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Prototype of the agroeconomic model, including crop productivity for the Neckar basin

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1 Introduction

The “Agro-eConomic pRoduction model on rEgional level” (ACRE) is used in RIVERTWIN-Neckar to simulate agricultural production under different scenario conditions (e.g. climate change). It is a derivative of a model developed by WINTER (2005) for the Danube basin¹. ACRE simulates agricultural production for 30 districts of Baden-Württemberg which are located in the Neckar-river-basin. ACRE is an optimization model, which represents the optimal agricultural production by optimizing agricultural total gross margin (TGM) on a regional (district) level. Farming of each district is represented by one single farm, which is assumed to manage the whole agricultural production in the districts. ACRE is a comparative static partial-equilibrium model with a simulation period of one year. Agricultural production includes 20 food and non food crops as well as 12 production processes for livestock. Consisting of a process analytical approach, feeding of animals and fertilization of crops are optimized by using feed and manure produced model-endogenously. Trade between the districts is not possible. By variation of parameters included in the model scenarios can be simulated. ACRE is programmed and calculated by the modelling software GAMS (General Algebraic Modeling System). The model transfers results to other models in the integrated modelling system and vice versa.

2 Methodology

ACRE is based on an extended version of the Positive Mathematical Programming (PMP) method, published by RÖHM & DABBERT (2003). PMP is an optimisation approach that maximizes an objective value of a total gross margin function. Compared to Linear Programming (LP), PMP has the following advantages:

- a) PMP models are exactly calibrated by the reference situation and avoid overspecialization,
- b) PMP models react continuously on parameter variations and allow a flexible result calculation,
- c) PMP models tend to require less data than LP models.

(adapted from DABBERT et al. 1999, UMSTÄTTER 1999)

These features characterise PMP as a method that promises a fruitful application for regional modelling of agricultural production.

PMP was developed originally by HOWITT & MEAN (1983). In several revisions the method was improved. PARIS (1988) developed a version that requires a reduced set of information and HOWITT (1995) complemented the approach of decreasing marginal cost by the approach of increasing marginal yields. PARIS & HOWITT (1998) combined PMP with the method of maximum entropy. Recently, RÖHM & DABBERT (2003) published a version of PMP which extended the method by a further sub-dimension, the variant-activity. This variant-activity extension differentiates between two levels of activities with different degrees of substitution characteristics. ACRE is based on this extended version.

In general a PMP-model is developed in two steps. First, a LP-model calculates dual values, the shadow prices. In a second step these values are used to calibrate the PMP-model. Thus, a PMP-model is not calibrated by means of flexibility constraints. Instead, it is calibrated by the shadow prices of restrictions making sure that the observed production pattern is reproduced by the model. Therefore, PMP simulations are not limited in simulation by fixed restrictions.

According to RÖHM & DABBERT (2003) a variant-activity version of PMP is described by the following equations (Equation (1) to Equation (8)):

Equation (1) is the total gross margin function (*TGM*) and the objective function of the LP-model. *TGM* is maximised by LP subject to Equation (2) to (6). $GM_{i,v}$ is the gross margin of

¹ A differentiation in ACRE-Neckar for the model used in RIVERTWIN-Neckar (for the Neckar-basin) and in ACRE-Danube used in GLOWA-Danube (for the Danube-basin) is useful in descriptions of both models. In this context we use ACRE meaning ACRE-Neckar.

variant-activity i, v , with $X_{i,v}$ as the optimised extension of the variant-activities and $\hat{X}_{i,v}$ as the extension of the activity-variant observed in the baseline situation.

max $f(X)$ where

$$f(X) = TGM = \sum_i \sum_v (X_{i,v} * GM_{i,v}) \quad (1)$$

subject to

$$\sum_i \sum_v (X_{i,v}) \leq \sum_i \sum_v (\hat{X}_{i,v}) \quad (2)$$

Equation (2) limits the resource land and produces the dual value λ_{land} which is, as the other dual values, used in the second step by the PMP-model.

$$\sum_v (X_{i,v}) \leq \sum_v (\hat{X}_{i,v}) * (1 + \varepsilon_1) \quad (3)$$

Equation (3) restricts the amount of the total-activities. The total-activities (X_i) (which can be e.g. crop activities) are the sums of the corresponding variant-activities ($X_{i,v}$). This total-activity constraint produces the dual value λ_i .

$$X_{i,v} \leq \hat{X}_{i,v} * (1 + \varepsilon_2) \quad (4)$$

Analogously, Equation (4) restricts the amount of the variant-activities ($X_{i,v}$) and produces the dual value of the variant-activities $\lambda_{i,v}$.

The perturbation coefficients ε_1 and ε_2 in Equation (3) and (4) are small positive numbers. Therefore, the right hand side factor enlarges the restriction of the observed amounts of the activities (\hat{X}_i and $\hat{X}_{i,v}$) by a small value. This enforces the LP-model to produce dual value for each activity. Nevertheless, because the number of constraints exceeds the number of variables by one constraint, one total-activity constraint produces the dual value zero. This problem has to be solved by the calibration of the least attractive total-activity (for details cf. RÖHM & DABBERT, 2003, RÖHM, 2001, UMSTÄTTER, 1999). Equation (5) restricts a stricter constraint given by Equation (3) for the total-activities than the restriction given by Equation (4) for the variant-activities. This leads to the fact that the model substitutes the variant-activities in total-activities rather than substitutes total-activities by other total-activities. (For example a production variant in a crop activity is replaced rather than a crop activity by another crop activity).

