A Regional Multi-Agent Model as a Tool for Modelling Small Structured Agricultural Land-Use

Jochen Kantelhardt[1], Martin Kapfer[1], Norbert Roeder[1]

[1] Technical University of Munich, Institute of Agricultural Economics and Farm Management, Freising, Germany

Contribution appeared in Arfini, F. (Ed.) (2005) "Modelling Agricultural Policies: State of the Art and New Challenges", proceedings of the 89th EAAE Seminar, pp. 737 - 756

February 2-5, 2005

Parma, Italy

A Regional Multi-Agent Model as a Tool for Modelling Small Structured Agricultural Land-Use

Jochen Kantelhardt, Martin Kapfer, Norbert Roeder

Technical University of Munich, Institute of Agricultural Economics and Farm Management, Freising, Germany

Abstract

Often, land-use models do not take into account social aspects. But in particular farmers' attitudes seem to be one of the driving forces for agricultural land-use and therefore for economic, ecological and social developments in rural areas. The presented land-use model is an attempt to incorporate data which are in a strict sense not economic. The farm must be viewed as the basic entity for many questions because farmland, farm equipment, and farmer's attitudes differ from farm to farm. Furthermore interactions between farms like knowledge transfer or market behaviour must kept in mind. Therefore the model presented conceives the farms as independent agents aiming at maximum individual utility which is dependent on personal attitudes. The utility is calculated by a linear programming algorithm which takes into account natural, economic and personal restrictions. Interactions between farms take place on the land market, which is modelled as an equilibrium market. Land distribution as well as corresponding land rents are calculated with the help of a modified Sequential Simplex Algorithm (SSO). The calculations yield data on two levels: On farm level economic and social data like income and workload are calculated. Regional results, as aggregation of the regarded farms, show regional opportunities and threats.

Keywords: linear programming, land market simulation, agent based modelling, farmers attitude, policy analysis, social impacts.

1. Introduction

Agriculture is strongly influenced by political decisions and legal constraints. As these factors basically determine the business environment of farmers they influence significantly the type as well as the intensity of farming. For example, a declining profitability of farming caused by liberalisation in general leads to a less intensive use of land (cf. BML, 1996). Especially in marginal regions this can result in a complete cessation of farming activities. Such a development would not only affect agriculture but also would have an effect on the quality of abiotic and biotic resources, landscape's aesthetic values and the economic and social structure of rural areas – hence making it relevant to the public in general (Heißenhuber et al., 2000).

Land use is in addition to economic conditions and the quality of land also determined by non-agricultural factors. Alternative employment opportunities, for example, as well as family structures, influence greatly farmers' decisions to continue with the prevailing farming system, to change or to abandon the production and lease their land (Balmann, 1997). Most farms are long-established and the farmers are often unwilling to sell or lease their land despite a clear lack of profitability. Due to the complexity of land-use developments political bodies have a high demand for consulting services. The increasing power of personal computers allows to develop appropriate land-use models considering all that factors mentioned above. The following paper presents such a model assessing the impacts of a changing agricultural business environment on land-use patterns on a regional level. The model sets a focus on the influence of farmers' attitudes. This model is based on previous works by Kantelhardt (2003) and Schemm (2004).

2. Modelling regional land use

2.1 Spatial and temporal aspects

The influence of political measures depends on regional peculiarities. So identical changes in the business environment of farms may have different effects in different regions. Such peculiarities concern agricultural factors such as farm structure and natural site conditions but also non-agricultural factors such as off-farm employment possibilities. When determining the effect of a changing business environment on land-use, one must take into account these differences. In contrast to most other factors site conditions vary within short distances. This mainly arises from varying soil and topographic conditions but also from the given structure influencing plot size and accessibility. To account for this heterogeneity, it is necessary to cluster the agricultural land into several groups of similar site qualities. The simplest classification would be the differentiation into grassland and arable land.

When designing a model not only the classification of land quality but also the determination of the region's size is necessary. Here it is to consider that farmers are reliant to agricultural land and they have to compete for it. The number of farms competing for a given plot is limited, because in general only a few farmers will be able to use a specific plot in a profitable way. The most important reason reducing the number of competitors is the distance between the farmstead and the plot, inducing transportation costs and time demands. Since there are only a few competitors, the influence of a single farm on the land market is high. Therefore the size of the study region has to be determined in a way that all relevant farms competing for agricultural land are included. In contrast to the land market, the influence of a single farm is fairly negligible on most other markets since these have often a national or global domain.

Beside the spatial aspect for the design of a land-use model the choice of an appropriate temporal resolution is important. A reasonable time horizon for agent-based land-use models ranges from five to ten years. A longer forecast seems to be unconfident because future politics and product prices, which are necessary inputs in such models are uncertain. For longer time horizons the determination can only be based on the extrapolation of current or assumed trends but not on causal chains on the level of the decision maker. The value of models with long time horizons lies in the assessment of changes of natural potential, e. g. potential yield of designated crops, depending on altering natural conditions, e. g. climate change.

On a time span as short as one year the production opportunities of farmers are to a large extent determined by the existing production factors of the respective farm. With such a limited time horizon a farmer has almost no investment opportunities; he has to base his production decisions on the achievable gross margins. Furthermore interactions between the farmers have hardly any impact either on the land-use in the region or on social or ecological parameters. The effects of strategic planning problems, e.g. cessation of the farm, in reality may occur in the considered year, but in short-term land-use models are not able to predict whether this will happen in the modelled year or a year later or earlier.

Within a time horizon of about five to ten years farmers face strategic planning problems. This means for modelling that changes in agricultural structure, such as growing or shrinking of farms, concentration processes and abandonment of agriculture for instance have to be considered in the calculations. But one has to take into account that the expressiveness of such models is limited. It is not possible to determine the effects of a unique occurrence. Such a break for instance is the generational transfer of the farm which is often accompanied by a change of farmers' attitudes. Furthermore the reaction of farmers on deep shifts of political and economic conditions are fairly unknown.

2.2 Human resources and farmers attitudes

The ability to realise operational work on a farm (with a given machine equipment) in time depends on the number of the workers and their physical and mental abilities. Therefore it is necessary to differentiate in a land-use model farms according to their available manpower. In many cases it is sufficient to determine the average capacity of available man power per farm in standardised form such as agricultural working units (AWU). But one has to be aware that especially on family farms various groups of activities compete for the limited time of the farmer. Among them are on-farm and off-farm employment, regeneration and leisure. The working time which a farmer is willing to dedicate to agriculture is limited by the extent of his off-farm employment, his personal desire for leisure and the time needed for regeneration.

