# DECISION SUPPORT MODELS FOR THE DESIGN OF ANIMAL HUSBANDRY AND PLANT PRODUCTION PROCEDURES

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Abstract: An agricultural system which conserves natural resources and operates on an economically sound basis needs decision support on the management level. Therefore models dealing with the choice and design of plant and animal production procedures are being developed at the ATB. A characteristic feature of these models is the simultaneous consideration of environmental substance flows and economic information. Physical data aggregated to environmental impact groups, supplemented for important segments by the estimation of environmental costs, are available as decision-making parameters in addition to economic data.

Keywords: decision-support-models, substance-flows, economy, plant-production, animal-husbandry

## 1 Introduction

Farms preparing to face the future must tackle problems on a number of fronts since successful agricultural production is limited not only by economic restrictions, but more and more also by ecological demands. These demands form the background to the development of computer-based models in the Institute of Agricultural Engineering Bornim (ATB, Germany) to support the decision-making process on the management level for the design and the choice of production procedures.

## 2 Components of the model

### *2.1Resource use*

The information about resource use is targeted to make the environmental load visible and to allow optimisation of the procedures with consideration given to relevant agro-environmental indicators. The resource use is therefore primarily monitored as a load on the environmental media air, soil and water.
Agriculture is responsible for relevant environmental stresses in the form of regional nutrient surpluses, particularly nitrogen and phosphorous. Additionally, agriculture contributes to the greenhouse effect in the atmosphere by producing climate relevant gases. Also relevant environmental impacts can be caused by the use of agriculture-specific ammonia, which contributes to local acidification of eco-systems.

The evaluation of the given substances is initially carried out by summarising and specific weighting in environmental impact groups (Table 1).

Table 1: Enviromental impact groups for the evaluation of resource use

| groups | relation | substances | | | | | | | dimension |
|---|---|---|---|---|---|---|---|---|---|
| | | $NO_x$ | $SO_2$ | $CO_2$ | $CH_4$ | $N_2O$ | $NH_3$ | $PO_4^{3-}$ | |
| | | environmental impact factor | | | | | | | |
| green-house gases * | $CO_2$ | | | 1 | 11 | 270 | | | global |
| eutrophication | $PO_4^{3-}$ | 0.13 | | | | | 0.33 | 1 | local |
| acidification | $SO_2$ | 0.7 | 1 | | | | 1.88 | | supra-regional |

* 100 years integration time (Source: IPCC)

*2.2 Economy*

Characteristic farm management indicators are calculated in the models besides resource use. Partial and full cost calculations of the production procedures are drawn up, depending on requirements. The micro-economic data base of the models is constituted by regularly used calculation data (KTBL 1996). The factor demand of the production procedures is calculated besides costs.
To be able to evaluate different environmental loads on a comparable basis, the noxious gases related to the production procedures are evaluated by calculated costs of environmental pollution. Values calculated by Berg (1995) are used as standard data set. For reasons of methodology and contents the calculated environmental pollution costs can currently only be seen as a rough orientation.

## 3 Model family

*3.1Plant production*

The process-oriented model for plant production combines economic and environmentally relevant data on a comparable basis.
Gross margins and costs are calculated on the economic level based on the quantity framework of the production by combining price and quantity data. Resource use is calculated by combining production inputs and noxious gases on the physical level. Some selected basic data for the calculation of air-borne environmental load which can be expected from the provision of farm inputs and capital investments are shown in Table 2.

The data shown in Table 2 are based on a process chain following the TEMIS - approach (**T**otal **E**mission **M**odel of **I**ntegrated **S**ystems, Fritsche et al. 1995). The calculation is based on specific energy use for raw material extraction, production and delivery of the product to the customers. The specific noxious gas load of Table 2 is calculated by referring to the mix of energy sources in the single production steps.

The reaction of the biological system has to be considered in addition to the data shown in Table 2. This includes the micro-biologically conditioned release of $N_2O$ and $N_2$, as well as the $NO_3$ - transfer depending on the fertiliser application.
A farm management calculation is drawn up in addition to the calculation of the resource use. The calculation of resource use and characteristic farm management figures is carried out using a Visual Objects based Windows-application.

### *3.2Animal husbandry*

The combination of environmentally critical substance flows and economic data represents the core of the animal husbandry model (see Figure 1).

