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# Determination of nitrogen reduction levels necessary to reach groundwater quality targets in Slovenia

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ABSTRACT

Within a collaborative project between Slovenian Environment Agency (ARSO) and Research Center Jülich (FZJ), nitrogen reduction levels necessary to reach groundwater quality targets in Slovenia were assessed. For this purpose the hydrological model GROWA–DENUZ was coupled with agricultural N balances and applied consistently to the whole territory of Slovenia in a spatial resolution of 100 × 100 m. GROWA was used to determine the water balance in Slovenia for the hydrologic period 1971–2000. Simultaneously, the displaceable N load in soil was assessed from agricultural Slovenian N surpluses for 2011 and the atmospheric N deposition. Subsequently, the DENUZ model was used to assess the nitrate degradation in soil and, in combination with the percolation water rates from the GROWA model, to determine nitrate concentration in the leachate. The areas showing predicted nitrate concentrations in the leachate above the EU groundwater quality standard of 50 mg $NO_3^-$/L have been identified as priority areas for implementing nitrogen reduction measures. For these "hot spot" areas DENUZ was used in a backward mode to quantify the maximal permissible nitrogen surplus levels in agriculture to guarantee a nitrate concentration in percolation water below 50 mg $NO_3^-$/L. Model results indicate that additional N reduction measures should be implemented in priority areas rather than area-covering. Research work will directly support the implementation of the European Union Water Framework Directive in Slovenia, e.g., by using the maximal permissible nitrogen surplus levels as a framework for the derivation of regionally adapted and hence effective nitrogen reduction measures.



## Introduction

Slovenia is one of the smaller European countries (20,273 km$^2$), with a total population of about 2 million inhabitants. It is located at the meeting point of four major European geographical regions: the Alps, the Dinaric Mountains, the Pannonian Basin and the Mediterranean (Adriatic Sea). Whereas only around 3% of Slovenian territory comprises settlement areas, ca. one third of the country is used for agriculture (mainly in the north-east). More than 58% of the country, however, is covered with forests and in some areas woodland scrub (Fig. 1), ranking Slovenia amongst the most forested countries in Europe. Nevertheless, the input of nitrates into groundwater from point pollution (unregulated livestock manure storage and sewage system) and non-point pollution due to the use of livestock manure

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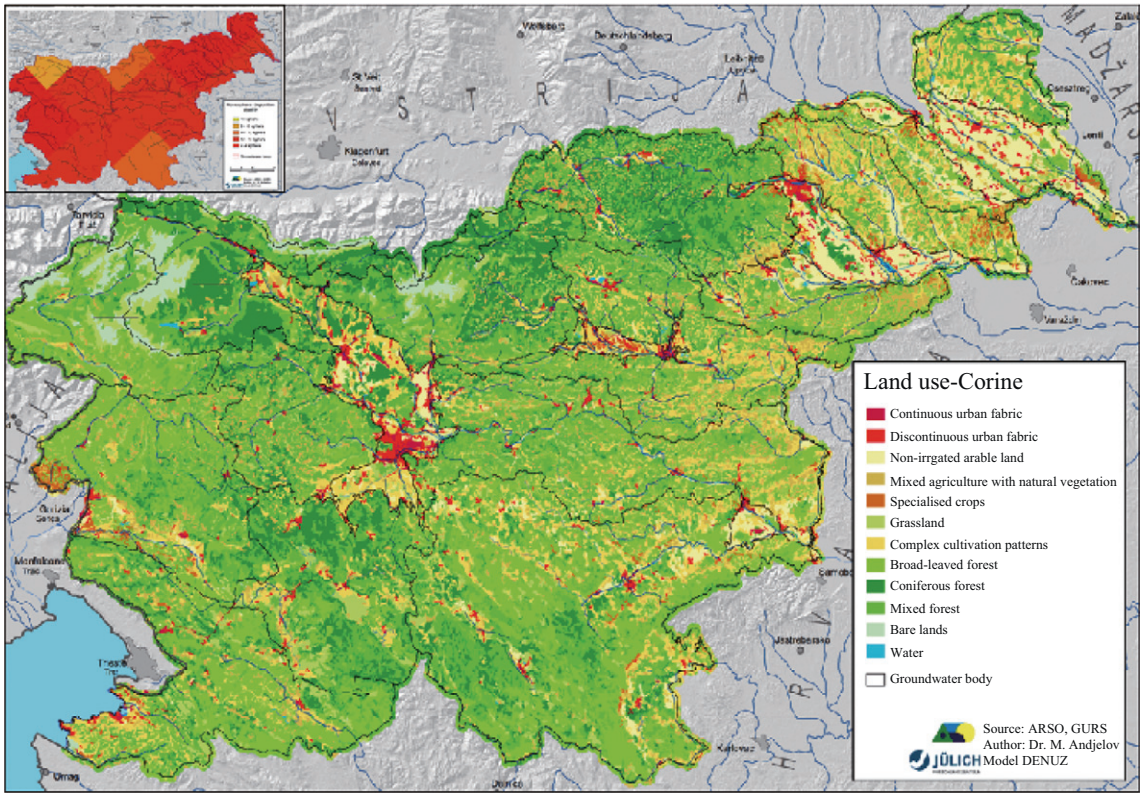


