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Agricultural nitrogen reduction requirement to reach groundwater and surface water quality targets in North Rhine-Westphalia, Germany

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Excessive nitrate inputs into groundwater have been recognized as a main reason for failing drinking water standards since decades. Agricultural N-emissions originating from mineral or organic fertilizers are regarded as the most relevant source of nitrate in groundwater worldwide. Accordingly, strategies to cope with the nitrate pollution of groundwater are focused on controlling the agricultural sources of nitrate. In Europe this is reflected in the water legislation on EU level, i.e. the EU Water Framework Directive (EU-WFD), the EU Marine Strategy Framework Directive and the EU Nitrates Directive, obliging the polluter to implement measures to reduce the nitrogen impact on groundwater.

With an average population density of 525 inhabitants/km^2 the Federal State of North Rhine-Westphalia represents an example for a densely populated region in Germany. Consequently, the assessment of water bodies showed that a number of groundwater and surface water bodies are not in good status due to high nitrogen loads resulting e.g. in high nitrate concentrations in groundwater. There is a debate in North Rhine-Westphalia to what extent agricultural and non-agricultural N-emissions contribute to high nitrate concentrations.

The German Working Group on water issues of the Federal States and the Federal Government, require that the nitrate concentration in the leachate should not exceed 50 mg NO_3/l. Against this background it is obvious that the nitrate concentration in the leachate represents a decisive parameter for both, the assessment on the nitrate pollution of groundwater and as starting point to determine the N reduction requirements.

We used an interdisciplinary model network consisting of a nutrient balance model, a nutrient balancing model (RAUMIS, Henrichsmeyer et al., 1996), a water balance model (mGROWA, Hermann et al., 2015), a reactive nitrate transport model in soil (DENUZ, Wendland et al., 2009) and a reactive nitrate transport model in groundwater (WEKU, Kunkel & Wendland, 1997) to predict the nitrogen intakes and the nitrogen losses to groundwater and surface waters from

different input sources and pathways.

The nitrogen flux was modelled using nitrogen input data from the time period 2014-2016 and hydrological data for the time period 1981-2010. The nitrate concentrations in the leachate were calculated separately for agricultural and non agricultural N-sources involved, to enable the identification of the main polluter in a certain region, i.e. the one who has to implement measures to to reduce the nitrogen impact on groundwater.

From the model analysis it becomes evident that non-agricultural sources do only locally cause nitrate concentrations in the leachate above 50 mg NO_3/l in spite of the high population density (525 inhabitants / km^2). It could be confirmed that agricultural sources (N-balance surpluses from agriculture and atmospheric NH_4 deposition) are exclusively responsible for extended areas of nitrate concentrations above 50 mg NO_3/l. Especially in the northern (Münsterland) and western (Lower Rhine basin) parts of the Federal State the implementation of measures to reduce agricultural N-emissions in the context of the WFD program of measures is necessary. These results will not only support the right dimensioning of agricultural N-reduction measures, but also affect the selection and implementation of regionally adapted N-reduction measures.