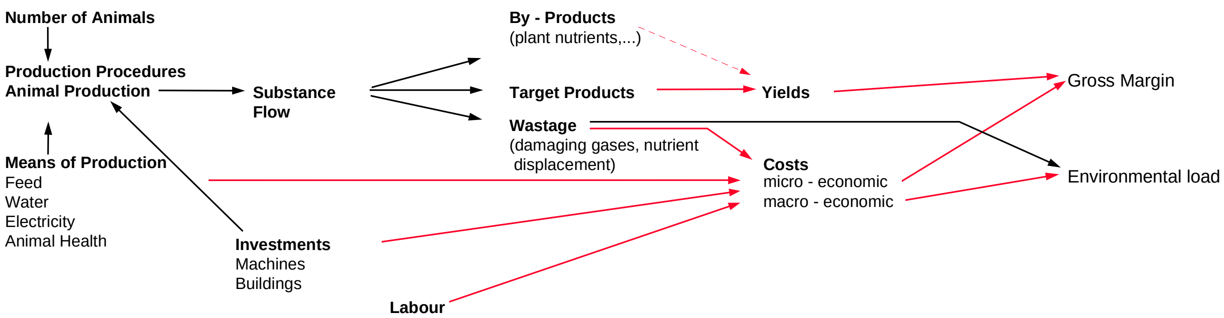


Figure 1: Information flow and output in the animal husbandry model

The information flow presented in Figure 1 is the basis of a decision-support model, SimSET, for cost-benefit-analyses of environmental protection measures in animal husbandry (Maul & Koch 1996).
The SimSET-model permits a holistic evaluation, starting from feeding up to slurry storage and referring to all relevant procedure steps. The user can combine multiple management and technical measures; the present prototype is able to calculate well over 1000 combinations. SimSET is currently limited to commonly used slurry-housing systems in pig fattening. The SimSET-prototype is now in the evaluation phase. It is planned to extend the procedures available by slurry field application and solid manure procedures at a future date.

## 4 Selected model results

In the following some calculation results of the SimSET model are presented and discussed. The calculated scenarios deal with different variants of environnmental protection measures in pig fattening. The reference variant was defined as a fattening house with slatted floor for 1000 pigs, two-phase liquid feeding, 25 kg piglet weight, 115 kg finished weight, 700 g daily weight increase, slurry storage tank with 12 m diameter (113 m² surface area), piglet price of 80 DM, 360 DM/t feed costs and 17.5 DM/LU other costs.
The reference variant thus defined is alternatively extended by different environmental protection measures:

- Emission reduction in the housing by using a biofilter.
- Emission reduction by acidification of slurry with lactic acid.
- Emission reduction by slurry store cover.
- Emission reduction by a combination of acidification of slurry and slurry store cover.
- Emission reduction by a combination of using a biofilter in the housing and a slurry store cover.

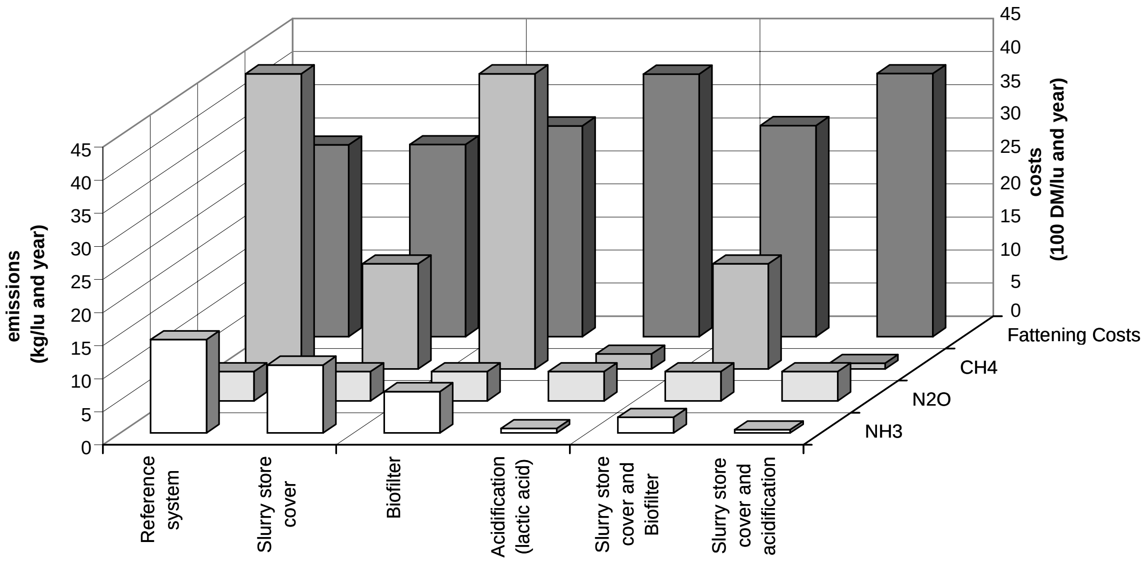


Figure 2: Impact of emission-reducing measures on emissions and fattening costs in pig fattening operations simulated with SimSET