**Fig. 1 – Land cover in Slovenia.**

and mineral fertilizers may lead to significant nutrient problems in the groundwater and surface waters of Slovenia.

The fundamental objectives of the European Union Water Framework Directive (EU-WFD) (WFD, 2000) and the European Union Groundwater Directive (EU-GWD) (GWD, 2006) are to attain a good status of all surface waters and groundwater resources in the EU by 2015. Following the WFD, the chemical status of the Slovenian groundwater had to be determined by 2004 and remediation measures to reduce groundwater pollution had to be implemented for groundwater bodies at risk until 2015 (Republic of Slovenia, 2011).

The main source of diffuse nitrogen inputs on agricultural land in Slovenia has been identified as nitrogen from mineral fertilizers and livestock manures, contributing to about 84% to the overall input of nitrogen. Contributions from other input sources like atmospheric deposition or biological fixation by legume crops are less important. The balance of nitrogen, thus the difference between the input and the output of nitrogen, indicates a balance surplus of nitrogen. In the time period 1992–2008, it amounted to be between 23 and 94 kg N/ha/year with a decreasing trend over time (ARSO, 2009).

Because the delineation of groundwater bodies was still in progress and no chemical groundwater status was assessed at 2004, compliance with quality standards was stated. Later investigations showed that groundwater quality problems occur mainly in the alluvial aquifers, especially in the northeastern part of Slovenia, mainly due to nitrates, pesticides and hydrocarbons (Krajnc et al., 2007). Uhan et al. (2012) pointed out that nitrate in Slovenian waters has been a major concern for decades and about 37% of the groundwater in alluvial aquifers has poor chemical status according to EU-WFD criteria, most frequently due to a high concentration of nitrate. In this context inputs from diffuse sources and most of all nitrate losses from agriculturally used land have been identified as one of the main reasons for probably failing the “good qualitative status” of water resources. Except for the Murska kotlina and Savinjska groundwater bodies which show a clear downward trend of the nitrate concentrations from 1998 to 2011, no statistically significant trends are present in the groundwater bodies of Slovenia (Mihorko and Gacin, 2011). Groundwater in karst and fractured aquifers is less burdened with nitrates due to its geographical conditions, low population density and scarce agricultural land.

Presently, the assessment of the chemical status of groundwater resources in Slovenia is assessed annually from a monitoring of the drinking water supply system and on a general monitoring of the groundwater quality alluvial aquifer and major springs. In total 928 supply areas of the drinking water supply system were investigated in 2011 (Lapajne and Sovič, 2012). National groundwater quality monitoring, which is carried out since 1987, is the systematic monitoring of the total 150 various physical and chemical parameters in groundwater bodies (Cvitanič et al., 2011). The monitoring sites in alluvial aquifers are wells and boreholes. In aquifers with karst and fissure porosity monitoring sites are springs and wells. In 2011, the national monitoring network included 130 monitoring sites, which were more concentrated in alluvial aquifers.

It is evident that the drafting and implementation of catchment wide measurement programs according to the overall goals of the EU-WFD have to include measures against diffuse nitrate pollution. Consequently, on the part of the water resources management in Slovenia there are increasing demands on the agricultural sector to contribute adequately to the lowering of nitrate inputs into groundwater and surface waters by introducing effective nitrate reduction measures. Agro-environmental measures to reduce nitrate pollution of surface and ground waters will however differently affect the historically evolved