$$\varepsilon_1 < \varepsilon_2 \quad (5)$$

$$X_{i,v} \geq 0 \quad (6)$$

Equation (7) describes the objective function of PMP version without the variant-activity extension. Only a crop activity (X_i and λ_i) appears and TGM is a sum of index i . The formulation of Equation (8) shows the hierarchical relationship between variant-activities and

total-activities. Inside the curly brackets the summands were summed up by index v , whereas the TGM is summed up by index i .

$$TGM = \sum_i X_i \left[X_i * \left(GM_i + \lambda_i * \left(1 - \frac{X_i}{\hat{X}_i} \right) \right) \right] \quad (7)$$

$$TGM = \sum_i \left\{ \sum_v \left[GM_{i,v} * X_{i,v} + \lambda_{i,v} * X_{i,v} * \left(1 - \frac{X_{i,v}}{\hat{X}_{i,v}} \right) \right] + \lambda_{i,v} * \sum_v X_{i,v} * \left(1 - \frac{\sum_v X_{i,v}}{\sum_v \hat{X}_{i,v}} \right) \right\} \quad (8)$$

Roughly described, this new version extends PMP in two notable aspects:

1) From the methodological point of view it is possible to differentiate sub-activities (called variant-activities) within main-activities (called total-activities). The flexibility of the substitution between variant-activities is larger within the total-activity than the flexibility to substitute between the total activities. This approach allows modelling of production systems where the hierarchy of substitution flexibilities determines the decision trees of alternative activities.

2) In application, it is possible to model production systems with different products and different alternatives of production. Agricultural production systems are characterised by products, which can be produced by alternative production processes. One aspect of production processes is the level of production intensity. Among other factors the choice of intensity level is influenced by local characteristics (e.g. limits of soil fertility for intensity levels) and/or by political instruments (e.g. subsidies for less intensive production). An important role can be attributed to both factors for agricultural regional and agricultural sector models.

3 Model structure

ACRE consists of two different modules: the LP-model for calibration and the PMP-model for scenario calculations. Two variants of input data are used. Parameters which are included in GAMS-code on the one hand, and comma-separated-value-data-files (csv-data-files) which are imported by GAMS on the other hand. These data files include statistical regional data of the reference year (e.g. regional crops acreages, regional number of animals, regional yields) called “basic-data” as well as scenario-input-data (e.g. available arable land, variation of yields) called “scenario-input data” which are delivered by other model parts of the integrated modelling system. Data which are included in GAMS-code are less voluminous than data in csv-files. Therefore, they can be implemented in GAMS-code and can be varied by editing the program code.

For calibration to the reference situation (year 1999) a reference model is used, while for calculating scenarios different models which were adapted to the scenario conditions are used. The reference model and the scenario models differ in their GAMS-program code, as well as in their scenario input data files.

GAMS-code implies as basic data all parameters which are used to represent the production processes (costs, labour, etc.), whereby prices and premiums are the most relevant data for scenario calculations. Further elements varied in GAMS-code for scenario calculations are constraints which are expressed as equations. Modifications of constraints are necessary for several socio-economic assumptions in the scenarios.

Csv-input-data include as basic-data:

- regional crops acreage
- regional yields
- regional livestock numbers

Scenario-input data which are delivered by other submodels include:

- watersupply and waterprice (both delivered by WEAP)
- available arable and grassland (both delivered by SLYSIS)
- changes in crop yields (delivered by EPIC)

Figure 1 shows a simplified scheme of data flow in ACRE reference model. The reference model is the model version of ACRE which is calibrated on the reference year 1999. It consists of a LP-calibration model and a PMP-scenario-model. The LP-model produces dual values which calibrate the PMP-model. These data are exported as output by the ACRE reference model via csv-data-files. The PMP-model imports the calibration data from the LP-model and imports the same basic-data as the LP-model. Also the data included in GAMS code of PMP-model are the same as in the LP-model. Thus the PMP-scenario-model represents the reference situation and calculates the output of reference scenario, which is exported as csv-data-files (scenario-output of reference scenario).

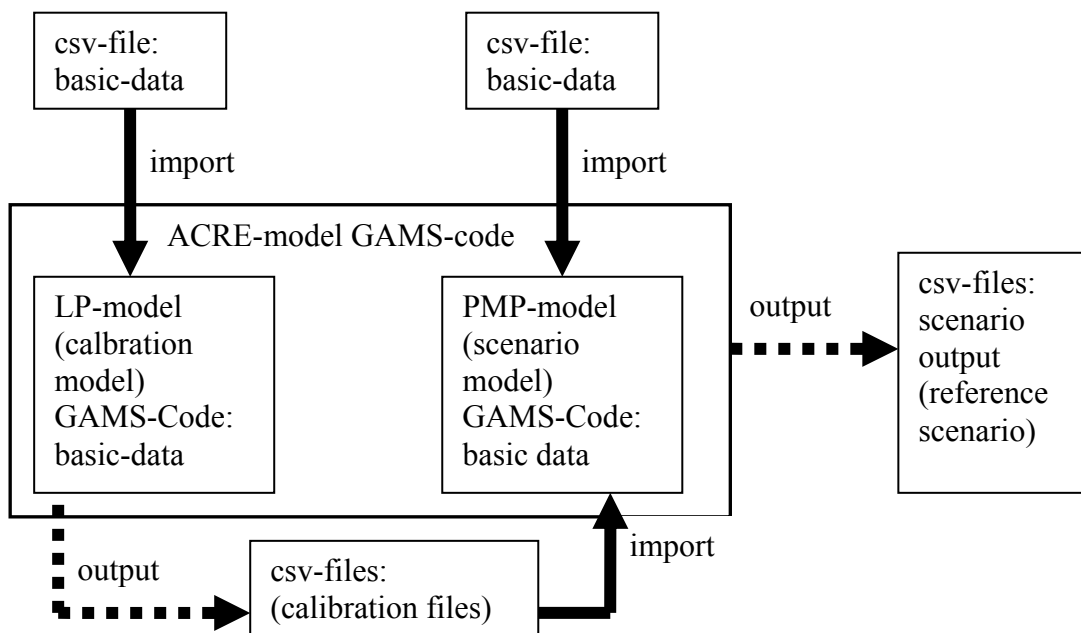


Figure 1: Data flow in ACRE reference model.

