Assessment of required increases in nitrogen use efficiencies in agriculture to comply with water and air quality objectives in EU27

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Abstract

Nitrogen (N) inputs in agriculture increased food production but also caused several environmental impacts. We present a spatially explicit estimation of required nitrogen use efficiencies (NUEs) to attain either current crop yields and target crop yields while complying with environmental standards within EU27. The standards refer to critical nitrogen deposition levels in terrestrial ecosystems, critical nitrogen concentrations in surface water and in groundwater. The calculated required NUEs to comply with the surface water standard are higher than for groundwater. For surface water the needed NUE increse is ofen higher than 0.3, whereas it mostly less than 0.2 for ground water.

Keywords: nitrogen, planetary boundary, surface water quality, groundwater quality, deposition, biodiversity, fertilizer, manure

1. Calculation of required NUE increases

Agricultural nitrogen (N) losses to air and water affect air and water quality. We used a spatially explicit N balance model to asses where agricultural N losses currently lead to an exceedance of critical N deposition levels on terrestrial ecosystems, critical NO_3 concentrations in groundwater in view of drinking water quality and critical N concentrations in surface water in view of eutrophication impacts. We then calculated the N inputs at which critical N depositions or concentrations are just not exceeded ('critical' N inputs). Meeting air or water quality objectives by reducing N inputs to 'critical' N inputs, however, implies a reduction in yields. Even though Europe is one of the most food secure regions worldwide, yields will probably need to increase in the future in order to meet European and global demands without converting natural areas to cropland. This can be achieved by closing the gap between current yields and the "yield potential", defined as the maximum yield for a given climate and soil, assuming optimal management.

We derived water-limited yield potential and assessed the required N inputs to achieve 80% of the yield potential at current N use efficiency (NUE). When critical N inputs were lower than current or required N inputs, we calculated the increase in NUE that is needed to avoid exceedance of critical N concentrations in groundwater and surface waters while also obtaining current yields or target yields, respectively. In addition, the needed reduction in ammonia emission fractions is calculated to avoid exceedance of critical N deposition levels on nature areas.

2. Results

Critical N inputs are on average 41 % and 26% lower than actual N inputs in view of critical N concentrations in surface water and critical N deposition lebvels, respectively. Critical N inputs for groundwater quality, however, are on average 6 % higher than actual N inputs. The risk of adverse impacts of N inputs on the environment is thus highest for surface water quality, followed by air quality and then groundwater quality. The spatial variation in required increases in NUEs for arable land to reach target crop yields without exceeding a critical N concentrations in runoff to surface water or in leaching to groundwater is given in Figure 1. Results show that the surface water criterion is more stringent and requires a higher increase in NUE, especially in Northwesteren Europe, with values being higher than 0.3. For groundwater the needed increase is mostly less than 0.2.

3. Discussion

The needed increase in NUEs will be hard to reach for areas with a needed increase above 0.2-0.3. This is about 25% of the area. Lowering NH_3 emissions up to a critical N deposition level is not attainable in 11% of the agricultural area at actual crop yields and in 16% at target crop yields. Additional reduction in livestock is then needed.

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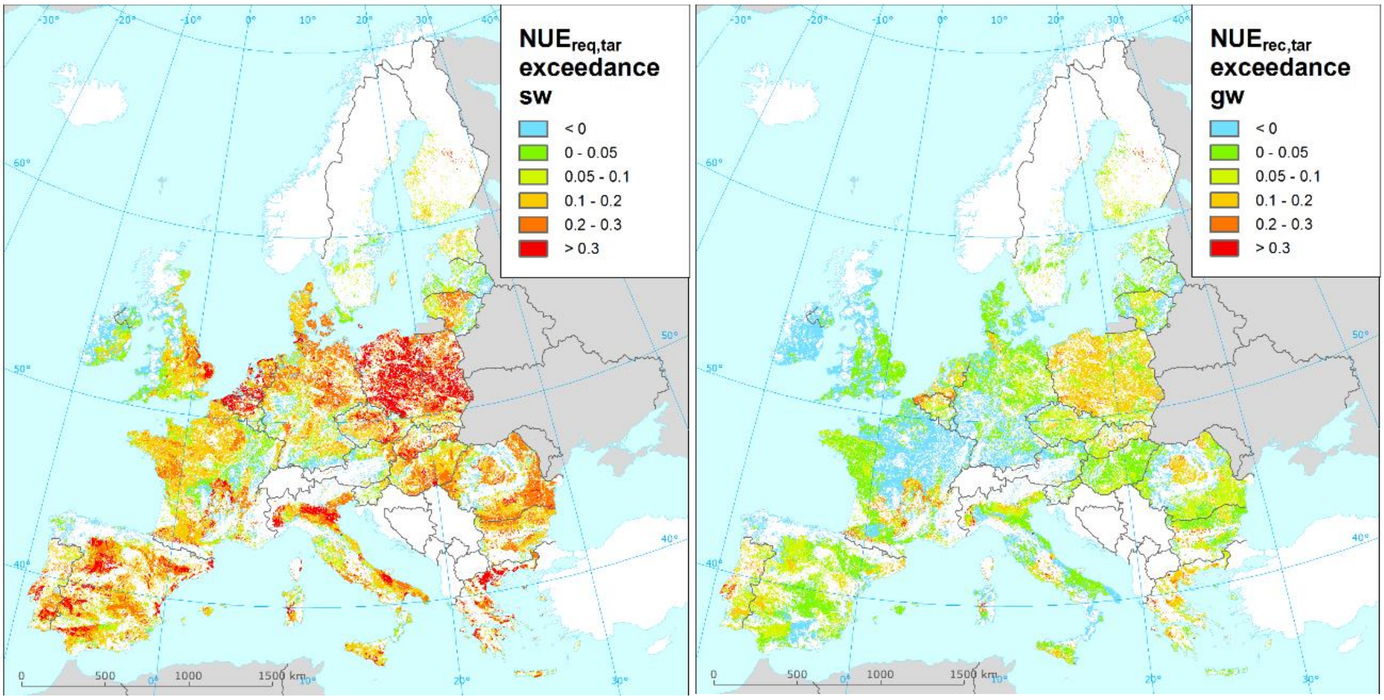

Fig. 1: The relationship between actual and necessary nitrogen use efficiencies to obtain actual yields (left) or target yields (right) without exceeding critical N runoff to surface water (top) and critical N leaching to groundwater (bottom). The solid line is the 1:1 line.