In this context other aspects of working in agriculture, like self-realisation, must be considered. If one is highly satisfied by his farm work, he does not feel that he must be compensated monetarily for the time he devotes to agriculture instead of to leisure. Further he is willing to spend more time on agriculture (Inglehart, 1989; Lehner-Hilmer, 1999). The amount of time demanded by the farmer for leisure activities may depend on age and family status. Generally one can assume that younger farmers demand more time for leisure activities than older ones. Regarding family farms the available working time is less as long as children are not grown up due to the fact that one has to care for the children. In addition, the effect of off-farm employment is ambiguous. While the amount of time which can be dedicated to on-farm work is lessened, the income generated by off-farm work reduces the amount of money which must be generated by the farm to secure the standard of living. In extreme cases there is a negative agricultural income which is compensated by the income of the off-farm employment. This means that the farmer is subsidising his farming activities (Schäfers, 2004; Lehner-Hilmer, 1999).

Another point is that the economic success depends on the farmers' capabilities. In cattle husbandry, for instance, the profitability can be more severely influenced by the farmer's capability to detect the heat period than by the genetics of the stock. The same applies to planning situations: A farmer with financial knowledge can judge better the profitability of different investment alternatives. Also personal risk management influences the profits. A risk-averse farmer who can choose among two alternatives differing in their expected returns and the volatility of the returns may opt for the less risky one, even if this option is resulting in lower returns.

Moreover it is necessary to mention that the meaning of economic success is not equal for all farmers. In reality, farmers do not maximise their profits but their individual utility of which their profit is only one part (Romero and Rehman, 1989, p. XI). The relative weight given to the profit in this individual utility function depends on the farmer's attitudes. Therefore, the personality of the farmer has a significant influence on the structure of the farm. The attitudes influencing the decision making process are manifold. For instance the profit assumption and the leisure demand differ from farmer to farmer. Also we can imagine that farmer disclaim because of personal aversions taking part in cooperative projects, although if this decision leads to lower profits. Even the profit can be regarded in a different way: The aim of a full time farmer is to achieve a reasonable income from agriculture to secure his standard of living. In case of missing off-farm employment opportunities he would accept a low income per working hour. In contrast to this situation one can imagine that the aim of a part-time farmer, who does not need farm income for livelihood, is to maximise his hourly earnings or minimise his workload.

Due to the fact that especially in agriculture household and business are often linked together family status has various effects on the farmer's decision making process. For example the presence of an heir influences the planning horizon. This factor is decisive for determining the level of depreciations which must be set aside for replacement investments or which can be spent on private consumption. On heirless farms dominate a short time strategy: The farmer can spend most of the surplus revenues for consumption. In contrast to this situation a growing enterprise not only has to execute replacement investments but also has to build up reserves for net investments.

Some land-use models take in account differences in farmers' capabilities, e.g. Happe and Balmann (2002). Also some methods of resolution which deal with the problem of imperfect information and individual risk assessment are developed. But until now there is no satisfactory solution how to depict individual farmers' attitudes in land use models.

3. The model

3.2 Basic assumptions

The model was developed against the background of the high degree of heterogeneity present in Bavaria's agriculture. This heterogeneity concerns the natural conditions as well as the agrarian structure. The undulated topography and varying soil conditions induce shifts from absolute grassland sites to pure cereal stands within the distance of a few kilometres. Regarding the agrarian structure, for instance, full-time farms alternate with part-time farms. In the same region there are farms producing for global market or local niche markets. These farms, modelled as independent agents, compete for the agricultural land. In order to cover all relevant competitors, the model has to include about thirty farms. Of course farms differ in the endowment of production factors and farmers' attitudes. So farms have different specialisations which lead to significantly different utilisation options of a given plot resulting in a different willingness to pay. This allows the distribution of land with the help of a market module.

Based on the number of farms modelled the spatial scale of the model ranges from about 500 to 2'500 ha of agricultural land. This acreage corresponds to the size of a rural village and may include a variety of different site qualities. Within the model it is not only possible to distinguish between grassland and arable land, but also to productivity, accessibility, plot size, and slope.

According to the considerations made in chapter 2.1 a medium time horizon of five to ten years is chosen. On this time horizon farmers are likely to face investment decisions. In this context path dependency is important. So it is easier for a farmer to enlarge already existing production methods than to establish new ones. For instance, if a farmer plans to enlarge his capacities from forty to eighty dairy cattle he can continue to use the old stables and tractors and will only have to do some additional investments. In contrast to that a farmer changing from milk production to pig fattening has much higher investment costs, because only a small part of his machinery and buildings fit to the new system.

A comparative-static analysis is chosen. For many questions this seems to be sufficient because farmers in the study region are often capable to compensate for possible liquidity squeezes. One primary target of the model is to investigate the effects of different farmers' attitudes and social settings on individual farms as well as on land use under a changing business environment. Therefore we focus on relevant aspects of farmers' attitude like farmers' personal planning horizon, farm income, leisure demand and wages. On the other hand personal risk assessment is set aside. Furthermore, we assume in contrast to Happe and Balmann (2002) equal capabilities to all farmers. A last important assumption is that we calculate with perfect information for all agents.

3.2 Structure of the model

Basically the presented model combines two techniques, the linear programming and the modelling of markets. All in all the model consists of an input module, a linear-programming (LP) module allowing the calculation of optimal farm organisation, a land-market module determining the distribution of land among the farmers and the land rent, and an output module (fig. 1).

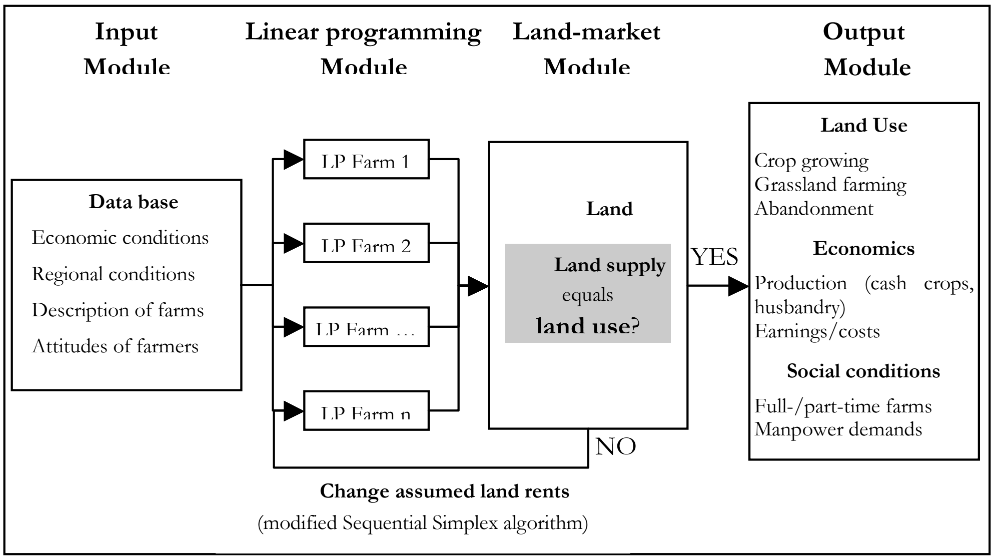


Figure 1. Structure of the land-use model

The **input module** contains all necessary data (see fig. 1). The exogenous data which influence agriculture in the modelled region must be determined. In the model the farm is regarded as system of attributes in different levels. One of the most important attributes is the farmer who is characterised by his personal attitudes and the amount of labour he is willing to devote towards farming. Each farm disposes of various types of agricultural land and production rights like milk quota. Important features of farms are their endowment with technical equipments consisting of buildings and machinery.