Figure 2 illustrates the data flow in ACRE scenario model. In scenario model the LP-model is deactivated. Only the PMP-scenario model is calculated. The PMP-model imports the calibration files calculated by the LP-model in the reference model. By these data the PMP-scenario model is calibrated to the reference situation. The ACRE-scenario model imports the basic-data as csv-data-file and includes the basic-data in GAMS-code. Data which are varied to simulate scenarios are either imported as scenario-input csv-files or are modified in GAMS-code. Csv-scenario input data are the interface to other models. Their output data are used as scenario input data in ACRE. Data which are varied in GAMS-code represent the assumed socio-economic scenarios. The exported output-files include the calculated scenario-

output data. For calculating more than one scenario the different versions of the ACRE scenario model were programmed differing in GAMS-code. These versions differ in GAMS-code scenario data as well as in constraints, which are equations of the model.

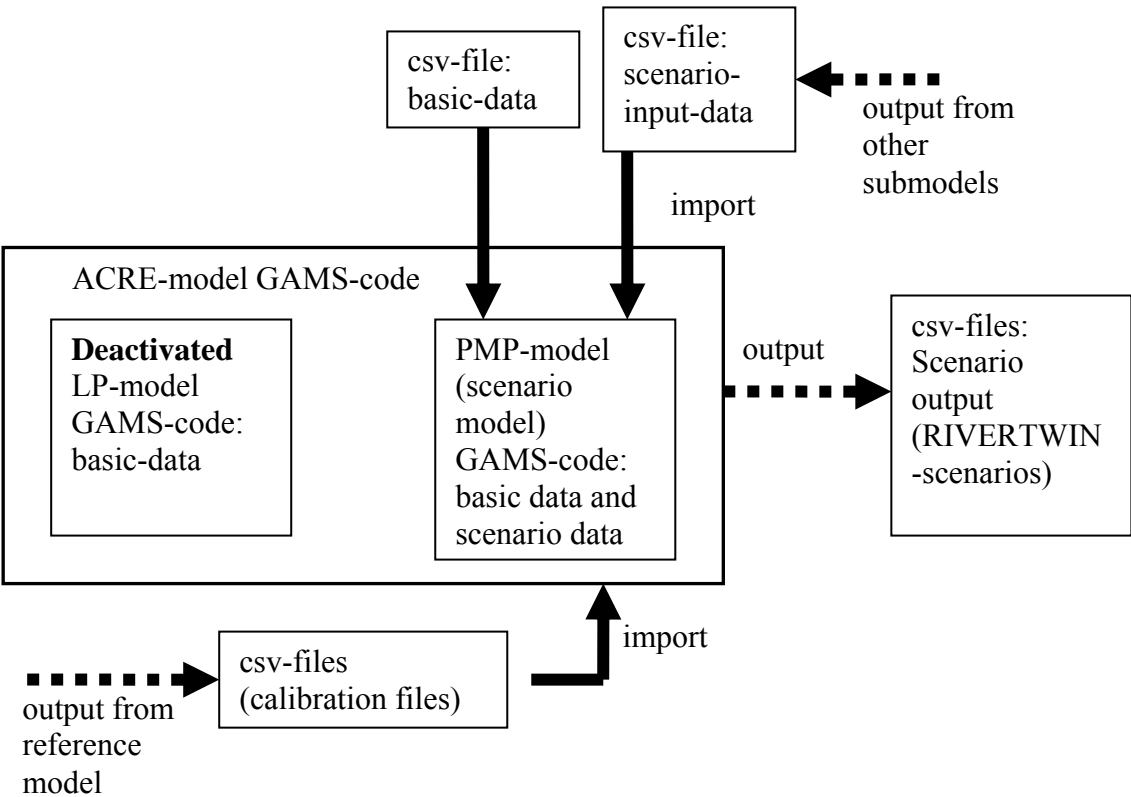


Figure 2: Data flow in ACRE scenario models

4 Agricultural production data

Agricultural production in ACRE includes the most relevant farming processes of the Neckar-basin area. Production processes are formulated by model algorithms and parameters which enable ACRE to represent realistic regional production. Farming activities include the most relevant parameters of crop and animal production. Table 1 shows the production processes on arable land and grassland and animal production. Table 2 lists the input factors which are used to calculate the production. Tables 3, 4 and 5 present the values assumed for the reference situation for prices, CAP(Common Agricultural Policy)-premiums and premiums of agri-environmental programs.

Table 1: Crops and animal production

Production on arable land and grassland			
winter wheat	spring wheat	winter barley	spring barley
oats	rye	corn	sunflowers
winter rape	potatoes	sugar beet	field peas
corn silage	clover	white cabbage	dessert apple
wine	inter crops	intensive grassland	extensive grassland
Animal production			
dairy cows	fattening bulls	breeding heifers	fattening heifers
male calves	female calves	breeding pigs	fattening pigs
horses	sheep	hens	broilers

Table 2: Input factors by which agricultural production activities are calculated

Crop production	Fertilization	Pesticides application	Animal production	Fodder production
producer prices	prices of nutrients	amount of pesticide-ingredients	producer prices	prices of concentrates
input of labour	input of labour	cost of pesticides	input of labour	input of labour
CAP-premiums	nutrient content of manure		variable production costs	grassland premiums
soil productivity			available housing	conservation losses
crop yields			regional milk performance	nutrient content
costs of hail insurance			nutrient requirements	
machine and seed costs				
fertilizer input				
input of pesticides				

