# *Evaluating the impact of intensification of dairy production on the sustainability and environmental safety*

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**Abstract:** The intensification of dairy production does, however, run the risk of overstretching the agricultural system, with a negative impact on the sustainability and environmental safety of the production itself. The increase in production intensity in the period stretching from 1993 to 2006 was analyzed, presented and assessed on the basis of the development of the Educational and Research Farm at the Justus-Liebig-University Gießen, Gladbacherhof. The aim is, therefore, to use computer assisted business balancing models and data from the inventory management to show the development of the business for a defined period, so that conclusions can be drawn for its continued development. The overall business production and reproduction processes were highlighted, differentiated for outdoor research (arable farming) and indoor research (livestock farming), taking into account the purchase of relevant resources and plant and animal market production. During the observation period the livestock numbers have grown from 0.5 LU ha /total agricultural land to 1.1 LU ha / total agricultural land. The change in livestock, in livestock numbers and feeding diets has brought about a continuous increase in the annual levels of organic fertilizers from livestock farming to supply arable land and grassland with nutrients and organic raw materials. The continuous increase in the supply of nutrients and organic raw materials per area unit as an expression of the increase in production intensity was not able to contribute to an increase in yield for the relevant arable crops in the investigation period. Continuous improvements in the results were achieved in the investigation period in the humus and NPK levels per ha of farming land. The humus supply rate rose from 80 to 120 %. Taking into account the changes in the soil content, the nitrogen balance increased from 40 to 80 kg/ha. Due to the unchanged yields, the overall nitrogen use on arable land dropped from 79 to 46%. In the present case it can be resumed that computer assisted business balancing models are able to evaluate the impact of intensification of the dairy production system on the sustainability and environmental safety.

**Keywords:** dairy production, sustainability, environmental safety

## Introduction

Low agricultural prices and increasing cost pressure are forcing even organic farming operations to increase their production intensity to enable them to stay in business. Typically, a decline in profit margins due to an increasing competition and lower revenues (Becker et al. 2004) as well as cost increases for labor and input use (Sanftleben 2004) are to be expected. In order to ensure the survival of the farm, alternative development strategies need to be searched starting from the operational management. Solutions are purpose to optimize company resources (e.g. more effective use of forage), in the expansion (e.g. enlargement of the land use or of the dairy herd) and / or the increase in productivity (e.g. increase in yields per hectare, increase in milk yield per cow (Pallauf 1977, 1985)).

### Increasing production

The intensity of production is to be understood as the degree of force or strength with which a production process is conducted, and will be described economically by the inverse of the production coefficients. In a farm system the production factors mainly correspond to the amounts, timings and frequencies of application of Fertilizer or of feed. By an increase of Livestock units and milk yield a change in the amount and form of manure and slurry as well as the nature and amount of purchased feed is to be expected.

### Use of Resources

The higher the level of milk production per cow and year is achieved, the higher is the demand for highly digestible, high-energy roughage and concentrate feed (Pallauf, 1985, Gruber et al., 2000, Spiekers, 2002). This principle applies to the conventional dairy farming and organic dairy farming alike. In particular, the model of ecological agriculture (Köpke, 1990) makes it necessary for the purposes of a largely closed corporate nutrient circuit to use in-house resources and to supply with them an increased need. However, if these requirements can not be fully covered from the farm`s own resources, feed purchasing is used to close the coverage gaps (Sundrum & Sommer, 2011). This kind of development does, however, run the risk of overstretching the business system.

### Aims of this study

The increase in production intensity in the period stretching from 1993 to 2006 was analysed, presented and assessed on the basis of the development of the Educational and Research Farm at the Justus-Liebig-University Gießen, Gladbacherhof. Over the investigation period it is clearly expressed in the specific increase in cattle numbers to approximately 1 LU/ha total agricultural land, combined with an increase in the annual milk yield to almost 8,000 kg/cow. The aim is, therefore, to use the computer assisted business balancing model REPRO and data from the inventory management to show the development of the farm for the above period, so that conclusions can be drawn for its continued development and its impact on the sustainability and environmental safety of the production itself

## Material and Methods

Crop and livestock production have been differentiated analysed to show the production and reproduction process. Data basis was the farm accountancy, the Acreage index and the milk recording data. Also analyzes of feed were carried out. The analysis and evaluation of the farm system was carried out in particular with the use of structure, earnings and reproduction indices according to the in REPRO implemented methods.