Other sets of data are valid for all farms. These sets encompass the feasible production methods, the investment alternatives and the total amount as well as the classification of the agricultural land in the modelled region. Each production method is described by a set of variables such as potential yields, costs, demands on labour and machinery. Some of these variables depend also on other sets of data. The potential yields in cropping, for instance, are site dependent and the labour demand is subject to the size of the utilised machinery. A farmer can only conduct a certain production method if he owns the appropriate technical equipment, like buildings and machinery. For example, in order to keep dairy cattle the farmer must possess a so-called grassland mechanisation and a dairy-cattle stable.

The stables and the mechanisations are defined in four size classes, which vary with respect to costs, type and extent of provided capacities. A specific combination of stables and mechanisations is called farm type. Changing the farm type induces costs, which depend on the new farm type as well as on the situation before the investment. This allows the representation of path dependencies in the model.

The determination of the applied production methods and the organisation of all modelled farms takes place in the linear-programming module. The key element is the single farm simulated with a linear programming (LP) approach. All farms act independently of each other and maximise their utility by adjusting the organisation of their farm. The farms react to the incentives given through changing prices, and subsidies. These reactions lead to a change of the land use on the regional level (cf. Rounsevell et al., 2003). The optimisation process is not only based on generally valid data as prices but also on farm specific data like farmer's attitudes or the existing equipment on the farm. Since the modelled farms can be distinguished in this way, they can be conceived as individual agents.

The results of the linear programming module are merged in the land-market module. In this module we design the land market as an equilibrium market. For each land quality (e.g. grassland, arable land) a own land market has to be compiled and a land rent has to be calculated. For a given set of land rents the farm module calculates the land demand for the respective land qualities. In the next step this demand is transmitted to the land market module. It gathers the demands of the different farms. If the aggregated demand of the farms for any land quality is unequal to the supply in the region the land-market module calculates a new set of land rents. The newly calculated set of land rents is fed back to the farms in the linear-programming module and the demand of land is recalculated. This process is repeated until for each land quality a land rent is determined where the demand equals the supply.

In this context it is necessary to mention, that land rents interdepend. For instance higher land rents on grassland lead to a higher demand on arable land for forage production resulting in higher land rents on arable land. In general one can say the higher the substitutability of one land quality by another, the higher is the cross price elasticity between these two site types. The consequence is that the calculation algorithm has to carry out simultaneously the calculation of land rents for various land qualities. Since the number of possible land rent combinations increases exponentially with the number of modelled markets, the determination of the equilibrium land rent by trial and error will result in a unreasonable high calculation effort. Therefore a search algorithm is needed. For this problem we select the Sequential Simplex Optimisation (SSO), which is explained in chapter 3.4.

The function of the output module finally is the conditioning and the analysis of the model results. The results are transmitted to a database which edits and analyses the data on farm and regional level with the target to provide an overview of the agriculture and land-use in the investigated region. This allows the presentation of the effects of changing prices, politics or legislation. The results on the farm level as well as the ones on a regional level include economic, ecological and social key figures.

On the farm level the output data focuses on land use and animal husbandry. The analyses of data on land use yields information on e. g. the overall intensity of agriculture. In addition, the analysis of a single farm's investments allows the quantification of socio-economic criteria on this level, like the transition from full-time to part time farming or vice versa. Of course, the farm specific results include indicators on the economic output and the relative degree of fulfilment of the farmer's attitudes.

On the regional level social and ecological questions are of main concern. In this context it is important to mention, that the region is conceived as the aggregate of the modelled farms. Objective at the regional level is the analyses of the effects of certain political measures. Beside the development of the land use also changes in socio-economic criteria can be shown. In particular the effects on different farming systems can be demonstrated. For instance it is possible to identify possible concentration processes or the danger of land abandonment.

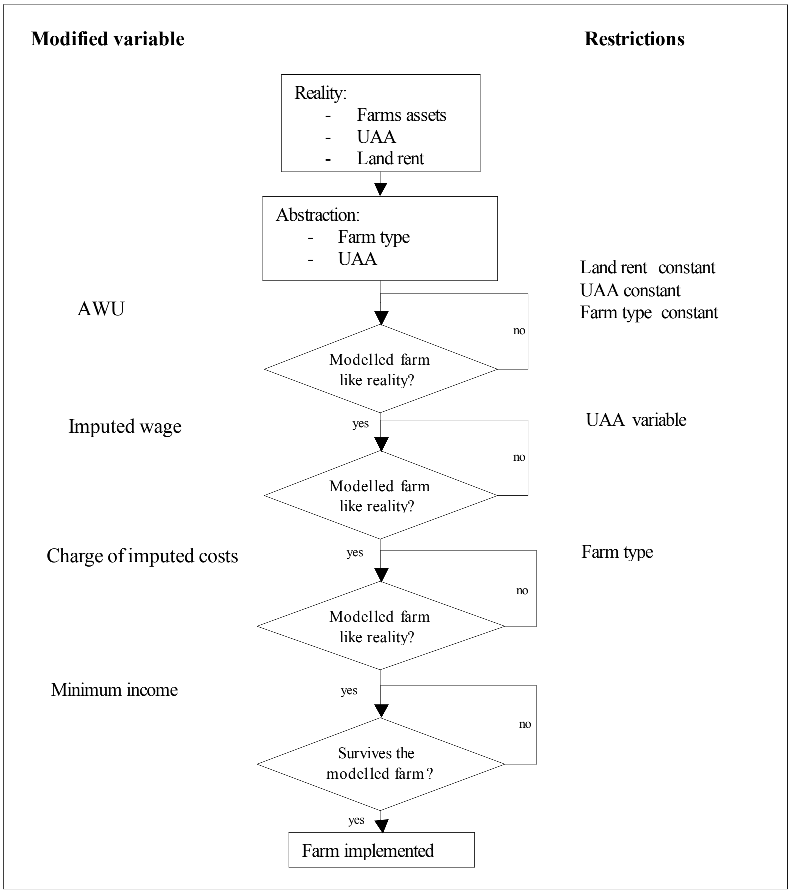
3.3 Implementing farmers' attitudes

Land-use models can be used in two ways to deal with social aspects. On the one hand they can help to test theoretical assumptions about the behaviour of farmers (e. g. Jager et al., 2000). On the other hand empirical behavioural data can be incorporated in models as an additional set of control variables in order to improve the modelling of land use. Van der Ploeg (2003, p. 116) classified Frisian dairy farmers in such a way. Based on empirical data he distinguishes six farmer types (e.g. 'cowmen', 'machinemen', 'large farmers'). To each type of farmer certain behavioural patterns and a certain set of attitudes can be assigned. For instance, machinemen try to realise the highest possible output per person, while large farmers concentrate on expanding the farm. Such individual strategies now can be integrated into land-use models.