Table 3: Prices for crops and animal products in the reference situation 1999

Prices for crops		Prices for animal products	
Crops	EUR/100kg	Animal products	EUR/animal or EUR/100kg slaughter weight
winter wheat	11.6	breeding heifer	1138
spring wheat	12.2	male cattle (5-12 months)	250
winter barley	11.3	female cattle (5-12 months)	374
spring barley	13.6	male calve	140
oats	10.4	female calve	89
rye	10.4	beef (from bull)	365
corn	12.6	beef (from calve)	321
sunflowers	22.4	milk (unit 100 kg)	34
winter rape	25.0	pork	132
potatoes	7.8	piglet	35
sugar beet	5.2	lamb	66
field peas	11.1	poultry	78
white cabbage	6.4	eggs (unit 100)	10
dessert apple	40.1	ride horse	600
wine	166.5		

Source: STALA BW 2004, LBV BW 2004, LEL 2004, BAYWA 2004, ZMP 1997-2000

Table 4: CAP-premiums for crop and animal production in the reference situation 1999

CAP-premiums for crop production		CAP-premiums for animals	
Crops	EUR/ha	Animals	EUR/animal
cereals	302	fattening bull	160
corn	427	sheep	21
winter rape	499		
field peas	384		

Source: BMVEL 2000, KTBL 2001, EC 2004

Table 5: Regional premiums of regional agri-environmental programs in the reference situation 1999

Premiums from agri-environmental programs	
	EUR/ha
intensive grassland	30
extensive grassland	50
intercrops	110

Source: WINTER 2005

A simplified scheme of the product flow in ACRE is outlined in Figure 1. Cash crops or fodder crops for livestock production can be produced. The animals produce manure which is used for fertilization in crop production. Both, prices for crops and animal products as well as premiums influence the total gross margin (TGM). In the optimization process ACRE maximizes the TGM for each district by optimizing the acreage of crops and the number of animals with respect to scenario constraints.

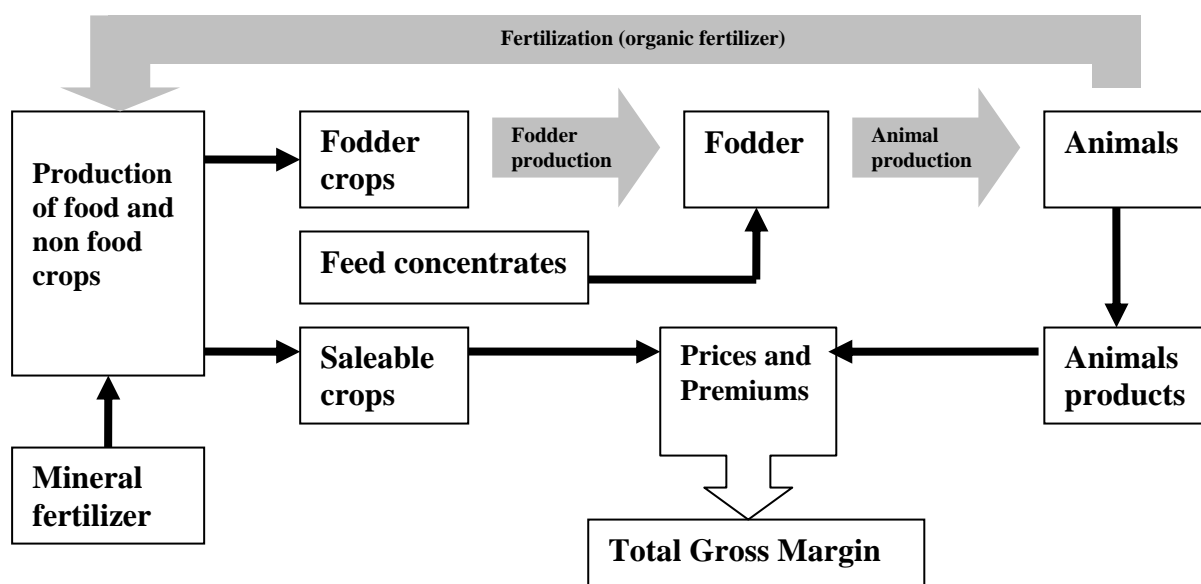


Figure 3: Simplified scheme of the flow of products in ACRE

5 First results of ACRE

ACRE exports output-data as csv-data-files. The results of the scenario calculation for 1999 (calculated by the PMP-scenario model) differ sufficiently few from the optimized reference situation of 1999 (calculated by the LP-reference model) that the model is assumed as

sufficiently exactly calibrated to the reference year 1999. As illustration of possible results examples of the scenario calculation for 1999 are presented in the following.

The optimized land use of the calculation is illustrated in Figure 4. In several districts grassland farming has a high share of farming land (e.g. Reutlingen, Tuttlingen and Zollernalbkreis) while in other dominates the production of arable crops (e.g. Heilbronn and Main-Tauber-Kreis). In districts with good conditions for arable farming arable crops are produced and fattening animals are fed by winter wheat and corn silage.

