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Sustainability of nutrient flow in intensive pig production

Using the example of pig production, the study analyses the specific circumstances of the ILA and its dynamic development for the corporate material flows. Based on a detailed material balance of nitrogen (N) and phosphorus (P), the study is particularly focused on the advantages and disadvantages of management in an Intensive Livestock Area (ILA). The study describes potential environmental impacts on growing regional and operationally focused pig production and demonstrates positive aspects of intensive animal husbandry on the material flow management.

Keywords
Nitrogen and phosphor flow, intensive Livestock Areas (ILA)

Abstract
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In the past, sundry authors have concerned themselves with material flows in intensive pig production [1, 2, 3]. Also the significance of regional concentration processes has found its way into various by different scientific disciplines [4, 5]. However, the sustainability of the current development in ILAs should be checked with respect to the flow of farm materials as there has been both a dynamic increase in regional concentration processes and an increase in the requirement for sustainable production. With respect to sustainable development, the farms in such regions often have a greater size and degree of specialisation than farms in other regions, which lead to higher individual material flows per farm.

Because of this, the management aspects of material flow of ILAs must always be considered with respect to the prevalent production conditions [6]. The ideal management strategy always depends on the individual situation [7, 8].

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The present study elucidates any possible environmental risks associated with contemporary concentration processes and recommend improvements in management techniques at the farm level.

Materials and methods

For the investigation, the total N and P flows on six pig farms was analysed over a period of 4 years. The region that was chosen for the present study was Northwest Germany which is characterised by a very high regional and farm concentration of pigs [9].

The average area of the six farms was 68.41 ha. The crop production primarily involved varying proportions of cereals (ø 36.32 ha) and maize (ø 25.68 ha), with small amounts of oilseed rape (ø 5.34 ha) and other crops (ø 1.09 ha). The farms' subsoil was sandy or clayey and of middling quality (German soil quality index: 18–35). In addition, both the number of animals per farm (ø 329 sows [PP + CF], ø 784 finishing places [FP + CF]) and the concentration of animals per unit area (farm ø 2.73 LSU/ ha; region ø 2.98 LSU/ ha) reflect the regional conditions. The production is middling (21.9 weaned piglets/sow & year [PP + CF]; daily weight increase/finishing pig 707 g [FP + CF]).

The flow of materials through the animals was budgeted according to the information given by the German Society of Nutritional Physiology [10]. The values for the types and quantity of gaseous and dissolved air pollutants arising from the crop production were taken from previous studies [11].

Particular attention was paid in this study to the use of manure because of its great importance for maintaining sustainability in an ILA. The farmers' own perception of the amount of manure produced on their farms and its contribution to plant nutrition was also considered in detail to see if there were any discrepancies in the perceived quantities used and the true ones. The nutrient content of the manure produced by each of the six farms was determined by sampling. The annual manure usage was then calculated by multiplying the nutrient content by the amount of manure applied to the individual crops as given by the farmer. These values were then compared with the true audited nutrient production on the farm and the differences to the perceived amount were determined.

Each farm audit covered the material input, the intra-farm transformation processes and the material output of all the farm's goods. The calculation period used was the standard German animal husbandry year (01 July–30 June). All the crops grown directly on the farm were included in the crop production audit. The soil on each of the farms was analysed over a period of 15 years.

Results

The analysed soil shows that in the mid-1990s the intensification of pig production and an associated non-professional manner with the manure has led to high accumulation of P in the soil (1995–2005 = 22,7 [± 21,3] mg/ 100 g soil).

Since then, the soil P concentrations have reduced and reached optimum values at present (2005–2009 = 12.7 [± 6,9] mg/100 g soil). In addition to the reduction in the mean P load of the farmland, there has also been a strong reduction in the variation in P load on the six farms. This means that the land on these farms has achieved a more uniform condition than before. Looking at the correlations of the soil P load with the distance of the field from the farm buildings, it is apparent that in the 1990s the P supply within the soil, at the farm level, was closely related to how near it was situated to the farm buildings: the manure was not evenly distributed over the total land of the farm.