## Results

### Farm development

The observation period could be divided into three distinct operational development stages:

1993 – 1996 (30 dairy cows in addition to progeny, tie stalls), 1997 – 2001 (Land lease, renovation of free stallbarn to sloping floor straw yard system, extension to 60 cows plus female progeny) and 2002 – 2006 (building of new cubicle housing, conversion to manure, extension to 86 cows plus female progeny). During the 2nd and 3rd development stage the proportion of agricultural land was relatively stable with approximately 70% arable land and 30% grassland. At the end of the 3rd development stage the proportion of agricultural land reached approximately 50 % cereals, 35% legume crops (fodder and grain legume crops) and 15% row crops, including silage maize. For the sake of a rise in milk yield, silage maize cultivation was increased from 5% to approximately 13% of the arable land during the 2nd and 3$^{rd}$ development stages, especially at the expense of grain legume crops. At the end of the investigation period, there was an ideal ratio of humus-consuming/humus-adding crops of 65:35 for organic farms.

The number of dairy cows increased from 29 to 84 in 2006 during the investigation period. The young cattle herd developed in line with the dairy cattle. The number of animals kept on the farm, expressed in livestock units, more than tripled from 40 LU in 1993 to 125 LU in 2006. Taking into account an additional lease of land in 1997, the livestock numbers have grown from 0.5 LU ha /total agricultural land to 1.1 LU ha / total agricultural land. Monogastric animal production has only ever played a minor role.

Table 1: General summarized characterization of the farm structure and its Development differentiated in the development stages of the farm.

| Stage | AL $ha^{-1}$ | GL $ha^{-1}$ | Cows | Young cattle | LU | LU ha $AL^{-1}$ | LU ha $LF^{-1}$ |
|---|---|---|---|---|---|---|---|
| **1993−1996** | 55 | 25 | 29−42 | 15−43 | 42−74 | 0,8−1,2 | 0,6−0,9 |
| **1997−2001** | 100 | 45 | 48−60 | 40−57 | 82−117 | 0,8−1,0 | 0,6−0,8 |
| **2002−2006** | 100 | 45 | 63−84 | 60−77 | 123−161 | 1,1−1,4 | 0,8−1,1 |

**AL:** arable land; **GL:** grasland; **LU:** Livestock Unit. Information: cows and young cattle in units per annum. First digit in each case shows number at beginning of the development stage, the last number at the end of the development stage. Example: LU ha $AL^{-1}$: 1.1 Livestock Units in 2002, 1.4 Livestock Units in 2006.

## Feeding development

The quantity of feed used yearly on the farm increased from 267.6 t DM to 799.4 t DM. Although the use of feeding stuffs from the farm itself increased its relative proportion dropped from 97% to 77%. The amount of feed purchased in the investigation period rose from 3% to 23% on the basis of the dry matter. The amount of forage in the feed ration represented between 75 and 90% in the same time, the average being 82%. The amount of concentrate in the feed ration represented between 10 and 25%, the average being 16%. The amount of mineral feed in the feed ration represented on the average 2%.