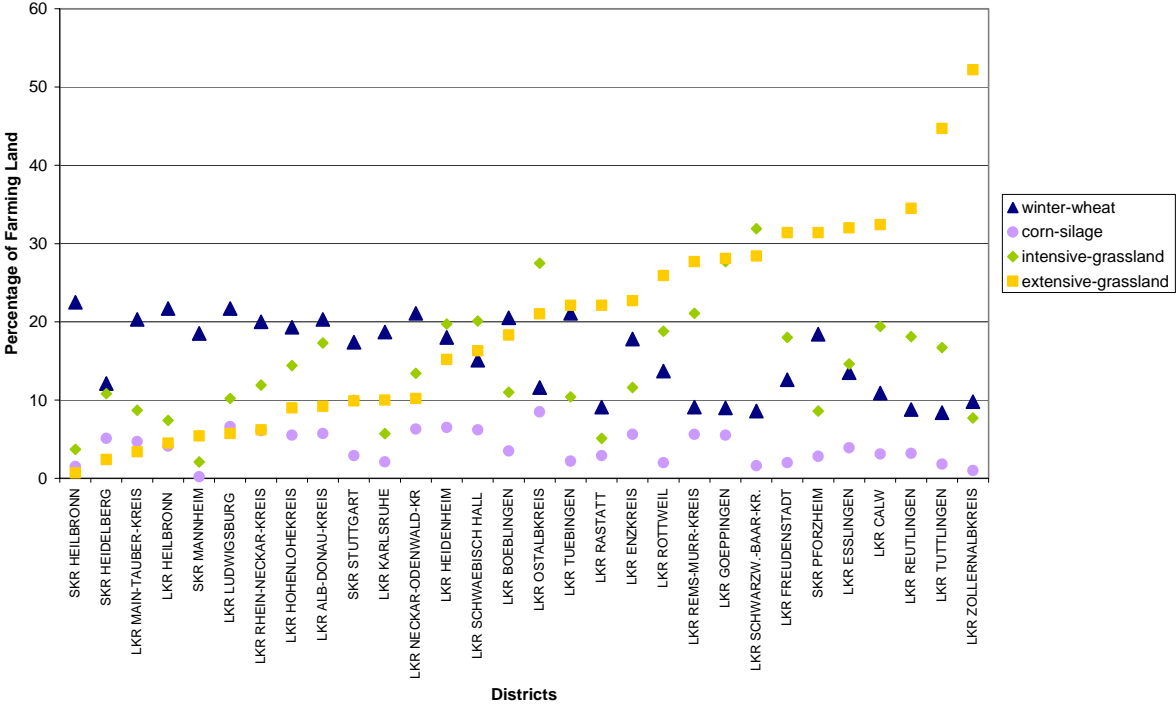


Figure 4: Percentage of selected crops of farming land in all districts in the reference situation 1999
Source: own calculations

Figure 5 and 6 show the percentages of livestock units (LU) of the total sum of LUs for fattening bulls, dairy cows, fattening pigs and breeding sows. In Goepingen, Calw and Schwarzwald-Baar-Kreis, a high share of intensive and extensive grassland (cf. Figure 4) is used for milk production. This can be concluded from the high share of dairy cows (cf. Figure 6). In districts with high production of corn silage (e.g. Ostalbkreis, Neckar-Odenwald-Kreis and Enzkreis, cf. Figure 4) the share of fattening bull production is higher than in other districts (cf. Figure 6). The production of fattening pigs is in districts relevant with a high share of arable crop productions (e.g. Hohenlohe, Alb-Donau-Kreis, cf. Figure 4 and 6).

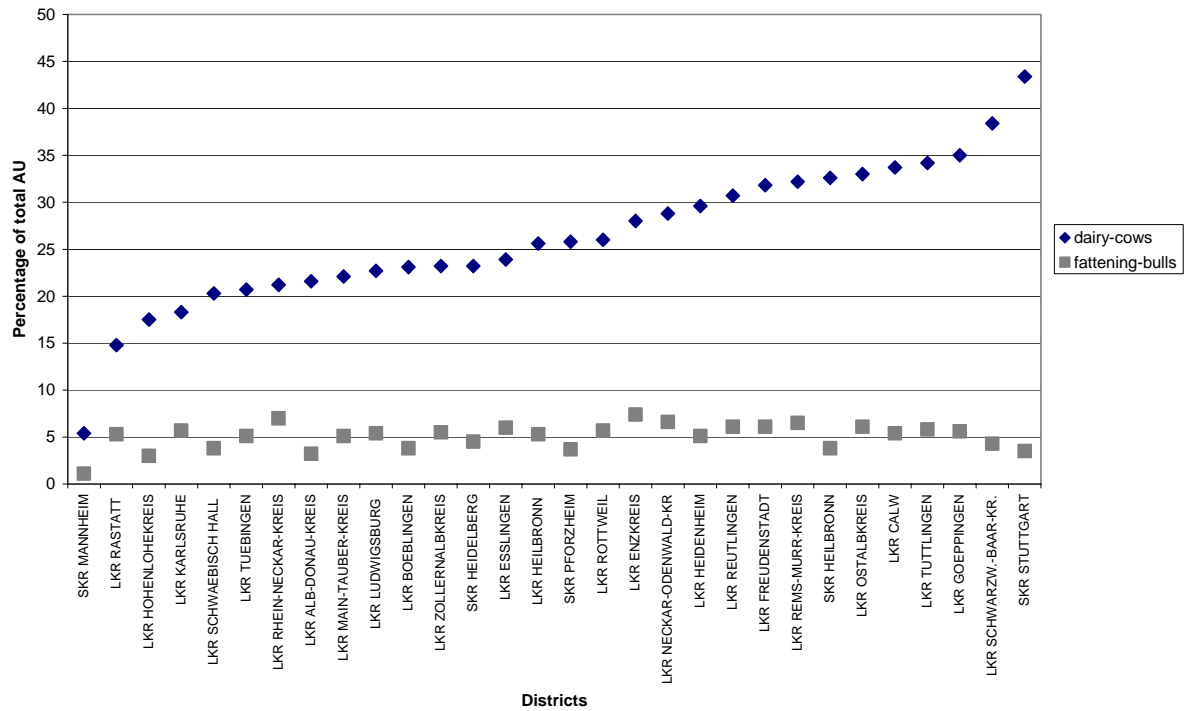


Figure 5: Percentage of dairy cows- and fattening bulls-livestock units (LU) of total LU in the reference year 1999