Social data on farmers can be directly surveyed or indirectly observed. The latter approach is applied in this paper. Comparatively easily accessible information such as farmer's age, family status or the extent and importance of off-farm employment are used to derive the farmer attitudes. The underlying assumption of this approach is that the farmer realises his aims without any external restriction being in force. Consequentially, the farm is operating at the optimum. It is to annotate that, if such an approach is applied, farmers' attitudes remain a black box, but farm organisation is an expression of these attitudes.

In order to implement the "real" farms with the farmer's attitudes in the model, every farm is optimised independently several times without using the market module (fig. 2). In a first step the farm type and the UAA (utilized agricultural acreage) is fixed for each farm to the observed levels. The set of land rents in the region is derived from real data and kept constant. The labour capacity is determined in such a way that the modelled farm has a similar combination of implemented production methods as the real farm. The imputed wage of the modelled farm is the result of the second optimisation process. One attribute of the farm type is the level of imputed costs (depreciation and imputed interests). We assume that each farmer decides individually which proportion of these costs he sets aside for replacement investments and which part he consumes. By varying this proportion, we insure that the farm-type is stable under the current settings. This means that the level of imputed costs is set in a way which insures that the farm is neither investing nor disinvesting, since we assume that the farm is optimally organised. In the last step the required minimum income is set. The respective level is chosen in such a way that the farm would continue to operate under the settings derived in the steps before. Finally a safety supplement of twenty percent of the cash flow of the respective farm is added on top of the minimum income since we assume that farmers would accept this income reduction before giving up farming.

The result of this procedure is the implementation of farmers' attitudes into the modelled farms. A run of the model with all implemented farms inclusively the market module must lead to an equilibrium market price which is similar to the exogenous fixed set of tenure fees.



1) UAA: utilised agricultural acreage

2) AWU: 1 AWU (agricultural working unit): 2,380 working hours

Figure 2. Scheme for the implementation of farms in the model

3.4 Sequential Simplex Algorithm

The Sequential Simplex Algorithm (SSO) is used in the land-market module. The SSO, a evolutionary operation method, is widely applied in process optimisation (Walters et. al 1999; p.6). It aims to find an optimal combination of different variables. In our case the variables are the land rents for the different site qualities. The optimum is achieved when for each considered land quality the land demand equals the land supply, which means that the land market is cleared totally. The mechanism of this optimisation process will be explained with the help of figure 3.

It shows the principle of the SSO for a region with two different land categories. In a first step three sample points are chosen at random. For each point the difference between land supply and land demand is calculated. This difference is an indicator for the quality of the observed set of land rents. The smaller the difference is, the higher is the so-called fitness. The sample points are ranked according to their fitness. The one with the highest is labelled B (best), the one with lowest W (waste) and the one with second lowest NW (next to waste). In a second step a point-through-point reflection of the point W through the centroid of the two remaining sample points (B and NW) is conducted. This yields the new sample point for which again the fitness is calculated. Even if the fitness of this new point is the worst of the new sample, it must not get the label W. Otherwise the search would stagnate. In a third step the procedure described in the second step is repeated until a satisfying result is achieved. In order to assure that the algorithm can reach any set of land rents the distance of the reflection can be elongated or contracted in dependence of the ranking of the fitness of the new point. For more details on this variable sized simplex algorithm see Walters et. al (1999; p.103 ff.).

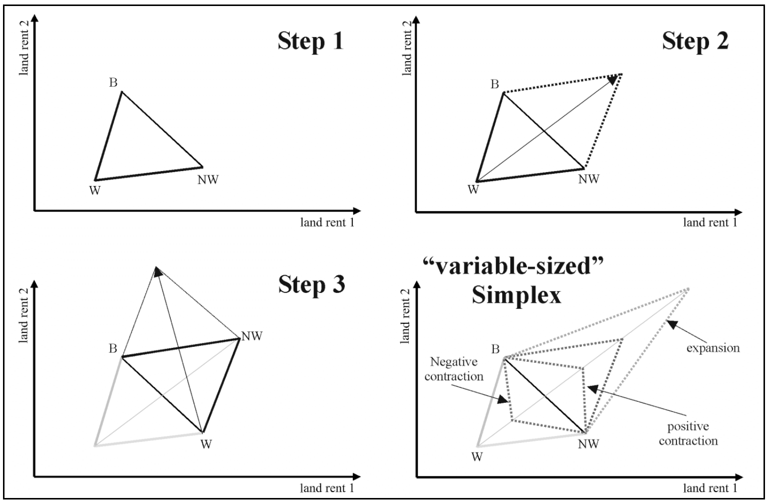


Figure 3. Principal steps of the Sequential Simplex Algorithm (after Walters et. al 1999)

Unfortunately the regional supply and demand function for land is stepwise constant and discontinuous (see fig. 4). This is a consequence of the utilisation of the linear-programming algorithm to derive the land-use on the level of the single farm. The problem occurs especially in the case that there are only a few competitors for the observed land quality and that these competitors are similar in their configuration and their attitude. In this case the relative degree of market clearance is not sufficient to describe the fitness of a set of land rents, as one can see in figure 4. The points A and B have the same degree of market clearance. Point B is clearly preferable since high demands lead to an augmentation of prices.

The correct ranking of these points could be easily achieved if one would use the land rent as a second criteria for the fitness. But in the case the supply exceeds the demand this yields to misleading results. In this case the fitness should increase with lower land rents (fig. 4, points C and D). To sum up, in the case of under supply the higher land rent leads to the higher fitness; in the case of over supply the lower land rent leads to the higher fitness. So both cases must be treated differently.

