitation), the catchments boundaries, the surface water network, the main groundwater bodies, the land cover using the main landuse classes.

DATABASE STRUCTURE

The database is organised as a workbook, each spreadsheet describing a component of the full database. The main component is the existing hydrological registry, transposed into a workbook application, in an active buttons structure, so:

- In a spreadsheet, each surface water body (river sector, natural or artificial reservoir) delimited in the cadastre is represented by an active button, transffering, by pressing, the information application control to a particular spreadsheet storing the data for that water body (fig. 1);

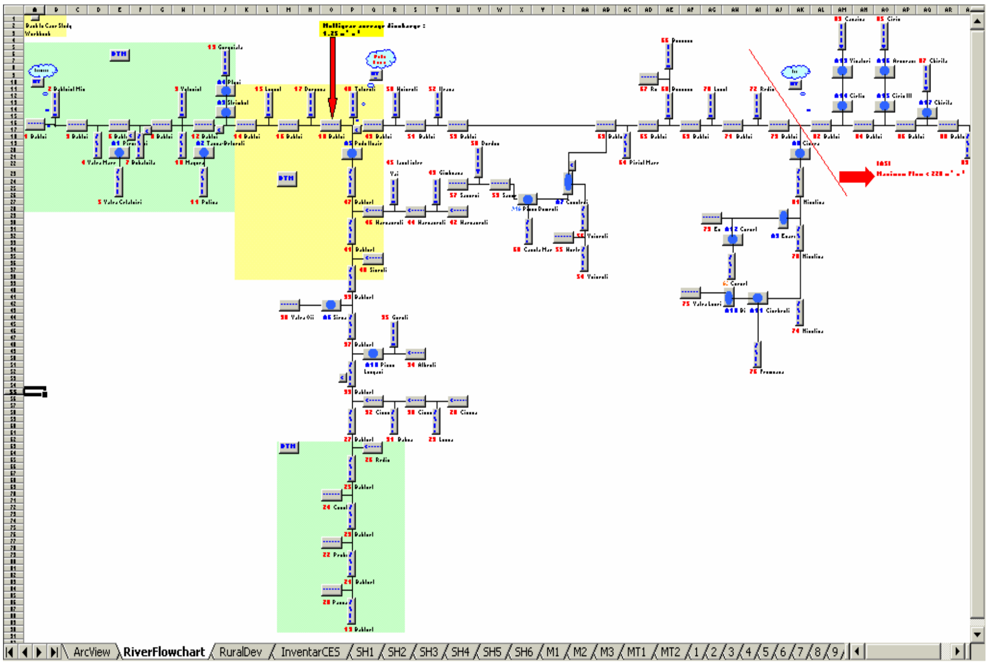


Fig. 1. ***The Bahlui river structure***

- The particular spreadsheet for each water body store the hydrological information for that water body (fig. 2): for rivers; catchments; lakes, technical characteristics for dams and draining systems of the water body.