Source: own calculations

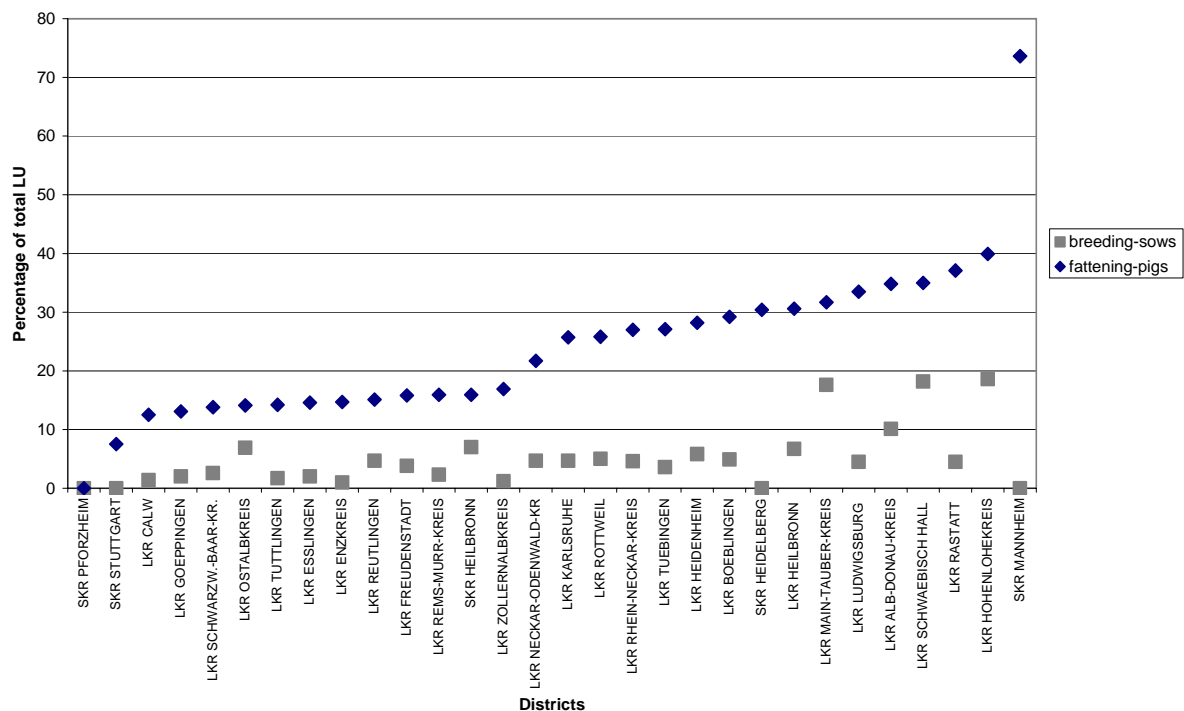


Figure 6: Percentage of breeding sows and fattening pigs livestock units (LU) of total LU in the reference year 1999

Source: own calculations

An important impact on water quality is the amount of nitrogen from agricultural production. Figure 7 illustrates the amount of applied nitrogen and the animal density. The figure shows, that a high animal density not necessarily results in a high fertilization by nitrogen. For

example in the districts Schwäbisch-Hall and Ostalbkreis data points of animal density exceed the data points of N-fertilization. In both districts the share of grassland is larger than the share of arable (cf. Figure 4), which leads to a quite low animal density. Another reason is that the amount of fertilizer applied on grassland is not as high as on arable land. The rate of N-fertilization is high in the districts Ludwigsburg and Heilbronn. Here the animal density is very low and mineral fertilizer has to be bought for arable production (in both districts production of cereals and root crops have a high share, cf. Table 3).