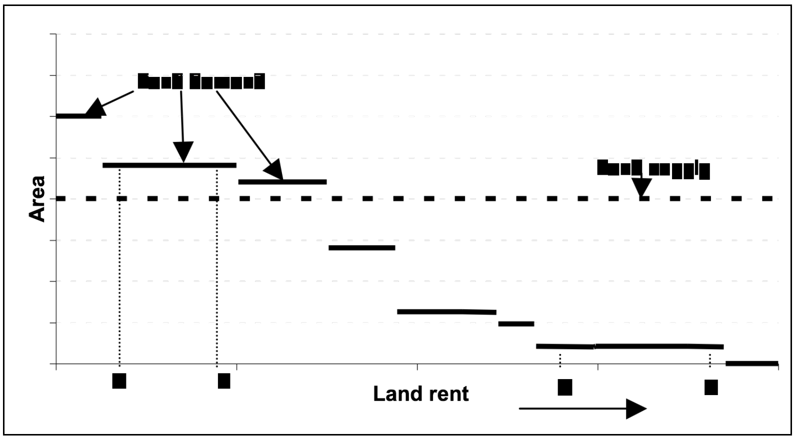


Figure 4. Constant discontinuous demand function as consequence of the LP-algorithm

If one simulates several markets the land rent can not be used anymore to calculate the fitness, since there is no uniform scale for the different markets. Here the (overall) turnover (area multiplied with land rent) is more appropriate. As a result of this considerations a two-dimensional lexicographic fitness function is implemented. The first dimension reflects the degree of market clearance, whereas the second is related to the turnover on the respective market. For the rating of the sample points the second criteria is only used when two or more sample points cannot be distinguished by market clearance. It is to annotate that the land supply can exceed land demand even if the land rent is zero. This would mean in reality, that this land will partly or fully fall fallow. In the model such an solution must be feasible, even if this represents a disequilibrium.

4. Application of the model

A first case study are the 27 farms which are members of the "Wald- und Weidegemeinschaft Garmisch e. G." (Registered Forest and Grazing Cooperative Garmisch). From an agricultural point of view the area of Garmisch-Partenkirchen in the Bavarian Alps is a marginal grassland region. Agriculture is of hardly any economic relevance but it is important in order to maintain scenery for tourism and to provide habitats for endangered species. Farms' individual data are derived from personal interviews (see tab. 1). Costs of the buildings and machinery as well as the data on labour demands and yields are calculated with the help of the following sources: BaySTMELF/BAYSTLU 2003; BaySTMLF 2002; LBA 1996; LBA 2000; LBA 2001; LBP 1997; LFL 2003a, b, c; Kirchgessner 1992; KTBL 2002a, b, c, d, e; KTBL 2004; RegMFr 2003. Prices and premiums are based on the situation of 2004.

4.1 Implementation of the model and formulation of scenarios

Seven farms of the sample are too small to make any sensible calculations so only the data of twenty farms are considered in the input module. Due to the fact that the seven non-considered farms are very small, their influence on land-use pattern is low and consequently the error by ignoring them is negligible. In the case of the study region legal restrictions impede investments, especially in animal husbandry. Several farmers pointed out that they would like to invest if they would get permission. Therefore changes in farm type in the implementation process are not feasible. The proportional charge of imputed costs is derived from survey data. Table 1 compares the implementation data and the sample data. In order to asses the stability of the model results, two implementation runs are conducted. The first model run, which is based on survey data, leads to land abandonment. Since in reality all agricultural land is used, a second model run with slightly reduced land rents is conducted. Table 1 shows that the implemented farms fit the real situation quite well.

Using the example of Garmisch we compare two scenarios. The first scenario abstracts away from the fact that attitudes and aims of farmers can differ. This means, that the objective function is equal for all farmers. We assume that farmers are not willing to work for less than five Euros per hour. Furthermore we act on the assumption that all farms have a long term planning perspective. Hence the charge of imputed costs is set to eighty percent. The second scenario takes into account farmers' attitudes. In this context it is necessary to mention that farmers in the study region in most cases are willing to subsidise their own farm. This willingness varies, as well as the imputed hourly wage, from farm to farm.

In addition to the described model calculation (chapter 3) a second calculation is conducted. This time we run the model without considering the land market. The land rents are set exogenous on a slightly lower level. A consequence of this is that the regional supply of agricultural land is no longer a restriction and over-demand is possible. This difference between the results of the two model runs serves as an indicator of the stability of the results and is called stability range. A wide stability range means that only a small change in the land rent results in great shifts in the considered output data. Results are more reliable if the results of the two model runs are similar and the stability range is narrow.

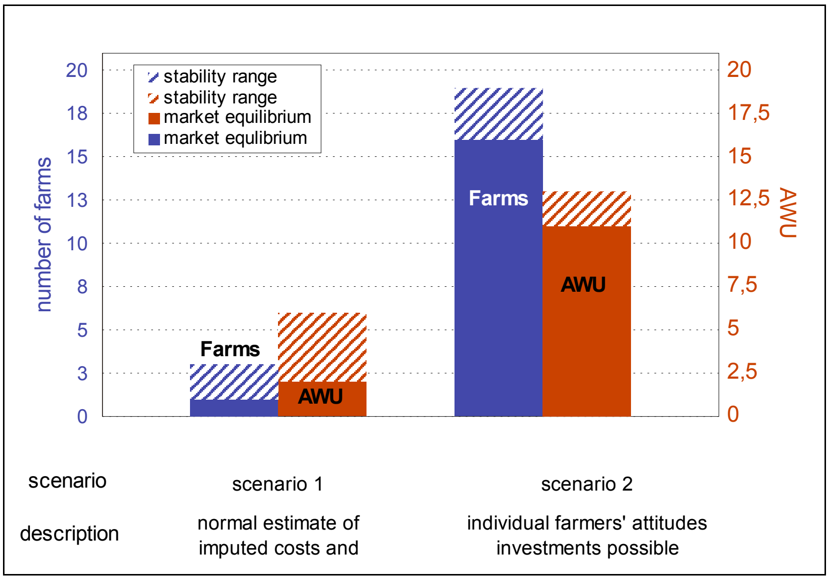
Table 1. Key figures of the farms in the Garmisch region: reality and depiction in the model

