# Simulating the effects of decoupled transfer payments using the land use model ProLand

# Simulation der Effekte entkoppelter Transferzahlungen mit dem Landnutzungsmodell ProLand

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## Abstract

**This paper describes the bio-economic land use model ProLand and presents selected results for scenarios of coupled and fully decoupled Pillar One transfer payments under the European Union's Common Agricultural Policy (CAP). The basic assumption for the model is that land users select the land use alternative from a set of agricultural and silvicultural land use systems which is expected to generate the highest possible land rent. The model is used to estimate effects of fully decoupled transfer payments on land use in a less favoured region in Hesse, Germany. The results confirm that the CAP Reform removes the distorting effects of coupled transfer payments. The extent and direction of land use changes are spatially variant. Overall, the CAP Reform will lead to increases of permanent grassland area at the cost of arable land. The total agricultural land rent generated in the region will grow substantially, mainly due to higher amounts of transfer payments.**

## Key words

**CAP Reform; land use modelling; decision support; spatial model; ProLand**

## Zusammenfassung

**Dieser Beitrag stellt das bio-ökonomische Landnutzungsmodell ProLand vor und präsentiert ausgewählte Ergebnisse für Szenarien bezüglich gekoppelter und vollständig entkoppelter Transferzahlungen der Ersten Säule der Gemeinsamen Agrarpolitik (GAP) der Europäischen Union. Die Grundannahme des Modells ist, dass Landnutzer diejenige Landnutzungsalternative aus einer Menge land- und forstwirtschaftlicher Landnutzungssysteme auswählen, welche die höchstmögliche Bodenrente auf einer Entscheidungseinheit erwarten lässt. Eine Modellanwendung simuliert die Auswirkungen vollständig entkoppelter Transferzahlungen auf eine benachteiligte Region in Hessen, Deutschland. Die Ergebnisse zeigen, dass die verzerrenden Wirkungen gekoppelter Transferzahlungen durch die Reform der GAP beseitigt werden. Der Umfang und die Richtung von Landnutzungswechseln sind raumvariant. Insgesamt führt die Reform der GAP zu Zunahmen der Dauergrünlandflächen zu Lasten des Ackerlandes. Die in der Region insgesamt erwirtschaftete landwirtschaftliche Grundrente wird vor allem wegen gestiegener Transferzahlungen substanziell zunehmen.**

## Schlüsselwörter

**Reform der GAP; Landnutzungsmodellierung; Entscheidungsunterstützung; räumlich explizit; ProLand**

## 1. Introduction and problem statement

Developments in the European Union's Common Agricultural Policy (CAP) over the past decade reflect the increasing importance of multiple, non-commodity landscape outputs, e. g. species habitats or drinking water (EUROPEAN COMMISSION, 1999; EUROPEAN COMMISSION, 2004). Also, society becomes increasingly aware of landscape's essential role in individual and societal well-being and people's quality of life (COUNCIL OF EUROPE, 2000). The discussion on multifunctionality combines these aspects by acknowledging the fact that landscapes may have multiple commodity and non-commodity outputs and may contribute to several of society's objectives at once (EUROPEAN COMMISSION, 1999 and 2004; OECD, 2001). In this context, the European Council initiated a landscape convention making the preservation of the rural environment one of CAP's key concepts (COUNCIL OF EUROPE, 2000; HEIßENHUBER and LIPPERT, 2000).

CAP strongly influences agriculture and forestry as it directly affects the comparative advantage of land use systems. Associated with changes of profitability are changes of land use and, consequently, multiple landscape functions linked to land use. Environmental changes, for example, almost always trace back to land use changes (LAMBIN et al., 2000). Therefore, it is essential for political decision makers to obtain reliable estimates of the economic effects of specific agricultural policy measures, associated land use changes and their allocation in space.