The actual components of the crop production on the six pig farms are shown in **Figure 1**.

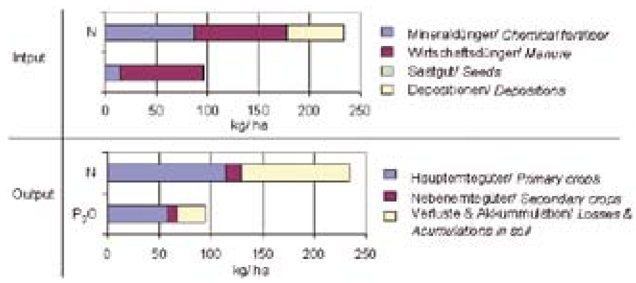
The mean turnover of these two elements in the crop production was 233.7 kg N/ha and 96.3 kg P_2O_5/ha, with efficiencies of 0.55 (kg Output/kg input) for N and 0.69 for P_2O_5 (kg Output/kg input). The mean input via chemical fertilisers was 86.9 kg N and 14.2 kg P_2O_5 per hectare. An average of 90.3 kg N and 81.4 kg P_2O_5 was applied via manure. Also the depositions have a high level which average 55 kg per hectar [11].

Soil accumulation or leaching also caused a loss of these elements from the crop production side of the system. This was found to be an average of 104.54 kg N and 26.8 kg P_2O_5 per hectare. The efficiency of the crop production was due to the differentiated utilisation of the output - the harvest products -, but though the material input (fertilisers) was found to have a greater effect. On the N balance a reduction in chemical fertiliser input had a greater effect than a reduction in manure application. In contrast to the N balance, however, there were no large differences between the effects of the chemical fertiliser and the manure on the P balance.

However there was a high difference between the perception of the fertilizer volume and the effective fertilized volume. **Figure 2** shows the differences between the amount of fertilizer applied as estimated by the farmer and the true amount of applied to the fields. The figure summarises the information from all six farms over the whole four-year period of the investigation.

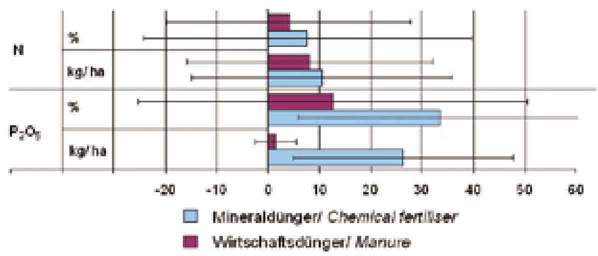
Despite the high degree of variation, it can be seen that the quantity of fertiliser used was underestimated for both elements and especially with respect to P: manure 33.6 % of amount applied and chemical fertiliser 12.7 %. The high degree of scattering of the differences shows the very high variations. Such high scattering means that there is a much greater potential for improvement in the farmers' perception of fertiliser use than can be assumed by just looking at the means of these values.

Fig. 1



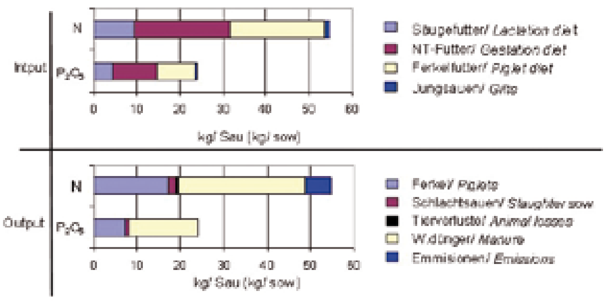
Balanced elements in the crop production

Fig. 2



Difference between the perception of the fertilizer volume and the effective fertilized volume

Fig. 3



Balanced elements by breeding sows

Figure 3 shows the balanced Elements by breeding sows by the study.