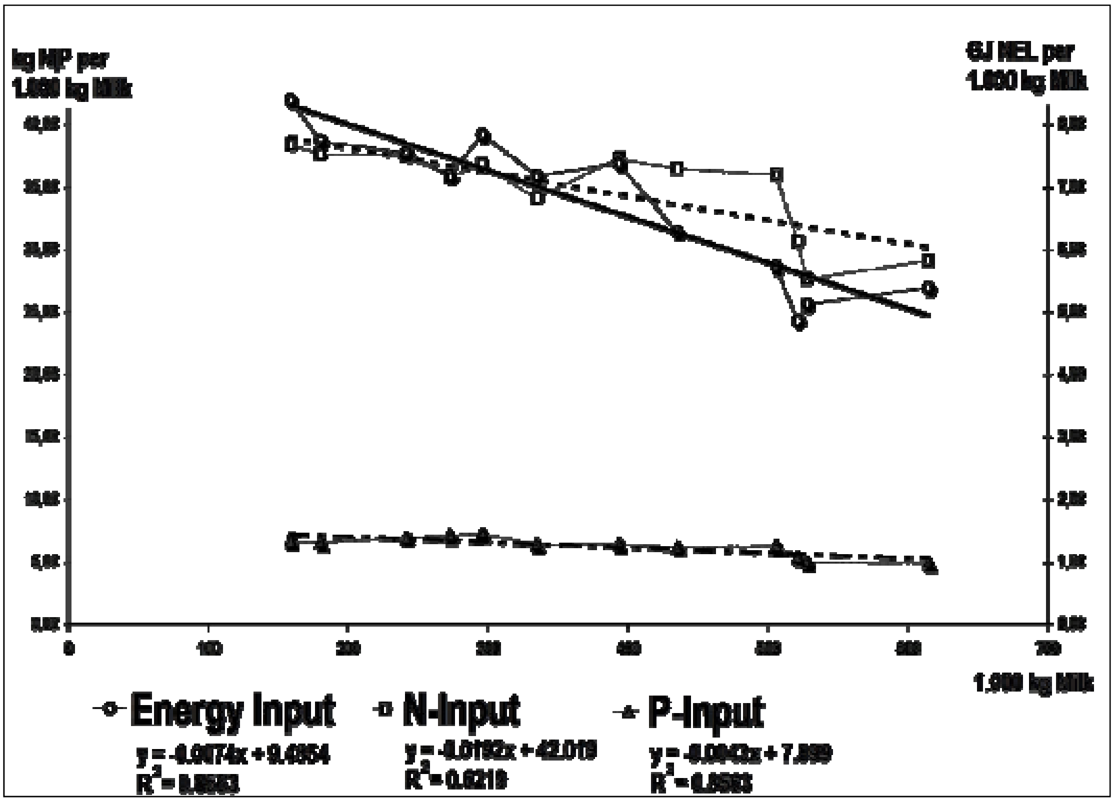
The energy concentration of the feed used was continually increased during the course of the 1st and 2nd stages, starting at 5.9 MJ NEL kg $DM^{-1}$ and rising to 7.2 MJ NEL kg DM-1 in 2002. In the same period the protein concentration of the feed rose from 152 to 206 kg XP kg $DM^{-1}$. On account of the restrictions on the use of feeding stuffs from conventional sources that came into force in 2002, the stated quality parameters could not be observed in the 3rd development stage, despite increasing the level of silage maize in the subsequent crop in the rotation and purchase of organic grain legume meal. This had a negative impact on the milk yield per cow.

## Dairy production

The annual milk level increased during the 13th year of the investigation from 190.000 kg to some 600.000 kg in 2006. The milk protein level also tripled, from about 5.900 kg/year in 1993 to reach approximately 19.500 kg/year in 2006. The N-volume exported with the milk sales increased from 945 to 3.125 kg/year in 2006. The qualitative and quantitative improvement in the feed available, improvements in farming conditions (1993 – 1996: tie stalls; 1997 - 2001: sloping floor straw yard system and since 2002 cubicle housing) and the use of breeding cattle that produce greater yields, have secured an increase in milk output from 6.243 to 8.157 kg milk per cow in 2003.

All these measures as a whole prevented a drastic drop in the milk output after 2003 with the prohibition on the use of conventional brewer`s grain malt. Over the investigation period the efficiency of the milk output raised steadily, i.e. for each kg of milk produced, less and less feed energy and nutrients were required in each subsequent year (see Fig. 1).

Figure 1: Development of the nitrogen, phosphorus, and energy input for the production of 1.000 kg of milk depending on the quantity of milk produced per year