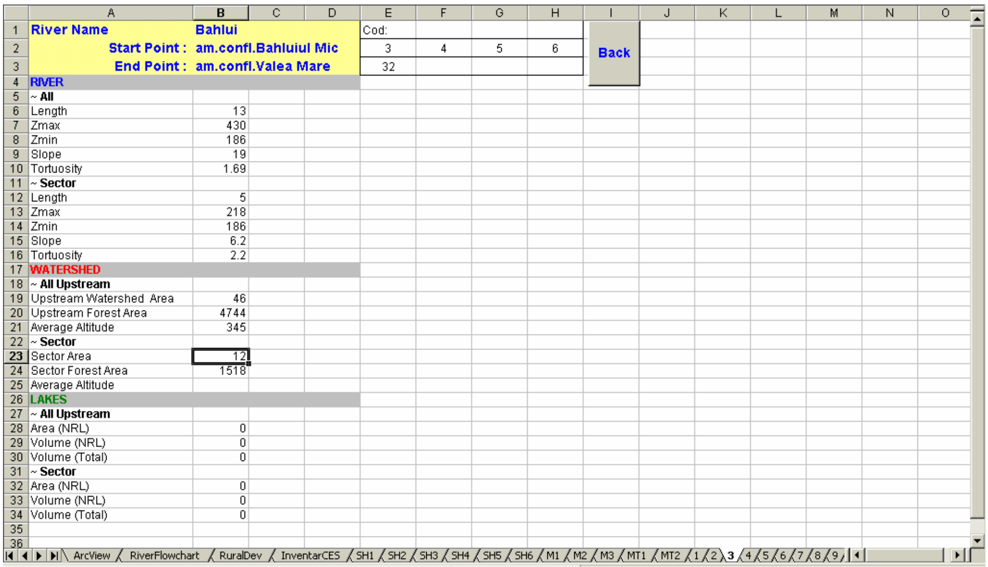


Fig. 2. ***The hydrological information stored for a segment of Bahlui river.***

- The weather (climate) data from the meteorological station of the area are stored in specific spreadsheets, that could be loaded from the spreadsheet describing the hydrological cadastre: the monthly average temperatures, precipitations and radiation on the basis of the climate time series for 1896-1955 (monography: Clima RPR), daily values for temperature, precipitation and sunshine interval, as well as monthly average values for another climatic parameters needed by the crop growing simulation models on the basis of 1960-1990 series.
- Information on rural development of the Bahlui catchment are stored in special spreadsheets al NUTS4 level.
- The Digital Terrain Model (obtained through SIG prelucration of topographic maps at a scale 1:200 000) for different areas of hidrographical catchment (fig. 3) is loaded from the central spreadsheet of the catchment (the DTM buttons from fig. 1). Inside the DTM included in the aplication, the main geographical elements (water arms, water bodies) of the region are specified.

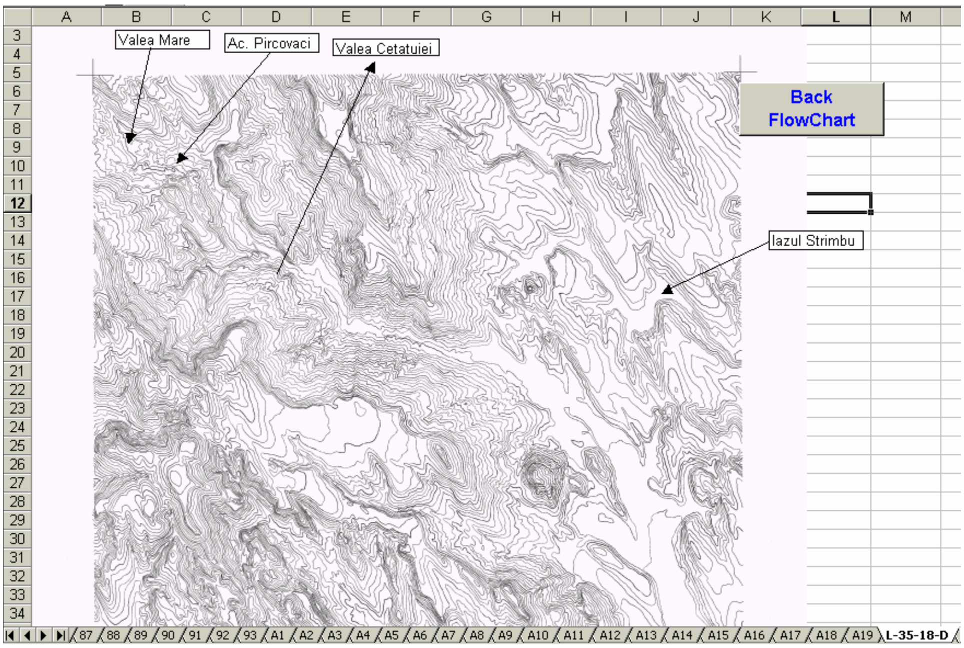


Fig. 3. ***The countur lines for an area of Bahlui catchment, the basis of the Digital Terrain Modelling (DTM).***

