# Effects of conventional and organic land use types on water protection criteria in Germany

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## 1 Introduction

The mean values and ranges of a number of water protection criteria (nitrogen budget, $N_{min}$ values in late autumn, nitrate concentrations of the percolation water, and leaching amounts) were calculated for characteristic landscapes (various conventional and organic types of arable land, grassland and forests) in Germany on the basis of research work and the literature (KOLBE, 2000, 2004). By additional evaluation steps, relationships were calculated between the recorded criteria by regression analysis, and yield, resource and environment-related efficiency coefficients were calculated for the different types of land use. Finally, the relatively close relationships between the N balance values and the other environment-related criteria were used as a basis to propose methods of balance calculations as preventive strategies for efficient water protection.

## 2 Results

### 2.1 Arable land

The main results are as follows (Table 1). Concerning the mean values for German agriculture as a whole, the main forms of land use (arable land and conventional field vegetable farming) are characterized by a total input of 234 kg and 274 kg N/ha and year, resulting in surplus values of 112 kg and 141 kg N/ha and nitrogen resource efficiencies of 54% and 49%, respectively. Intensively cultivated arable land has a mean $N_{min}$ value of 72 kg, a nitrate level of 79 mg/l and leaching of 60 kg/ha, while the corresponding values for vegetable production are even higher. A nitrogen surplus of 88 kg, a $N_{min}$ value of 57 kg and a leaching amount of 47 kg are rated as the production efficiency criteria for the pollution potential of a 100 kg N output unit for conventional, intensive arable land cultivation.

Compared to this arable land cultivation (= 100%), using the best improvements known (widespread forms of integrated crop production) and restricting cultivation in water protection areas (usually 20% less N fertilization than optimum values) can produce the following decreases: total N input –8 to -20%, N surplus –30 to –48%, $N_{min}$ –14 to –19%, leaching –5 to –27%. As with the best integrated cultivation methods, which were primarily developed from field trials, the same mean N efficiency of

**Table 1:** **Nitrogen budget criteria, $N_{min}$ values in late autumn, nitrate concentrations of the percolation water, and leaching amounts for characteristic landscapes in Germany**

| No. | Land use form | Input (kg N/ha) | Output (kg N/ha) | Surplus (kg N/ha) | $N_{min}$ (kg N/ha) | Leaching (kg N/ha) | Nitrate content (mg $NO_3$/l) |
|---|---|---|---|---|---|---|---|
| | **Arable land:** | | | | | | |
| 0 | Field vegetables (intensive) | 274 (190-443) | 133 (98-176) | 141 (92-189) | 124 (62-237) | 105 (25-170) | 142 (76-233) |
| 1 | Conventional (intensive) | 234 (172-294) | 127 (74-176) | 112 (70-170) | 72 (51-100) | 60 (20-100) | 79 (15-200) |
| 2 | Integrated farming | 214 | 126 | 78 | 62 | 57 | 70 |
| 3 | Water protection | 190 | 118 | 70 | 58 | 44 (38-50) | 51 |
| 4 | Best conventional methods | 188 (152-275) | 135 (106-169) | 58 (21-109) | 59 (31-83) | 46 (18-67) | 53 (14-149) |
| 5 | Organic farming | 126 (98-175) | 89 (55-141) | 38 (4-59) | 41 (18-57) | 22 (8-34) | 29 (12-48) |
| 6 | Long term fallows | 38 (30-100) | 34 (3-121) | 5 (-71-32) | 20 (4-47) | 14 (5-18) | 23 (1-67) |
| | **Permanent grassland:** | | | | | | |
| 7 | Conventional (intensive) | 282 (160-510) | 197 (129-340) | 91 (27-201) | 59 (11-180) | 31 (5-110) | 45 (5-110) |
| 8 | Meadow (intensive) | | | | 50 | 22 | 25 |
| 9 | Pasture (intensiv) | | | | 79 | 56 | 88 |
| 10 | Conventional (extensive), Organic farming | 127 (100-150) | 103 (24-155) | 24 (-55-80) | 25 (6-65) | 13 (1-40) | 19 (3-40) |
| 11 | No fertilisation, with crop removal or rough grazing | 33 (20-40) | 64 (32-138) | -39 (-99--2) | 11 (1-25) | 12 (5-29) | 8 (2-18) |
| 12 | No fertilisation, without crop removal, mulching | 54 (35-65) | 4 (3-5) | 50 (32-60) | 13 (2-52) | | |
| 13 | Secundary succession | 35 (30-40) | 4 (2-5) | 32 (30-33) | 22 (2-59) | | |
| 14 | Uncultivated open landscapes (non-polluted) | 10 (5-15) | 3 (1-5) | 7 (4-10) | 7 | 5 (2-10) | 3 (2-4) |
| | **Permanent forests:** | | | | | | |
| 15 | Common forests (+ new forestations of arable land) | 39 (11-64) | 18 (8-30) | 20 (8-49) | 61 (5-285) | 23 (0-70) | 24 (0-438) |
| 16 | Broad leaved forests | 35 | 18 | 17 | 60 (18-169) | 16 (1-22) | 41 (20-72) |
| 17 | Conifers | 42 | 16 | 27 | 98 (22-285) | 27 (3-70) | 56 (20-100) |
| 18 | Natural forests (non-polluted) | 12 (5-15) | 9 (5-15) | 4 (1-5) | 10 (2-20) | 3 (0-9) | 2 (0-5) |