Equilibrium models are a common methodology to gain information on the spatial distribution of land use systems. They are based on the assumption that a region can be divided into punctiform, homogeneous demand and producer sub-regions. The spatial distribution of agricultural land use is then calculated based on economic efficiency criteria (see HENRICHSMEYER, 1994; BORK et al., 1995; WEINGARTEN, 1995; HENRICHSMEYER, 1995; BALMANN et al., 1998; MOXEY and WHITE, 1998; ROUNSEVELL et al. 1998; BERNHARDT and AHRENS, 1999; DABBERT et al., 1999). A major problem of these approaches is disaggregating the calculated shares of land use systems to land users' individual decision units, especially for landscapes of up to 1,000 km$^2$ with heterogeneous production conditions (HENRICHSMEYER, 1994; BORK et al., 1995; MOXEY and WHITE, 1998; ROUNSEVELL, et al., 1998; DABBERT et al., 1999). The spatial scale and level of detail at which information on land use changes is required varies with the investigated function. For example, biodiversity and associated indicators such as α- and β-diversity, are influenced by changes at multiple scales, ranging from individual patches to regions (MAGURRAN, 1988, BOCKSTAEL, 1996, DUELLI, 1997). Therefore, "instead of trying to put the spatial dimension of landscapes and environment into inherently dimensionless economic models, one should try to come from spatial distribution and merge spatial units to decision units in order to impose spatial on economic relations"

(HANF, 1994). In addition to changes between land use categories, e.g. from grassland to arable farming, different land use systems affect environmental quality as they influence abiotic and biotic aspects both directly and indirectly (WALDHARDT et al., 2003). Agricultural and forestal land use models need to address these issues and provide sufficiently detailed results.

Approaches based on aggregate farms which examine production programmes using linear or non-linear programming need primary information on size, type, organisation, ownership and especially location of agricultural land with a particular land use programme. Even if these data are available, conflicts arise when a comparative static modelling approach is employed. Farm sizes and field ownership are dynamic, hence restrictions concerning labour, capital, machinery and other production capacities resulting from particular farm structures are valid only in the short term. This applies also to current land use patterns. The actual land use pattern, e.g. derived from satellite images, is just a snapshot of dynamic long-term processes. To a large extent, the situation captured is sub-optimal with respect to an objective function, mainly due to the land users' time consuming adaptation and learning processes. Accordingly, land use predictions as a function of current land use are only valid in the short term. A long-term prognosis has to consider these adaptation and learning processes. This, however, is a challenging problem, mainly caused by the spatial and temporal variability of risk behaviour and opportunity costs of labour. Therefore, assuming a spatially and temporally invariant land user with risk neutral behaviour may be considered the best possible approximation. KUHLMANN et al. provide a detailed discussion of related problems (KUHLMANN et al., 2002).

This paper presents the bio-economic land use model ProLand (WEINMANN, 2002; KUHLMANN et al., 2002) which can be employed as a decision support system (DSS) for policy makers. The emphasis is on the methodology of ProLand, as it differs from the approaches discussed above. An application elaborates the long term agricultural and forestal land use patterns at the plot scale in a less favoured region in Hesse, Germany, given coupled (Agenda 2000) and fully decoupled (CAP Reform) Pillar One payments. Differences in land use between both results are discussed.

## 2. The land use model ProLand

The land use model ProLand is developed at the collaborative research center SFB 299 "Land Use Options For Peripheral Regions" of the Justus Liebig University, Gießen. At the center, researchers from multiple disciplines investigate land use options for less favoured regions, their major objective being the development of transferable models and strategies which may support politicians and other stakeholders in their decision processes. The resulting ITE$^2$M (Integrated Tool for Economic and Ecological Modelling) is a network of models covering economic, abiotic, and biotic aspects with high spatial resolution (compare MÖLLER et al., 1999). ITE$^2$M allows the evaluation of multifunctional landscapes with actual and simulated land use patterns, based on scenarios addressing different political, socio-economic, and natural conditions (see MÖLLER et al., 2002).