- The image provided by CORINE Landcover for the area of interest with the landuse types is completed with active buttons which, by pressing, transfer the control to the spreadsheets containing characteristic information for specific location (fig. 4)

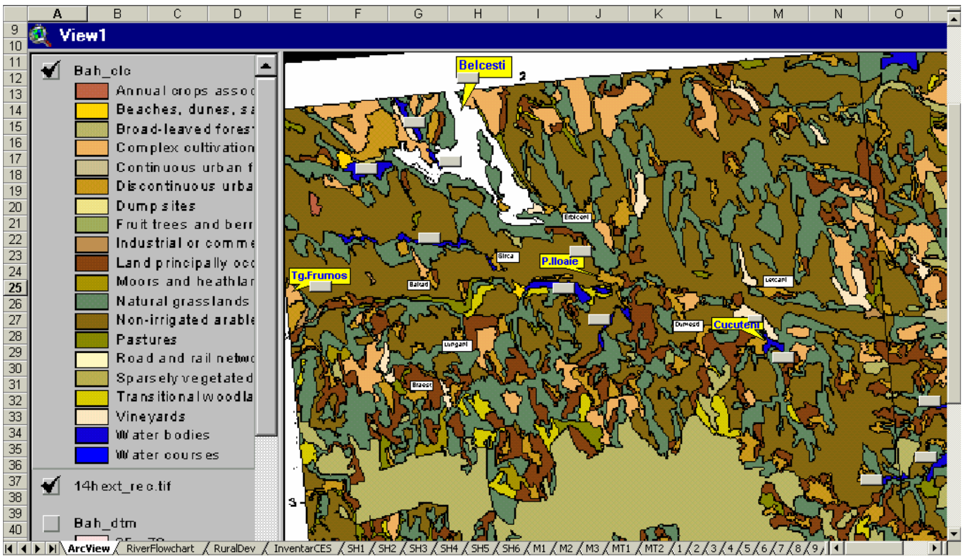


Fig. 4. ***Landuse in an area of Bahlui catchment.***

METHOLODOLOGY

To evaluate the nitrates fluxes to the groundwater the agro-climatic simulation model ROIMPEL was used, developed in the frame of an international colaboration, the IMPEL project (Rounsevell, 1998).

The model simulates the crop yields and the water and nitrogen balances in a specific area, like in a catchment, and for various systems of agriculture, based on long-time-series of recorded climate data. The output of the ROIMPEL model serves in a next step for assessing economic parameters, using the energy equivalent of the main activities (soil tillage, mineral fertilisation, and weed control by pesticides) in each of the specified agricultural systems. ROIMPEL is a site-specific, modular mechanistic simulation model of crop yields limited by soil water and nitrogen availability, using limited easy-to-map soil and weather data. Therefore, ROIMPEL is appropriate for GIS based regional and sub-regional land use projects.

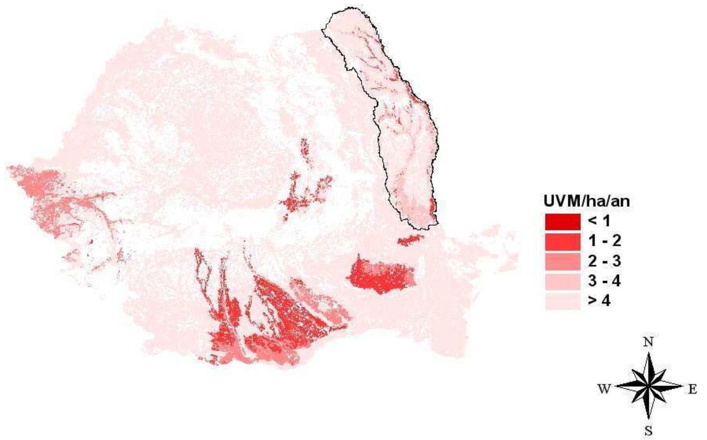
The minimum requirements for soil data are the soil texture and organic matter classes. With them, additionally soil parameters could be derived, using pedotransfer functions (Voltz at al., 1997; Daroussin & King, 1997). The Maximum Available Soil Water Content to the root front depth was the key soil parameter used for spatial extrapolation of the site specific simulation output. This soil parameter was computed using a standard methodology from soil water parameters (soil water retention curve, field capacity, wilting point), soil mechanical parameters (soil resistance to penetration, defining root elongation rate) and a climate index characterising the cumulated atmospheric water deficit during the vegetation period. The minimum weather data are monthly values of the average daily temperature and the month cumulated rainfall.