The total annual turnover per pig place in the piglet production lay between 54.7 kg (PP) – 54.9 kg (CF) for N and between 24.0 kg (PP) – 24.2 kg (CF) for P_2O_5. The average values in the finishing pig production ranged from 17.7 kg (CF) – 18.0 kg (FP) for N and 7.7 kg (FP) – 7.9 kg (CF) for P_2O_5. Losses to the system arose through the outputs mortality, emissions and manure. The audit revealed an annual manure production per pig place between 29.3 (PP) – 29.6 kg (CF) N and 15.6 (PP) – 15.9 (CF) kg P_2O_5 in the piglet production and 7.2 (FP) – 7.6 kg N (CF) and 4.6 (FP) – 5.1 (CF) kg P_2O_5 in the finishing pig production.

As expected, the balance in the piglet production (PP: N = 0.35, P_2O_5 = 0.34; CF: N=0.34, P_2O_5 = 0.33) lay under that of the finishing pigs (FP: N = 0.39, P_2O_5 = 0.39; CF: N = 0.36, P_2O_5 = 0.34) due to the different production processes involved in these two production systems.

In the piglet production, an average of 85.07 g N/kg piglet produced and 38.26 g P_2O_5 /kg piglet produced entered the system via the feed. The sow diet had a greater influence on both the N balance and the P_2O_5 balance than the piglet diet. On average, the farms provided 50.03 g N and 23.06 g P_2O_5 per kg output (piglet diet: 35.04 g N, 15.20 g P_2O_5). The differences in the input data are due to the use of various diets at the different stages of production despite their similar N and P_2O_5 concentrations (lactation diet ø 26.8 g N/kg and ø 12.6 g P_2O_5/kg; gestation diet ø 22.7 g N/kg, ø 10.4 g P_2O_5/kg; piglet diet = ø 28.0 g N/kg, ø 12.6 g P_2O_5/kg).

With a mean N balance of 0.39 (± 0.17), a mean of 73.20 (± 5.03) g feed N was required for each kg increase in finishing pig body weight. While with a mean P_2O_5 balance of 0.38 (± 0.14), a mean of 31.93 (± 1.87) g feed P_2O_5 was required for each kg increase in finishing pig body weight. With a mean feed intake of 2.88 (± 0.1) kg/kg increase in body weight, the feed input had a concentration of N = 25.5 (± 1.4) g/kg and P_2O_5 = 11.1 (± 0.5) g/ kg. The balance ist resulting by a daily weight of 610–798 g.

Conclusions

The analysis of the flows of N and P in the ILA in Northwest Germany has shown that intensive farming can also fulfil the requirements of an environmentally friendly system with sustainable material flows. The N and P efficiency was still higher than with other less intensive forms of pig production. In addition to the differences in the utilisation of the material input arising from the different types of pig farm (PP, FP, CF), a differentiated exploitation of the genetic potential of the animals (i.e. weaned piglets/sow and finisher pig feed conversion) was decisive for ensuring a high degree of mass efficiency. The efficiency of the crop production was due to the differentiated utilisation of the output – the harvest products – in the ILA in Northwest Germany; though the material input (fertilisers) was found to have a greater effect. Both the material input from chemical fertilizer and the manure are existing differences here.

The general regional differentiation of farm types with respect to intensive animal production and regions with crop production appears to be reflected on farm level in the ILA Northwest Germany. Particularly, the contribution of the animal production (via the manure) to the nutrient supply in the crop production has not been taken enough into consideration with respect to determining the chemical fertiliser input. The high variation in the individual farmers' perception of the amount of fertiliser used underlines this de-integration.

High productivity in animal production may not take place if it overloads the land with manure. Even though an ILA's economic advantages lie in animal production, the interconnections between animal and crop production and their potential danger for the environment make it necessary that attention is particularly paid to the usage of manure produced within the system. The production sustainability in an ILA is much more a consequence of how the farmers react to the conditions prevalent in the region and not just on the production conditions themselves.

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