As expected the calculated emissions of the reference variant without environmental protection measure are highest and the fattening costs are lowest here (2900 DM/LU and year). None of the defined environmental protection measures has an impact on the extent of $N_2O$-emissions. $CH_4$- and $NH_3$-emissions are substantially reduced by using a slurry store cover, while the total fattening costs are hardly increased. Fattening costs are increased by 300 DM/LU and year if a biofilter is used in the stable. The load on the environment is not substantially relieved by this measure. A considerable reduction of $NH_3$- as well as of $CH_4$-emissions results from acidification of slurry with lactic acid. However at the same time the calculated fattening costs are increased by about 1100 DM/LU and year compared to the reference variant. It can therefore be concluded that the acidification of slurry with lactic acid is a highly efficient possibility of reducing emissions, but it does not pay at farm level under the existing frame conditions.

## 5 Conclusion

The models refer to agricultural production, using a holistic evaluation approach. This means, that not only the direct environmental load in the farm is made visible, but also the consumption of resources related to the provision of farm inputs and capital investments.

The differentiation on the process-relevant level combined with environmentally relevant and economic data allows a multi-dimensional assessment of management and technical measures. This means that the decision support models presented allow the user to conduct cost-benefit analyses of environmental protection strategies and to plan site-specific optimal production processes. Additionally the economic consequences of defined environment quality targets can be made visible with the models presented.

## 6 References


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Table 2: Selected basic data for the calculation of environmental load due to provision of agricultural inputs and capital investments

| Product | primary energy | $SO_2$ | $NO_x$ | $CO_2$ | CO | $CH_4$ | NMVOC | $N_2O$ |
|---|---|---|---|---|---|---|---|---|
| | GJ/t | g/t | g/t | g/t | g/t | g/t | g/t | g/t |
| Herbicide (AS) | 238.7 | 18255.7 | 19415.7 | 18851920 | 9170.1 | 40032.4 | 2609.7 | 2812.1 |
| Fungicide (AS) | 92.2 | 7049.0 | 7496.9 | 7279173 | 3540.8 | 15457.4 | 1007.7 | 1085.8 |
| Insecticide (AS) | 184.4 | 14106.3 | 15002.6 | 14567034 | 7085.8 | 30933.3 | 2016.6 | 2173.0 |
| Nitrogen-mineral fertiliser | 49.1 | 4200.0 | 101600.0 | 2343000 | 2100.0 | 8500.0 | 4900.0 | 200.0 |
| Phosphorus-mineral fertiliser | 17.8 | 1601.8 | 2448.7 | 2240535 | 1575.8 | 5559.4 | 248.5 | 167.6 |
| Potassium-mineral fertiliser | 9.1 | 749.0 | 1079.0 | 1004699 | 658.0 | 2351.1 | 117.9 | 76.9 |
| Lime-mineral fertiliser | 1.9 | 400.0 | 200.0 | 644000 | 100.0 | 300.0 | 0.0 | 0.0 |
| Agricultural machine | 46.8 | 2972.2 | 4026.7 | 1418242 | 20500.4 | 6016.9 | 523.3 | 6.5 |
| Spec.emiss. coal heating | 29.4 | 508.6 | 376.3 | 138356 | 85.3 | 14702.9 | 20.6 | 2.9 |
| Spec. emiss.diesel engine (<1MWth) | 42.8 | 5362.8 | 28795.8 | 3519444 | 3103.0 | 821.8 | 894.5 | 132.7 |
| Spec. emiss. oil-large heating (> 300 MWth) | 40.7 | 5824.2 | 4713.1 | 3623073 | 1579.2 | 989.0 | 891.3 | 130.2 |
| Spec.emiss. diesel engine (η = 0.3)* | 42.8 | 5366.6 | 42558.5 | 3522000 | 9395.7 | 903.4 | 960.4 | 137.0 |
| Spec.emiss. boiler η = 0.85)* | 43.0 | 44184.0 | 8022.7 | 3957000 | 3761.5 | 484.1 | 809.7 | 102.0 |
| Spec. emiss. gas heating (>10 MWth) | MJ/m³<br>35.4 | g/ m³<br>0,1 | g/ m³<br>1.4 | g/ m³<br>2048 | g/ m³<br>1.0 | g/ m³<br>5.4 | g/ m³<br>0.1 | g/ m³<br>0.0 |
| Avg. electricity (Mix) | MJ/kW<br>3.6 | g/kWh<br>0.5 | g/kWh<br>0.8 | g/kWh<br>712 | g/kWh<br>0.6 | g/kWh<br>1.8 | g/kWh<br>0.1 | g/kWh<br>0.0 |

* Source: Fritsche et al. (1995)