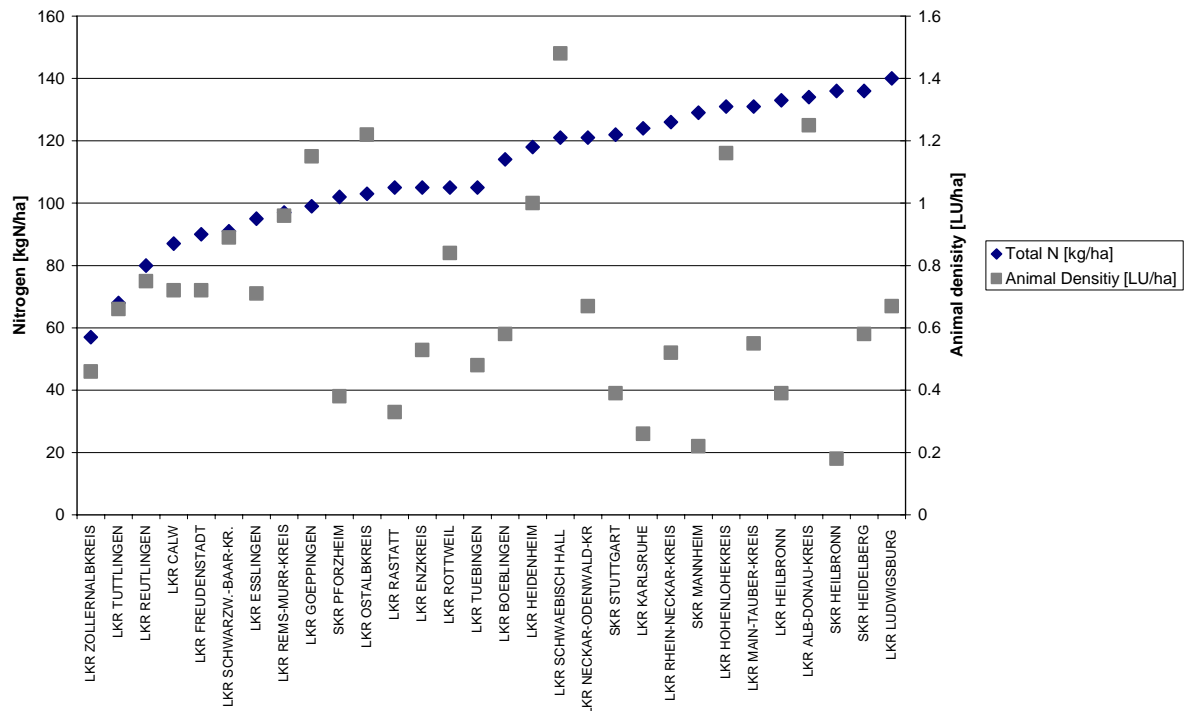


Figure 7: Application of nitrogen and animal density in 1999

Source: own calculations

Results concerning the farm income in form of the average gross margin (TGM) are presented in Table 3. High gross margins can be found in districts with favourable arable land and a relatively high percentage of wine and either vegetable production (e.g. Stuttgart, Heilbronn) or a high density of pigs like in the Hohenlohekreis. Low gross margins can be found in grassland dominated regions like e.g. the Schwarzwald-Baar-Kreis.

Table 3: Average gross margin and percentage of crops in the districts in the reference scenario 1999

NUTS-3 districts in the Neckar-River Basin	Average gross margin	Percentage of crops and grassland						
	EUR/ha	Ce-reals	Root crops	Oil seeds	Wine	Vege-tables	Fruit	Forage and grass-land
STUTTGART	2008	38	6	3	16	8	4	25
BOEBLINGEN	916	48	5	8	0	1	1	37
ESSLINGEN	889	32	2	4	1	4	1	56
GOEPPINGEN	855	21	0	3	0	0	0	76
LUDWIGSBURG	1530	52	11	5	5	2	1	24
REMS-MURR-KREIS	1203	25	2	2	4	1	2	64
HEILBRONN (SKR)	1746	47	22	3	14	5	1	8
HEILBRONN (LKR)	1655	51	15	5	10	3	2	14
HOHENLOHEKREIS	1649	46	5	7	2	1	2	37
SCHWAEBISCH HALL	1299	35	1	7	0	0	0	57
MAIN-TAUBER-KREIS	992	57	3	15	1	0	0	24
HEIDENHEIM	940	35	1	7	0	0	0	57
OSTALBKREIS	902	24	0	5	0	0	0	71
KARLSRUHE	860	59	6	8	2	2	1	22
RASTATT	1059	52	0	4	3	3	4	34
HEIDELBERG	1366	51	13	3	3	8	1	21
MANNHEIM	730	70	9	6	0	3	0	12
NECKAR-ODENWALD-KREIS	851	50	2	13	0	0	0	35
RHEIN-NECKAR-KREIS	1092	55	7	7	2	2	1	26
PFORZHEIM	569	22	0	12	0	2	0	64
CALW	770	34	1	6	0	0	0	59
ENZKREIS	696	41	2	8	1	0	0	48
FREUDENSTADT	616	27	0	6	0	0	0	67
ROTTWEIL	759	38	0	10	0	0	0	52
SCHWARZWALD-BAAR-KREIS	636	19	0	5	0	0	0	76

Source: own calculations

Data transfer to other models

For the transfer into the integrated modelling system of RIVERTWIN and scenario analysis ACRE produces several output files which inform on possible effects of different scenarios on the structure of agricultural production, income, fertilizer and pesticide application and agricultural water demand on district level. All output files which are exported by are listed below.

Crops

- acreage of produced crops per district; unit: hectares
- percentage of the acreage of produced crops related to the total farming area per district; unit: percent

Animals

- produced number of animals per district; unit: numbers
- percentage of livestock units of animals classes related to the total of large animal units per district; unit: percent

Gross margin

- total gross margin per district; unit: Euro
- average of total gross margin per hectare farming land per districts; unit: Euro per hectare
- gross margin of animal production per district; unit: Euro per hectare
- gross margin of crop production per district; unit: Euro per hectare

Nutrients/Fertilizer

- amount of nutrients (nitrogen, phosphorus, potassium) applied by organic fertilizer per district; unit: kilograms nutrient per ha manure-applied area
- amount of nutrients (nitrogen, phosphorus, potassium) applied by mineral fertilizer per district; unit: kilograms nutrient per ha agricultural area total amount of nutrients (nitrogen, phosphorus, potassium) applied by organic and mineral fertilizer per district; unit: kilograms nutrient per ha agricultural area
- total amount of nutrients (nitrogen, phosphorus, potassium) applied by organic and mineral fertilizer on crops per district; unit: kilograms nutrient

Pesticides

- total amount of pesticide ingredients applied for crop production per district; unit: kg nutrient

Water

- water demand by animal and crop production per district; unit: cubic metres

6 Validation of the model

In order to test simulation quality of the model prototype the data of reference year 1999 calculated by ACRE were compared with the statistical data of 1999 used to calibrate the model. The deviations between these data quantify the simulation quality for the reference situation and thus can be used for a first validation of the model. The percentage deviations were computed for all crops and the differences indicated crops which the prototype model does not represent exactly. This can be caused by inaccuracies of the formulations of the production processes and/or by insufficient fitting of statistical data in calibration process.