somewhat more than 70% is attained by the methods of organic agriculture practised nowadays in arable farming. The reduction of the crop yield output by 30% produces a much higher decrease for all the environment-related criteria: N surplus –66%, $N_{min}$ –43%, leaching –63%. The pollution potentials for a 100 kg output unit can be calculated for organic arable land use with 43 kg N surplus, 46 kg $N_{min}$, and 25 kg N leaching.

## 2.2 Grassland

Of all the recorded grassland systems, the common cultivation form is characterized by the following mean values (Table 1): input 282 kg, output 197 kg, surplus 91 kg, $N_{min}$ 59 kg, and leaching 31 kg N/ha. Compared to this intensive grassland use, when employing more extensively conventional or organic grassland cultivation, a N usage efficiency of over 80% and output of somewhat more than 50% leads to a distinct decrease in the environment-related criteria values: input –45%, surplus -74%, $N_{min}$ and leaching –37 to –39%.

Other mostly not yet productive types of extensive grassland use (no fertilization, with and without the removal of harvested crops, rough grazing, secondary succession) as well as long-term fallow types of the intensively used arable land prevailing showed additional improvement of the environmental criteria. However, only by permanently removing the harvested materials is annual soil exhaustion (–99 to –2kg N/ha) possible with resulting $N_{min}$ and leaching values of about 10 kg N/ha.

Owing to the nowadays usually high N depositions originating from the atmosphere, the total input values of these extensively used grasslands and long-term fallows, and especially of uncultivated open landscapes (including nature reserves), are higher than their relatively low output values, so that in the long run the critical loads of these land types may be exceeded, resulting in an increase in the environmental criteria analysed.

## 2.3 Forests

Due to this high atmospheric nitrogen deposition and the corresponding relatively low output values (rates of growth), conifers and new forestations of the common forest types appear to be especially at risk, particularly in exposed areas. With a mean input of 39 kg N and a modest output of 18 kg N, a surplus of about 20 kg N/ha (range 8–49 kg) ultimately remains every year in these permanent forests (Table 1). Because of these higher surplus ranges, the $N_{min}$ values and nitrate concentrations rise at sometimes significantly different rates, resulting in leaching amounts of 0–70 kg and a mean value of 23 kg N/ha and year to be observed. By contrast, non-polluted natural landscapes (grassland and forests) are characterized by a N input of 5–15 kg and a N surplus range of between 1 and 5 kg/ha and year. In these areas, which nowadays hardly exist anymore in Central Europe, the mean $N_{min}$ and leaching values are found to be lower than 5 kg N/ha.

# 3 Conclusions

## 3.1 Diminishing yield return

The study has shown that there are close causal relationships between the nitrogen input and output relations and the water protection criteria $N_{min}$ values in autumn, the $NO_3$ concentration of the water, and the N leaching amount of the typical land use types in Germany (Figure 1). The basic process is as follows: The increase in N input (by fertilization or deposition from precipitation) is paralleled by a diminishing increase in the N output caused by the declining yield increase of the growing plants. Therefore, the N surplus of the land use type is increasing disproportionately – and consequently so are the $N_{min}$ values, the nitrate content of the percolating water and the leaching amount.

The three fundamentally different land types' (forests, arable land and grassland) very different amounts of nitrogen need to increase before the N surplus and water characteristics change to unfavourable values. Forests, for example, use only 10–20 kg N/ha and year for their growth. But their N input today is often much higher through atmospheric N import due to intensive agriculture (and other reasons). Accordingly, the water characteristics are changing to unfavourable values despite the relatively low total nitrogen input – and the critical loads for forests are being easily exceeded today.

Arable land is characterized by genetically determined much higher crop growth and nitrogen concentrations and, therefore, a higher export potential for nitrogen occurs with the yields of the arable crops, so that the highly disproportionate increase in the nitrogen surplus, nitrate content of the water and leaching amounts takes place at much higher input values. Moreover, these non-linear processes can be seen with grassland at even higher N input values, because the N output values with the yields are usually higher than with arable crops (Figure 1).

## 3.2 Relevance to organic agriculture

As can be seen from Table 1 and Figure 1, the total N input of the actually existing forms of organic arable land as well as for organic grassland use is much lower (sometimes more than 50%) than in the intensive conventional forms of land use. Given the rule of diminishing yield increase, the yield and hence also the mean output of nitrogen are only somewhat lower, so that the N surplus and the water protection criteria of the extensive forms of agriculture are more favourable. Therefore, these environmental effects of organic agriculture seem to be 'internalized' in the organic products.