ProLand, the land use model of ITE$^2$M, is employed in a deterministic, comparative static mode. It divides regions into economic decision units without defining specific farm structures. A decision unit can be a grid cell or a vector element of discretionary size such as an individual field. ProLand calculates the land rent maximizing land use system and economic key indicators for every decision unit. Spatial information is associated with all elements of the output vector.

The model can be used as an economic laboratory to analyse the effects of changes in political, technological, socio-economic, and natural conditions (see MÖLLER et al., 1998; MÖLLER et al., 2000; WEBER et al., 2001; MÖLLER et al., 2002). In addition to land use maps, the model also generates key indicators describing a region's economic performance. As all results are spatially explicit they can easily be aggregated in common GIS or database management systems. Also, they can be combined with ecological as well as hydrological indicators provided by respective models (MÖLLER et al., 1999; WEBER et al., 2001).

### 2.1 A relational database for land use systems and land use activities

Land is used through land use systems. Using the entity-relationship data model (CHEN, 1976), agricultural and silvicultural land use systems consist, at the primary level, of the entity sets "crops", "field operations", "animal husbandry", and their relations. These entities are described using biological and technological attributes, specific to each entity. Land use systems are determined by political, socio-economic, natural, and technological conditions as well as their relations. A land use system at the secondary level is thus extended by these entity sets and the relations between all sets. Consequently, a comprehensive description of a specific agricultural or silvicultural land use system requires data on all entity sets and relations (SCHROERS and SHERIDAN, 2004).

The following example of dairy cow keeping illustrates this approach. A description of the corresponding land use system requires data on what fodder crops are grown (entity set "crops"), how these crops are produced (entity set "field operations"), and how the animals are kept (entity set "animal husbandry"). To comprehensively describe the system, additional data are required, e.g. factor and product prices, transfer payments, interest rates, wage rates, and production quotas.

A land use activity is a predefined production process including all sub-processes in crop and animal production, like e.g. seedbed preparation, plant protection or milking. Two land use activities differ at least in one aspect. For example, wheat production with and without ploughing are two different land use activities, as are wheat production processes with different machinery configurations.

Land use activities are grouped into land use systems within the three categories arable farming, grassland farming or forest management. For example, an arable farming land use system consists of different land use activities, like e.g. wheat, barley and rapeseed production in a crop rotation. A grassland system may consist of combined grazing and silage making. A similar approach was developed to simulate forest management (STROEDE, 2004). Land use activities within the category are defined for individual tree species. A silvicultural land use system can be the cultivation of a single tree species as well as a set of different tree species in a mixed forest.

This structure is used for all agricultural and forestal production processes. Animal husbandry includes all land-dependent production processes like dairying and feeder cattle. Pork, egg, and poultry production are assumed to be spatially independent and therefore without effect on regional land use patterns. They are not modelled yet.

ProLand's land use systems database reflects the biological, socio-economic and political attributes of agricultural production. Spatially explicit land use modelling requires additional site specific information on natural, structural and political attributes that influence the costs and benefits of land use systems. A geodatabase with data on natural and political conditions, as well as landscape structure, satisfies these requirements. Attributes include, among others, plant available water and temperature as non-controllable growth factors, site specific transfer payments, slope, and field size.

The spatial resolution varies with the type of information stored. While information on natural conditions is derived from 25 m by 25 m grid cells, field polygons are stored with their actual shape and size. Associating the grid-based data with the field polygons creates subunits with homogeneous natural conditions within the decision units. During the simulation process, each subunit is estimated and one land use system is selected for the entire field polygon (compare equation 2).

The relational databases and the direct link to a geographical information system (GIS) enable ProLand to simulate spatially variant interventions in land structure, market policy, and land use restrictions. The land use systems available for simulation can be specified in each scenario. This allows to estimate, for example, opportunity costs of land use restrictions, like conservation programmes, for selected sub-regions.

The aforementioned approach has several advantages: it allows to store information without data redundancy, provides a means to integrate virtually all land use systems including energy farming, as well as conservation measures, and makes it possible to generate scenarios as dependent on e.g. prices, policy instruments and technological change.