Key figure	Sample data	Model data [1)]
Agricultural land	224	191/225
Grassland (ha)	146	134/175
Litter meadows (ha)	27	21/25
Rough grazing and other grassland of low yield (ha)	51	25/37
Average land rent (EUR / ha)	50	50/70
Number of Farms	27	20
Structure of Holdings		
Number of full time farms	0 (n = 9)	0
Number of spare time farms	9 (n = 9)	17/20
Labour[2)]		
Labour input per farm (AWU): mean	1.5 (n = 9)	0.7
Labour input per farm (AWU): minimum … maximum	1…3 (n = 9)	0.4…1.2
Land / Size of Holdings		
UAA (ha): mean	8 (n = 27)	11.2
UAA (ha): minimum … maximum	1 … 41 (n = 27)	4.7 … 44.5
Livestock husbandry		
Mean (LU)	9 (n = 27)	12/15
Minimum … maximum	1…33(n = 27)	7…45
Number of sheep, goats	132 (n = 17)	-
Number of horses	17 (n = 17)	-
Number of heifers	44 (n = 17)	115/137[3)]
Number of suckler cows	33 (n = 17)	110/133[3)]
Number of dairy cattle	64 (n = 17)	61/71
Farmers attitude		
Economic relevance of agriculture		
Number of farms with high relevance: more than 40 % of family income from agriculture[2)]	2 (n = 9)	
Number of farms with medium relevance: 20 to 40 % of family income from agriculture[2)]	2 (n = 9)	
Number of farms with low relevance: less than 20 % of family income from agriculture[2)]	5 (n = 9)	
Farmers' personal planning horizon		
Number of farmers intending long term farm survival / Charge of 50 % of imputed costs	8 (n = 9)	18
Number of farmers intending only short term farm survival / Charge of 10 % of imputed costs	1 (n = 9)	2
Minimum income from agriculture		derived

1) lower and upper values of the two implementation runs
2) Sample data include forestry
3) Overestimated since horses and sheep are depicted in the model as suckler cows

4.2 Effects of the consideration of farmers' attitudes on the results of model simulations by the example of the study case

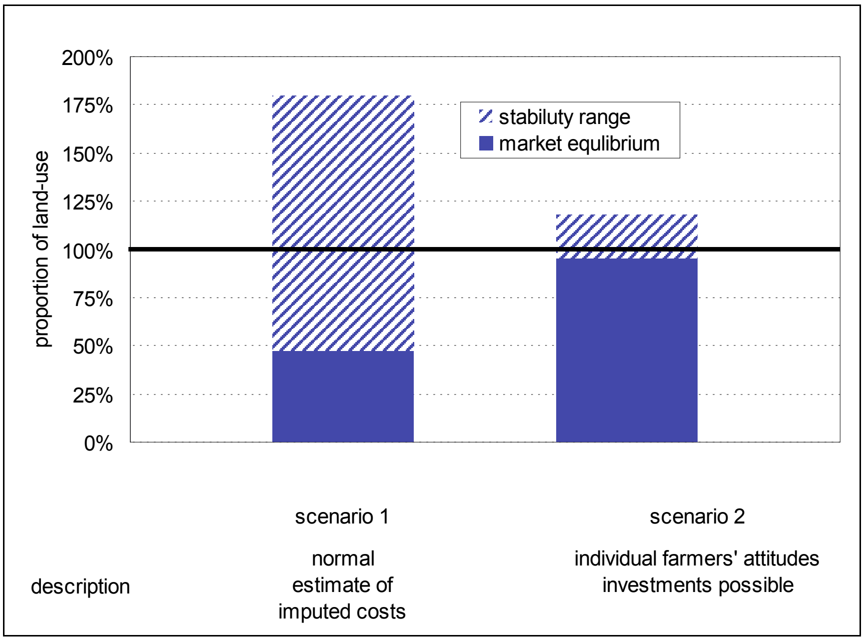
Figure 5 shows the effects on selected agro-social aspects in the two scenarios. Without regarding differences in farmer's attitudes (scenario 1) only a few farms have a long time perspective under the current business environment. Most farmers give up farming because of a clear lack of profitability. At the market equilibrium the model predicts that only one farm with two AWUs survives. The stability range reaches up to three surviving farms with an total labour demand of four AWUs (assuming slightly reduced land rents). In contrast to that the model calculations for scenario 2 predict a long term perspective for most farms in the study region. At market equilibrium 16 part time farms share the cultivation of the agricultural land in the study region. The stability of this result is quite high: the second calculation predicts a number of 19 surviving farms with 13 AWUs.



Annotation: stability range calculated with slightly lower land rents than at equilibrium solution

Figure 5. Scenario 1 and 2: Number of farms and total labour input in agriculture in the case study area

Considering the overall extend of agricultural land-use the model results show that the risk of land abandonment at the market equilibrium is higher in scenario 1 than in scenario 2 (fig. 6). But the settings in scenario 1 demand a large farms size in order to be profitable. Due to the fact that there is no differentiation in farmers' attitudes they would be very similar. In combination with the stepwise constant and discontinuous land demand function this leads to a wide stability range. Consequently the predicted land abandonment is not very reliable. In contrast to that scenario 2 with the more detailed differentiation of farms leads to more stable results. The stability range is obviously narrower.



Annotation: stability range calculated with slightly lower land rents than at equilibrium solution

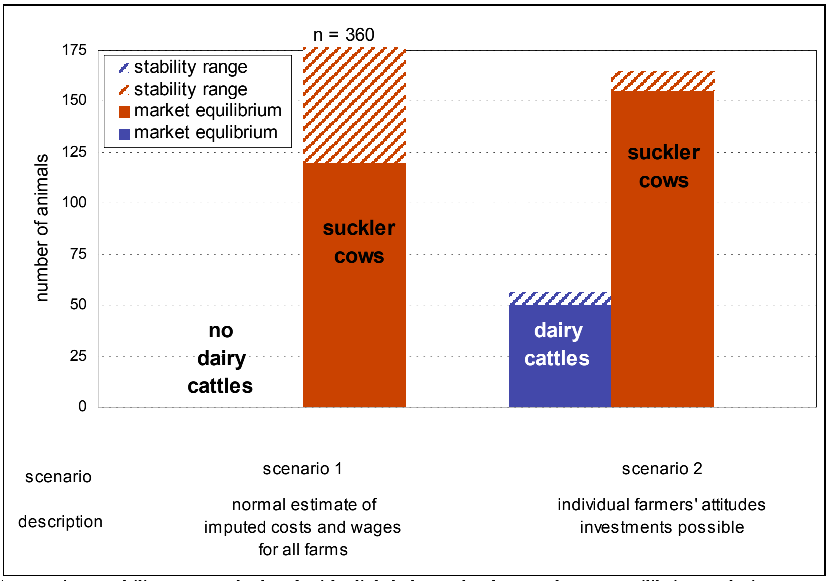
Figure 6. Land use in the case study area under different business environments

Table 2 depicts further information on the farm structure. In contrast to scenario 1 the socio-economic farm type in scenario 2 is the same as in the initial implementation. In both cases exist only part-time farms, while the farms in scenario 1 are on the verge of full time farming. In scenario 2 due to the strong competition and the resulting limitation of land there is no increase in farm size. In scenario 1 farm size exceeds 100 ha. Land rent is very low, because at market equilibrium only one farm survives.