In Table 4 the percentage differences of all crops were listed. Deviations of less or equal absolute 10 % were assumed as sufficiently small enough to attribute ACRE a good simulation quality for these crops. For crops with more than absolute 10 % percentage difference the simulation of crop production is not sufficient exactly. Most of the crops were calculated sufficiently exactly with deviation of less or equal absolute 10 %. In several districts crops with deviations greater than absolute 10 % are sunflowers, clover and inter crops (shadowed grey in Table 4). In Table 5 the deviations greater than absolute 10 % were checked for their absolute hectare values and the percentage of the total farming land was calculated. This weighted deviation allows an estimation of the impact of the simulation error for whole districts. Only in the district Heilbronn the percentage of the deviation of intercrops is quite large with 14 % of total farming land. The influence of the acreage of intercrops to other crops is not relevant. Thus, the simulation error which causes this relative large deviation of intercrops as well as the small weighted deviations of the other crops (from absolute <0.1 % to 0.3 %), are accepted as simulation errors which are not necessary to correct in the prototype of ACRE.

The acceptable small deviations ($\leq |10\%$) and the estimation of a small impact of large deviations ($\geq |10\%$) let conclude a good simulation quality of ACRE for the reference situation. By this fact a necessary condition for valid scenario simulation is fulfilled by the prototype of ACRE and valid scenario calculations can be supposed.

Table 4: Percentage deviation between statistical and calculated data of the reference situation

	Winter wheat	Spring wheat	Rye	Winter barley	Spring barley	Oats	Grain maize	Field peas	Late potatoes	Sugar beets	Winter rape	Sunflowers	Clover	Silage maize	Fallow land	Inter crops	Special crops	Grassland
STUTTGART	0	0	0	0	0	-1	0	0	0	0	0	0	2	0	0	0	0	0
BOEBLINGEN	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
ESSLINGEN	0	0	-1	-1	0	0	0	0	0	0	0	0	5	0	0	0	0	0
GOEPINGEN	0	0	0	-1	0	-1	0	0	0	0	0	0	3	0	0	0	0	0
LUDWIGSBURG	0	0	-5	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
REMS-MURR-KREIS	-1	0	-1	-1	0	-1	0	0	0	0	0	0	5	0	-1	0	0	0
HEILBRONN (LKR)	0	0	0	0	0	0	0	0	0	0	0	-1	6	0	0	-12	0	0
HEILBRONN (SKR)	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
HOHENLOHEKREIS	0	0	0	-1	0	-1	0	0	0	0	0	0	9	0	0	0	0	0
SCHWAEBISCH HALL	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
MAIN-TAUBER-KREIS	0	0	-1	-1	0	-1	0	0	0	0	0	-1	17	-2	-1	0	0	0
HEIDENHEIM	0	0	0	0	0	-1	0	0	0	0	0	0	2	0	0	0	0	0
OSTALBKREIS	0	0	0	0	0	-1	0	0	0	0	0	0	3	0	0	0	0	0
KARLSRUHE	0	0	0	0	0	0	0	0	0	0	0	0	11	-2	0	0	0	0
RASTATT	0	0	0	0	0	0	0	0	0	0	0	0	8	-1	0	0	0	0
HEIDELBERG	0	0	-3	-1	0	-1	0	0	0	0	0	0	5	0	0	-48	0	0
MANNHEIM	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
NECKAR-ODENWALD-KR	0	0	0	-1	0	0	0	0	0	0	0	0	6	0	0	0	0	0
RHEIN-NECKAR-KREIS	-1	0	-3	-1	0	-1	0	0	0	0	0	-1	24	-2	-1	0	0	0
PFORZHEIM	0	0	0	-1	0	0	0	0	0	0	0	-21	8	0	0	0	0	0
CALW	0	0	-2	-1	0	0	0	0	0	0	0	0	3	0	0	0	0	0
LKR ENZKREIS	0	0	0	0	0	0	0	0	0	0	0	0	10	-3	-1	0	0	-2
LKR FREUDENSTADT	-1	0	-1	-1	-1	-1	0	0	0	0	0	-1	8	0	-1	0	0	0
LKR ROTTWEIL	0	0	-1	-1	0	0	0	0	0	0	0	0	4	0	0	0	0	0
LKR SCHWARZW.-BAAR-KR.	-1	0	-1	-1	-1	-2	0	-1	0	0	0	-1	12	-5	-1	0	0	0
LKR TUTTLINGEN	-1	-1	-1	-2	-1	-2	0	-1	0	0	-1	-1	14	-2	-1	0	0	0
LKR REUTLINGEN	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
LKR TUEBINGEN	0	0	0	0	0	0	0	0	0	0	0	0	3	-2	0	0	0	0
LKR ZOLLERNALBKREIS	0	0	0	0	0	0	0	0	0	0	0	0	6	-2	0	0	0	-1
LKR ALB-DONAU-KREIS	0	0	0	-1	0	-1	0	0	0	0	0	0	5	0	0	0	0	0

Source: own calculations

Table 5: Districts and crops with significant deviations and the percentage of total farming area

Districts / simulated crop acreage with deviations	Total farming land		Deviations of corresponding crops	
	ha	ha	ha	% of total farming land
HEILBRONN (LKR) / inter crops	55333	-158		-0.3
MAIN-TAUBER-KREIS / clover	70176	154		0.2
KARLSRUHE / clover	37564	-75		-0.2
HEIDELBERG / inter crops	1856	-273		-14.7
MANNHEIM / clover	3094	3		0.1
RHEIN-NECKAR-KREIS / clover	38754	81		0.2
PFORZHEIM / sunflowers	1207	< 1		< 0.1
LKR SCHWARZW.-BAAR-KR. / clover	40621	74		0.2
LKR TUTTLINGEN / clover	25423	41		0.2

Source: own calculations

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