Various practices for nitrogen and water management could be very easily considered specifying some easy to derive parameters through external files, and the nitrate concentrations, which are potentially hazardous for groundwater contamination, are optionally derived.

THE FLOW CHART

1. The selection of the catchment, as well as the available layers from the database for this catchment (the soil, surface water bodies, groundwater, and landuse coverages, the Digital Terrain Model).
2. The selection of the climate data characterizing this catchment, from the available weather database.
3. The evaluation of some parameters needed by the model and that are not available directly from the database.
4. The evaluation of some parameters from PROFISOL database, characterizing soil profiles (point database), using pedotransfer functions, and the extrapolation of the results to the whole area of the catchment.
5. Running ROIMPEL in order to evaluate the average nitrates flux leached below the root front depth considering homogeneous al the soil-terrain units, and for different scenarios:
    - various autumn and spring crops (maize, winter wheat, grass)
    - different manure amount applied on the field (0, 2, 4 animal unit /ha/year)

6. The evaluation of quadratic regressions between the leached nitrates flux (expressed as kg NO_3/year) and applied manure amount (expressed by animal units/ha) for each homogeneous soil-terrain unit, using simulation model output.
7. The evaluation using these regressions of maximum livestock (animal units/ha) in order not to exceed the maximum nitrates flux allowed by the aquifer dinamics (the drained nitrates flux has to be lower than that allowed by the aquifer dinamics) (fig. 5).



Fg. 5. ***The maximum number of animal units ha^{-1} for the whole country.***

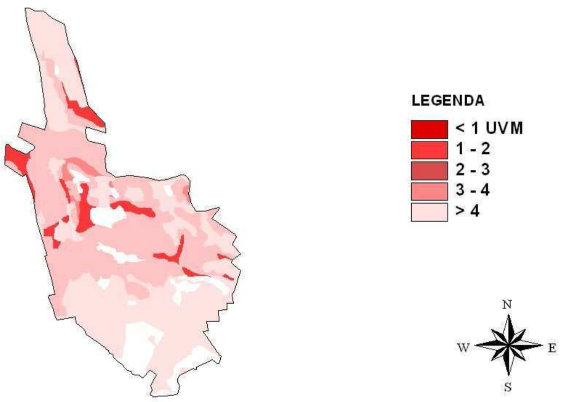


Fig. 6. ***An example for a "comuna" (NUTS4 level) from Bahlui catchment with the maximum animal units (com. Miroslava, county Iaşi).***

8. In the case of soil-terrain units draining not in an open aquifer, the maximum livestock is designed by the Code of Good Agicultural Practice.
9. Data aggregation at the „comuna" level (NUTS4 level) (fig. 6)

CONCLUSIONS

- Running the simulation model for water and nitrates dinamics in soil ROIMPEL in order to evaluate the average nitrates flux leached under the roots depth allow:
  - The evaluation of the quadratic regressions between the leached nitrates flux (kg NO_3 $year^{-1}$) and the manure applied in the field (expressed through the number of animal units ha^{-1}), for each homogeneous soil-terrain unit (using model output)
  - The evaluation using these regressions of the maximum number of animals (animal units/ha) in order not to exceed the maximum nitrates flux allowed by the aquifer dinamics.
- The results could be aggregated at the NUTS4 level, "comuna", obtaining a characterization of the "comuna":
  - The evaluation of the potential livestock for a "comuna" (following the Nitrates Directive requirements)
  - The comparasion with the real livestock of the "comuna" allow the evaluation of potential development at NUTS4 level.

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