Table 2. Agricultural structure in the two scenarios

Structural key figures	Scenario 1	Scenario 2
Farm structure	1-3 part time to full time farms	17-19 part time farms
Avg. size (ha)	137	12
min … max (ha)	118 - 147	5 - 45
Avg. land rent (EUR / ha)	0 - 1	60 - 80

Figure 7 focuses on animal husbandry in the different scenarios. The labour-intensive dairy farming is given up because of the higher charge on labour in scenario 1. Within the current subsidy scheme suckler cows are more profitable. As one can see considering farmers' attitudes (scenario 2) the model leads to results which are closer to the current situation.



Annotation: stability range calculated with slightly lower land rents than at equilibrium solution

Figure 7. Animal husbandry in the case study area under different business environments

In order to compare the economic effects of the consideration of farmers' attitudes, the results of both scenarios are adjusted to equal wages of 10 Euros per AWh (tab. 3). All imputed costs are fully considered. Under these conditions agriculture cannot be operated profitable in the study region although the subsidies exceed 500 Euros per ha.

Due to the higher proportion of suckler-cow farming in scenario 1 the market revenues are lower while the amount of transfer payments per ha is slightly higher than in scenario 2. In case of scenario 1 farms make an average loss of 150 Euros per ha or 12'000 Euros per AWU. In scenario 2 the overall loss is ten times as high as in scenario 1. In other words, the farmers pay in total 370'000 Euros per year in order to stay farmer in the long run.

Table 3. Economic key figures in the two scenarios

Economic key figures	Scenario 1	Scenario 2
Avg. market revenues (EUR / ha)	600	900
Avg. premium (EUR / ha)	600	550
Avg. profit[1)] (EUR / ha)	- 150	- 1'400
Avg. profit[1)] (EUR / AWU)	- 12'000	- 30'000
Total profit in the region[1)] (EUR)	- 36'000	- 370'000

[1)] for comparison based on imputed wage of 10 EUR per hour and 100% accounting of imputed costs

To sum up it is to say that the Garmisch example shows that considering farmers' attitudes in land use models can lead to totally different results than assuming equal aims for all agents. If we implement farmers' attitudes in the model we obtain a better representation of the agriculture in this region. Furthermore it becomes clear that maximising profits is not the only aim of the farmers. Therefore, the impacts of agricultural policy in the study region are rather low in contrast to the farmers' personality. A drastic change in agriculture and land use patterns will take place if farmers' attitudes shift in a more economic direction. This can happen in the context of farm transfer.

5. Discussion of the model and outlook

As demonstrated by the example of Garmisch, individuality of farms is often of great importance for future land use. So it is to assume that even comparable farms will react to an identical change of the business environment differently and the adaptation process to the new conditions will depend to a large extent on the attitudes of the concerned agents (Jager et al., 2000). This applies in particular for small-structured regions with high heterogeneity with regard to farm structure and farmers' attitudes. With our approach we try to integrate elusive factors such as farmers' attitudes into a land-use model.

The integration of farmers' attitudes demands the modelling of individual farms trying to achieve their individual interests. In order to cope with this problem a multi-agent technique is the mean of choice. This technique allows for the consideration of individual farms. With our model we show a possibility to implement farmer's attitudes in land-use models in an indirect way. We assume that the present farm organisation is the result of an optimisation process realising the individual aims of farmers under current settings. This means that we consider farmers' attitudes as a black box, but farm organisation is an expression of these attitudes.

Of course this can be only a first attempt to integrate individuality in land-use models. Due to the fact that we consider farmers attitude as a black box, we avoided to survey personal aims very detailed. It is to assume that this way of implementing farmers' attitudes indirectly is not sufficient for describing farmers' decision making process. Even if this would be a valid way to explain previous developments, it is to question if this data can be extrapolated into future.

This applies in particular for up to now unique occurrences like the decoupling process in the current CAP reform. Furthermore important constituent parts of farmers' attitudes have not been considered. For instance risk behaviour might influence model results significantly. Despite all open questions the presented way leads to reasonable results. By applying the model in the study region of Garmisch we could explain land use developments more appropriate. It is to assume, that further model applications with a changing business environment will lead to more reliant predictions.

Spatial explicitness is often demanded in land-use planning. One constraint of our approach is the lack of this feature. One way to integrate spatial explicitness in land-use models is shown in the Multi-Agent-System Cellular-Automata Model (MAS-CA) of Berger (2000, also compare Balmann 1997 and Ligtenberg et al. 2001). This type of model also considers different farms or rather 'agents' competing against each other in order to optimise their individual land use. Due to the implementation of cellular automata - representing agricultural plots which can be leased by farms - the MAS-CA model is spatially explicit and allows theoretically the prediction of future land-use of each single plot.

It is to say that agent-based models in general show an insecurity due to the fact that a lot of necessary input data cannot be achieved with a sufficient accuracy. This problem does augment in case of modelling spatially explicit. A way out of this ambivalence is perhaps to complement model results with expert knowledge. In a first step, for instance, the model derives the share of different production methods within a certain land quality. In a second step the productions methods are assigned according to a expert system using GIS technique to all plots of the considered quality (compare Hermann 2003).

To summarize it can be said that the model is suitable to derive land-use developments of smaller regions and helps to identify relevant factors influencing such development. The model may become especially important during the next decade when the European NATURA 2000 guidelines have to be implemented concerning in particular small- and medium-sized regions. Currently we adapt the model to more typical regions of Bavaria and to perform detailed analyses especially with respect to economic and ecological data.

Literature

Balmann A. (1997): "Farm-based Modelling of Regional Structural Change", *European Review of Agricultural Economics*, 24 (1): 85-108.

Bayerische Landesanstalt für Betriebswirtschaft und Agrarstruktur (LBA) (1996): "Anbauflächen in den bayerischen Agrar- und Erzeugungsgebieten in den Jahren 1977, 1979, 1983, 1987, 1991 und 1995 sowie Bayerns insgesamt in den Jahren 1977, 1979 und 1983 bis 1995", "Arbeiten der Bayerischen Landesanstalt für Betriebswirtschaft und Agrarstruktur", Heft 22, München.

Bayerische Landesanstalt für Betriebswirtschaft und Agrarstruktur (LBA) (2000): "Ernteträge in den bayerischen Agrar- und Erzeugungsgebieten sowie Bayerns insgesamt von 1980 bis 1999", "Arbeiten der Bayerischen Landesanstalt für Betriebswirtschaft und Agrarstruktur", Heft 21, München.

Bayerische Landesanstalt für Betriebswirtschaft und Agrarstruktur (LBA) (2001): "Rinderreport Bayern", in "Arbeiten der Bayerischen Landesanstalt für Betriebswirtschaft und Agrarstruktur", Heft 27, Auflage 5, München.