## 2.2 Objective function and simulation procedure

The model assumes land rent maximizing behaviour of land users. Land rent is an appropriate and useful approach to measure the potential economic performance of land use systems (comp. VAN KOOTEN, 1993: 15 et sqq.). It is defined as revenues minus costs including opportunity costs for capital and labour in monetary units per area unit (compare equation 2). It represents the remuneration for the land employed in agricultural or silvicultural production (KUHLMANN, 2003). Each decision unit (pos) is assigned the land use system with the highest land rent according to equation (1).

$$(1)\quad LR_{max,\,pos} = \operatorname{Max}\left\{LR_{cl_1,pos},\dots,LR_{cl_n,pos},LR_{pa_1,pos},\dots,LR_{pa_k,pos},LR_{fo_1,pos},\dots,LR_{fo_l,pos}\right\}$$

where

pos = decision unit

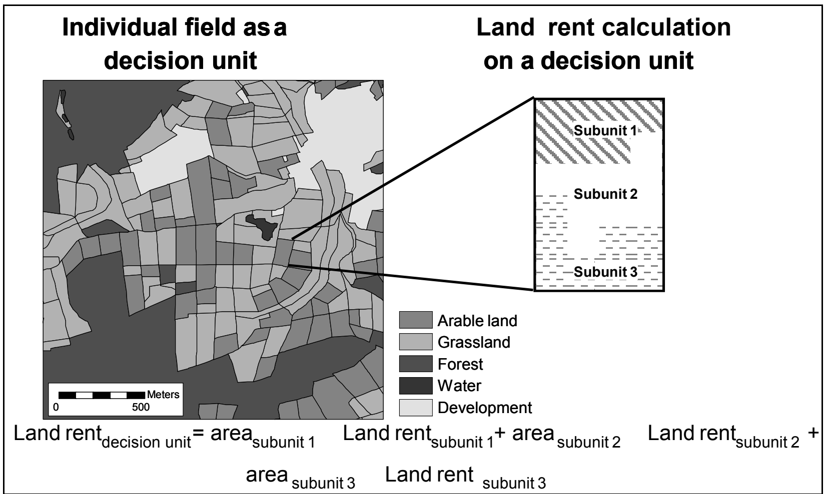
$LR_{cl_1,pos},\dots,LR_{cl_n,pos}$ = land rent of land use systems arable land

$LR_{pa_1,pos},\dots,LR_{pa_k,pos}$ = land rent of land use systems grassland

$LR_{fo_1,pos},\dots,LR_{fo_l,pos}$ = land rent of land use systems forestry

A decision unit can exhibit varying natural conditions, which influence productivity and consequently, the land rent. Therefore, a land use activity's land rent is calculated on subunits with homogeneous natural conditions (compare figure 1).

**Figure 1. Individual fields as decision units**




Source: author

The area-weighted sum of the subunits' land rents yields the land rent GR $_{i,pos}$ on a decision unit (compare equation 2).

$$(2)\quad LR_{i,pos} = \sum_{f=1}^{n} a_{pos,f}\left(R_{i,pos,f} - C_{i,pos,f}\right).$$

$$LR_{i,pos} = \sum_{f=1}^{n} a_{pos,f}\left(\left(\sum_k p_{i,k}\, y_{i,pos,f} + \sum_l s_{i,l,pos,f} + \sum_m s_{i,m}\, y_{i,pos,f}\right) - \left(\left(\sum_n cy_{i,n}\, py_n\right) y_{i,pos,f} - \sum_p ca_{i,p,pos,f}\, pa_p\right)\right)$$

where

$LR_{i,pos}$ = land rent (LR) for land use activity i on decision unit pos expressed in €/ha,

$a_{pos,f}$ = area share of subunit f (f = 1,…,n) of decision unit pos expressed in percent,

$R_{i,pos,f}$ = the revenue of land use activity i on subunit f of decision unit pos expressed in €/ha,

$C_{i,pos,f}$ = production costs for land use activity i on sub unit f of decision unit pos expressed in €/ha,

