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Nitrogen surpluses and diffuse water pollution in German agriculture - trends and measures
Nieder, R.
Institute of Geocology, Technische Universität Braunschweig, 38106 Braunschweig, Germany

1. Background and Objectives
Emissions of nitrogen (N) from different sources affect both the hydrosphere and the atmosphere with serious consequences for human health and the environment. While N, particularly nitrate (NO$_3^-$) emissions from point sources, such as sewage treatment plants, have been significantly lowered in Germany, the reduction of N emissions from diffuse sources, mainly agricultural land, is not yet satisfactory. Since agriculture is the main source for NO$_3^-$ pollution of water resources, there is urgent need for action. According to the Water Framework Directive, all waters in the EU are to reach a „good status“ by 2015. It is expected that the majority of surface and groundwater bodies in Germany will not be able to meet the objective in time, unless additional measures are taken. Nitrogen balances are important indicators which describe the magnitude of potential N losses from farming systems to the environment (Nieder et al., 1995). This study presents the N surplus development in German agriculture from 1950 to 2009 and discusses the existing legal framework. Moreover, it examines measures that could help to reduce NO$_3^-$ pollution.

2. Materials and Methods
The data for calculation of the N balances for Western Germany (Federal Republic of Germany until 1989 and reunified Germany from 1990 to 2009) were drawn from the publications of the Federal Statistical Office (Anonymous 1) and for Eastern Germany (former German Democratic Republic until 1989), data were provided by a scientific institute (Anonymous 2). The procedure of N balance calculation was described in detail by Nieder et al. (2003; 2007).

3. Results and Discussion
In the 1950s the mean N surplus in Germany did not exceed 30 kg N ha$^{-1}$ (Figure 1). During the following decades the N surplus increased continuously and reached a maximum in Eastern Germany in the 1970s, and in Western Germany during the 1980s. The developments were similar in both states until the reunification in 1990. Due to the collapse of collectivized agriculture after 1989, the N surplus in Eastern Germany first decreased drastically, but has reincreased again in the recent two decades due to revival of the agricultural sector. In Western Germany the N surplus has remained almost constant since 1990 and currently amounts to about 100 kg N ha$^{-1}$ y$^{-1}$. The current mean annual N surplus in the whole of Germany amounts to 85 kg N ha$^{-1}$ y$^{-1}$. The cumulative N surplus from 1950 up to now has recently exceeded 4,000 kg N ha$^{-1}$ (mean for Germany; Figure 2).

Figure 1: N surpluses in Germany 1950-2009
(Adapted from Nieder et al., 2007)

Figure 2: Cumulative N surpluses in Germany
(Adapted from Nieder et al., 2007)
Table 1 shows the annual N surpluses for the federal states 2000-2004. The highest N surpluses of more than 80 kg ha\(^{-1}\) N y\(^{-1}\) were calculated for Northrhine Westphalia, Lower Saxony, Bavaria and Schleswig-Holstein. The major reason for the high N surpluses is more intensive animal husbandry compared to the other states. In parts of these states \(\text{NO}_3^-\) concentrations in groundwater are currently still increasing. Comparison of the N surplus per unit agricultural area in the EU 15 states (Nieder and Benbi, 2008) shows an extremely high value for the Netherlands (>250 kg N ha\(^{-1}\) y\(^{-1}\)), high values for Belgium (140 kg N ha\(^{-1}\) y\(^{-1}\)), Denmark (110 kg N ha\(^{-1}\) y\(^{-1}\)), Luxemburg (95 kg N ha\(^{-1}\) y\(^{-1}\)) and Germany (85 kg N ha\(^{-1}\) y\(^{-1}\)), while they are around (Ireland and Finland) or below 50 kg N ha\(^{-1}\) y\(^{-1}\) in the other countries (UK, Greece, France, Italy, Spain, Portugal, Austria and Sweden.

Table 1: Nitrogen surplus (kg N ha\(^{-1}\) y\(^{-1}\)) in German federal states 2000-2004 (Nieder et al., 2007)

<table>
<thead>
<tr>
<th>Federal state</th>
<th>N surplus kg N ha(^{-1}) y(^{-1})</th>
<th>Federal state</th>
<th>N surplus kg N ha(^{-1}) y(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baden-Wuerttemberg</td>
<td>75</td>
<td>Schleswig-Holstein</td>
<td>162</td>
</tr>
<tr>
<td>Bavaria</td>
<td>80</td>
<td>Brandenburg</td>
<td>55</td>
</tr>
<tr>
<td>Hesse</td>
<td>69</td>
<td>Mecklenburg-W. Pommerania</td>
<td>55</td>
</tr>
<tr>
<td>Lower Saxony</td>
<td>135</td>
<td>Saxony</td>
<td>65</td>
</tr>
<tr>
<td>Northrhine-Westphalia</td>
<td>141</td>
<td>Saxony-Anhalt</td>
<td>73</td>
</tr>
<tr>
<td>Rhineland-Palatinate</td>
<td>28</td>
<td>Thuringia</td>
<td>43</td>
</tr>
<tr>
<td>Saarland</td>
<td>3</td>
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4. Conclusions
Continuing high N surpluses and \(\text{NO}_3^-\) accumulation in groundwater and surface waters in some regions of Germany indicate that it is necessary to examine to what extent existing regulations need to be revised and the implementation of existing instruments is to be improved. There is a wide spectrum of precautionary measures ranging from restrictions on the regional density of livestock to nitrogen taxes/quotas. In Germany the Fertilizer Ordinance is the key ordinance which regulates the amounts of nutrients applied per unit area. It was recently revised in view of implementing the EU Nitrate Directive into German legislation. According to the currently valid provisions of the Ordinance, the spreading of organic nitrogen from animal excretions is usually limited to 170 kg N ha\(^{-1}\) y\(^{-1}\). Under certain conditions, the ordinance permits spreading of 230 kg N ha\(^{-1}\) y\(^{-1}\) from animal manure on intensive grassland, temporary grassland and field grass. However, there are several legal loopholes such as toleration of high amounts of “unavoidable” N emissions due to storage and application of animal manures, extra mineral N fertilizer application in cereals (e.g. late top dressing) and N application after incorporation of cereal straw. These legal parameters allow scope for surplus N in soils and the risk of \(\text{NO}_3^-\) leaching into waters. A first step must be therefore to improve the current Ordinance and new provisions must be examined in view of their efficiency.

References