Bayerische Landesanstalt für Bodenkultur und Pflanzenbau (LPB) (1997): "Leitfaden für die Düngung von Acker- und Grünland", 6. Aufl., München.

Bayerische Landesanstalt für Landwirtschaft (LfL) (2003a): "Buchführungsergebnisse des Wirtschaftsjahres 2002/2003", Freising.

Bayerische Landesanstalt für Landwirtschaft (LfL) (2003b): "Landwirtschaftliche Erzeugerpreise in Bayern. Datensammlung für die Landwirtschaftsberatung", Freising.

Bayerische Landesanstalt für Landwirtschaft (LfL) (2003c): "Wirtschaftlichkeit der Mutterkuhhaltung - Prämien und Vermarktungsform sind entscheidend" (http://www.stmlf.bayern.de/proxy.php?url=/lba/sg_32/mutterkuh/&prxctx=/landwirtschaft/unternehmensfuehrung/wirtschaftlichkeit/) (lastly accessed on 24.09.2004), Freising.

Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten and Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen (BayStMELF / BayStLU) (2003): "Plan zur Förderung der Entwicklung des ländlichen Raumes in Bayern. Verordnung (EG) Nr. 1257/1999 des Rates vom 17. Mai 1999 über die Förderung der Entwicklung des ländlichen Raumes durch den EAGFL 2000-2006", Konsolidierte Fassung (http://www.stmlfdesign2.bayern.de/stmelf/g_5/programmplanungsdokument_gesamt_konsolidiert.pdf (lastly modified on 10.3.2004), München.

Bayerisches Staatsministerium für Landwirtschaft und Forsten (BayStMLF) (2002): "Bayerischer Agrarbericht 2002", München.

Berger T. (2000): "Agentenbasierte räumliche Simulationsmodelle in der Landwirtschaft - Anwendungsmöglichkeiten zur Bewertung von Diffusionsprozessen, Ressourcennutzung und Politikoptionen", Sonderheft der Agrarwirtschaft 168, Agrimedia, Bergen/Dumme.

Bundesministerium für Ernährung, Landwirtschaft und Forsten (BML) (1996): "Zur Neuorientierung der Landnutzung in Deutschland", in "Schriftenreihe des BML", Bonn 453.

Geißler R. (2002): "Die Sozialstruktur Deutschlands. Die gesellschaftliche Entwicklung vor und nach der Vereinigung", Westdeutscher Verlag, Wiesbaden.

Happe K. and Balmann A. (2002): 'Struktur-, Effizienz und Einkommensverteilung von Direktzahlungen", *Agrarwirtschaft*, 51: 376-388.

Heißenhuber A. and Kantelhardt Zarate M.S. (2003): "Disaggregation agrarökonomischer Daten als Grundvoraussetzung für eine disziplinübergreifende Modellkopplung - das Beispiel GLOWA – Danube", GEWISOLA 2003, Stuttgart- Hohenheim.

Hillert D., Ahrens H. and Harth M. (2004): "Modellgestützte Politikberatung im Naturschutz: Zur „optimalen" Flächennutzung in der Agrarlandschaft des Biosphärenreservates „Mittlere Elbe", *Agrarwirtschaft*, 53: 131-141.

Inglehart R. (1989): *Kultureller Umbruch. Wertwandel in der westlichen Welt*, Campus, Frankfurt a.M./ New York.

Jager W., Janssen M.A., de Vries H.J.M., de Greef J. and Vlek C.A.J. (2000): "Behaviour in commons dilemmas: Homo economicus and Homo psychologicus in an ecological-economic model", *Ecological Economics*, 35: 357-379.

Kantelhardt J. (2003): "Perspektiven für eine extensive Grünlandnutzung. Modellierung und Bewertung ausgewählter Landnutzungsszenarien", Sonderheft der Agrarwirtschaft 176, Agrimedia, Bergen/Dumme.

Kirchgessner M. (1992): *Tierernährung*, 8 edition, Frankfurt a.M.

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2002a): "AVOR-Win. Kapazitätsplanung in der Außenwirtschaft", Version 2.0. (computer programme), Darmstadt.

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2002b): "Betriebsplanung Landwirtschaft 2002/2003. Daten für die Betriebsplanung in der Landwirtschaft", 18. Aufl., Darmstadt.

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2002c): "KTBL-Taschenbuch Landwirtschaft. Daten für betriebliche Kalkulationen in der Landwirtschaft 2002/2003´, 21. Aufl., Darmstadt.

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2002d): "MA-KOST. Maschinenkosten-Kalkulation für Windows", Version 3.0. (computer programme), Darmstadt.

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2002e): "Spezielle Betriebszweige in der Tierhaltung. Datensammlung", 2. Aufl., Darmstadt.

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2004): "BAUKOST Investitionsbedarf und Jahreskosten landwirtschaftlicher Betriebsgebäude", Version 1.2., (computer programme), Darmstadt.

Lehner-Hilmer A. (1999): *Einstellungen der Landwirte zu selbstständigen Erwerbskombinationen. Auswirkungen auf den Strukturwandel in der Landwirtschaft*, Kovacs-Verlag, Hamburg.

Lightenberg A., Bregt A.K. and Lammeren R. van (2001): "Multi-actor-based land use modelling: spatial planning using agents', *Landscape and Urban Planning*, 56: 21-33.

Ploeg J.D. van der (2003): *The Virtual farmer - Past, present and future of the Dutch peasantry*, Royal Van Gorkum, Assen, The Netherlands.

Regierung von Mittelfranken (RegMFr) (2003): "Deckungsbeiträge. Variable Kosten. AKh-Bedarf der wichtigsten landwirtschaftlichen Produktionsverfahren incl. Sonderkulturen", 13. Aufl., Ansbach.

Romero C. and Rehman T. (1989): *Multi Criteria Analysis for Agricultural Decisions*, Elsevier, Amsterdam, Oxford, New York.

Rounsevell M.D.A., Annetts J.E., Audsley E., Mayr T. and Reginster I. (2003): "Modelling the spatial distribution of agricultural land use at the regional scale", *Agriculture, Ecosystems & Environment*, 95: 465-479.

Schäfers B. (2004): *Sozialstruktur und sozialer Wandel in Deutschland*, UTB, Stuttgart.

Schemm H. (2004): *Konzeption eines Rechenmodells zur Analyse agrarpolitischer Szenarien in einer Kleinstregion*, Ph. D. Thesis at the chair of agricultural economics at the TU München-Weihenstephan, Freising.

Walters F.H., Morgan S.L., Parker L.R. and Deming S.N. (1999): *Sequential Simplex Optimization*, Karlskrona.