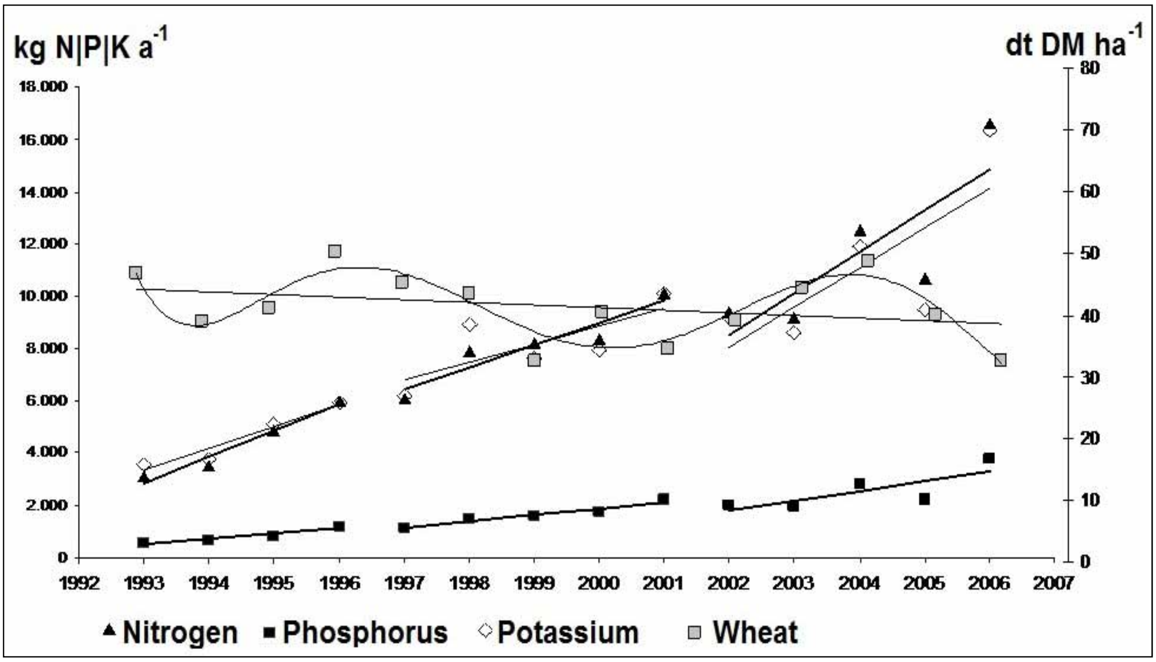



## Cropping system

The change in livestock, in livestock numbers and feeding diets has brought about a continuous increase in the annual levels of organic fertilizers from livestock farming to supply arable land and grassland with nutrients and organic raw materials. Annual levels of dry fertiliser supplied and applied via barn dung and slurry or liquid manure increased for each hectare AL from roughly 1.4 to roughly 3.3 t, or from approximately 1.8 to approximately 2.7 t per hectare of total agricultural land. This therefore led to a significant increase in the supply of nitrogen, phosphorus and potassium. The continuous increase in the supply of nutrients and organic raw materials per area unit as an expression of the increase in production intensity was not able to contribute to an increase in yield for the relevant arable crops in the investigation period.

The mean yield level was 3.9 t/ha for cereals, 26.0 t/ha for silage maize, and 23.5 t/ha for potatoes. The yield level can at best be described as stable. Continuous improvements in the results were achieved in the investigation period in the humus and NPK levels per ha of farming land. The humus supply rate rose from 80 to 120 %. Taking into account the changes in the soil content, the nitrogen balance increased from 40 to 80 kg/ha. Due to the unchanged yields, the overall nitrogen use on arable land dropped from 79 to 46%. This result still needs to be checked. Overall, substantial reserves for a step-up in yield are obvious (see Fig. 2).

Figure 2: Development of the supply of nitrogen, phosphorus and potassium in the investigation period compared with the development of the yield at the example of winter wheat




## Discussion

It turned the question first, how the available nutrient supply could be increased. This was due mainly by extending the additional feed purchase. In this way, the strong increase in demand for feed the dairy herd could be satisfied. This led to larger amounts of nutrient excretion and to a higher offer of manure and slurry on an unchanged sized agricultural area since 1997. By opening the farm nutrient cycle, a higher yield potential in organic farming revealed, as well Kristensen et al. (1995) suspected. The fact of increasing nutrient balances shows that the additional nutrient supply could not be converted to yield. It remains to clarify the question of whether a constant supply of nutrients would possibly not lead to a permanent loss of yield. At this point, the risk of overburdening the farm system gets clearly. While an increase in productivity was achieved through appropriate measures in milk production, the success stayed on the arable land off yet. Indication of this is in particular the development of the N-balances, which is, by definition, the lost amount of reactive nitrogen (Leithold 1991). As a result the sustainability and environmental impact of the production process decreases. It is therefore for the future the task of improving the utilization of nutrients on the plant area. Here it is important to delineate the responsible factors (Eltun 1995). Using optimized production technology, customized fertilizer application rates (Nieder and Richter 1999) especially in corn (see Maier (1998), Büchter et al. (2001)) and a good crop rotation can reduce N losses (Ruhe et al. 2003) and so presumably convert into additional yield.

## Conclusions

The specific increase in cattle numbers to approximately 1 LU/ha total agricultural land can raise the level of available nutrients in the farm nutrient cycle. This higher production intensity level must not automatically lead to additional yield. Therefore it is necessary to optimize the production processes especially on the arable land to make nutrient use more efficient. Otherwise the sustainability and environmental safety of the farm cycle system can be weakened because of rising nitrogen balances. In the present case it can be resumed that computer assisted business balancing models are able to evaluate the impact of intensification of the dairy production system on the sustainability and environmental safety.

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