The same is true with calculated efficiency coefficients. Favourable results are always obtained for organic land use forms compared to conventional forms after calculating the input/output relation for nitrogen on a land area or product amount basis. A mean value of around 25 mg nitrate in the water is observed with organic forms of arable or even better with organic grassland use. With conventional

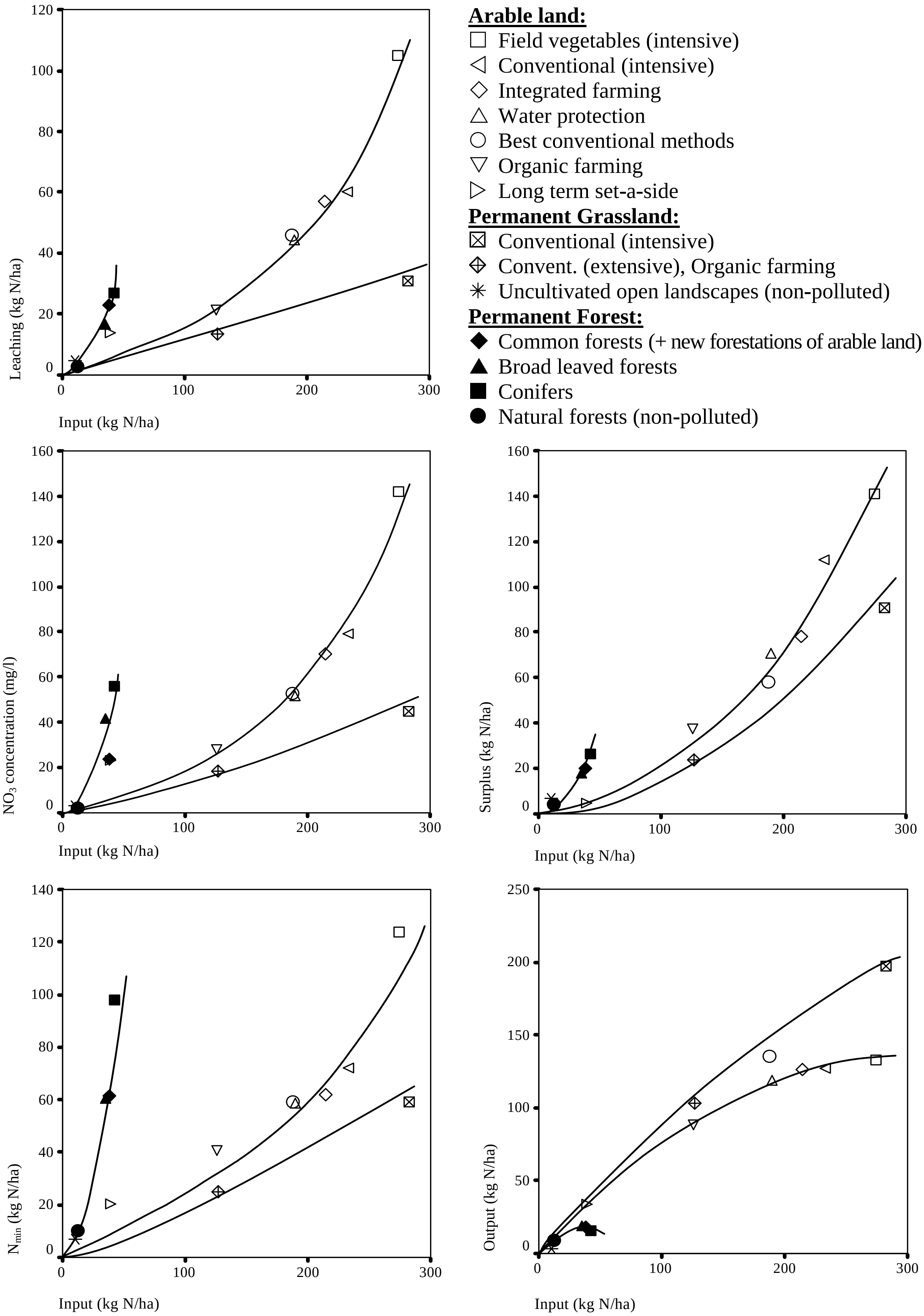


**Figure 1:** **Relationships between increasing nitrogen input and nitrogen output of plant material, nitrogen surplus, $N_{min}$ content of the soil, leaching amount and nitrate concentration of the water in arable land, grassland and forests in Germany**

forms, the limit of 50 mg nitrate is often exceeded. The forms of organic agriculture mentioned have very favourable environmental effects, especially concerning the water protection criteria examined.

In addition, the study has shown that the dispersion of the calculated values of every criterion is very high in every land use type. But when calculating absolute values, those forms with mean lower input values (for example organic farming) also have lower ranges. From these results it can be concluded that there is high variation caused by the crop species, land form, soil type, climatic factors and the amount of input. Consequently, there is still plenty of room to optimize not only conventional forms but also organic forms of agriculture to minimize the negative environmental effects. But in the long run, optimization strategies can only be successful by decreasing the nitrogen surplus, either by securing a healthy yield with decreasing input or by aiming at a higher output with equivalent input.

## 5 References

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