$p_{i,k}$ = farm-gate product prices for the k-th yield component of land use activity i expressed in €/dt,

$y_{i,pos,f}$ = the maximum realisable yield of the land use activity i on subunit f of decision unit pos ex pressed in dt/ha,
$s_{i,l,pos,f}$ = l-th area payment for subunit f of decision unit pos for the land use activity i expressed in €/ha,
$s_{i,m}$ = m-th yield dependent subsidy of land use activity i in €/ha,
$cy_{i,n}$ = coefficient determining the consumption of the yield dependent production factor n of land use activity i expressed in quantity unit per yield unit,
$py_n$ = price of the yield dependent production factor n expressed in € per quantity unit,
$ca_{i,p,pos,f}$ = coefficient determining the consumption of the area dependent production factor p of land use activity i on subunit f of decision unit pos ex pressed in quantity units per hectare,
$pa_p$ = price of the area dependent production factor p expressed in € per quantity unit.

First, the site-specific maximum realisable yield for every land use activity is estimated. Two important assumptions in the estimation are that (i) land users are able to reach the estimated crop yield in the long term and (ii) all controllable production factors do not restrict the attainment of the maximum realisable yield. The maximum realisable yield $y_{i,pos,f}$ on subunit f of decision unit pos is calculated using linear-limitational yield functions. The functions describe the influence of the non-controllable growth factors annual precipitation, usable field capacity and annual temperature sum on crop yield. The yield is either limited by plant available water or temperature sum. Thus, maximum realisable yields are endogenous variables and dependent on the site specific values of the non-controllable growth factors.

The revenue $R_{i,pos,f}$ of land use activity i on subunit f of decision unit pos is the product of the maximum realisable yield $y_{i,pos,f}$ on subunit f of decision unit pos and the corresponding farm-gate product prices $p_{i,k}$. Self-produced fodder is valued by calculating the revenues for the animal products less their production costs (except fodder costs). Subsidies and premiums, separated into area dependent $s_{i,l,pos,f}$ and yield dependent components $s_{i,m}$, are added.

Production costs are calculated in the second step. Each land use activity has a predefined input-output structure. Production costs $C_{i,pos,a}$ of land use activity i on subunit f of decision unit pos consist of yield and area dependent cost components. The area dependent input-output coefficients are adjusted to site-specific conditions using correction factors for field size, slope, and soil composition. Factor requirements of livestock keeping activities are simulated for every livestock unit. Using annual fodder requirements and the maximum realisable yield allows to transfer factor consumption in the livestock keeping activities to the spatial unit under consideration.

Figure 2 illustrates the necessary steps to predict land use based on the rent calculated according to equation 2. For details on model validation see WEINMANN (2002) and KUHLMANN et al. (2002).

### 2.3 Methodological particularities

Calculating land rent according to equation (2) requires all production factors to be defined on one spatial unit. This implies that all production factors are mobile, fully divisible and infinitely available at given prices. All machinery is assumed to be employed at 100% of the depreciation threshold. Consequently, depreciations are performance-related and depend solely on cultivated area.

Assuming total factor mobility is adequate considering that (i) making use of private contractors is the rule rather than the exception, (ii) alternative income opportunities outside agriculture, e.g. in tourism or landscape conservation, are available on an hourly basis in most rural areas, (iii) mobility retarding factors, such as traditions, personal preferences, and commuting costs, are incorporated in the opportunity costs of labour, and finally (iv) total factor mobility may justly be assumed for long-run considerations anyway.

Transportation costs are incorporated assuming average farm to field distances and farm-gate prices for production factors and marketable products. For further discussion see KUHLMANN et al. ( 2002).

## 3. Application: effects of decoupled transfer payments in the Lahn-Dill region

In the following application to the Lahn-Dill region the model ProLand is used to simulate the long-term effects of coupled (Agenda 2000) and decoupled (CAP Reform) transfer payments on land use as well as associated economic indicators.

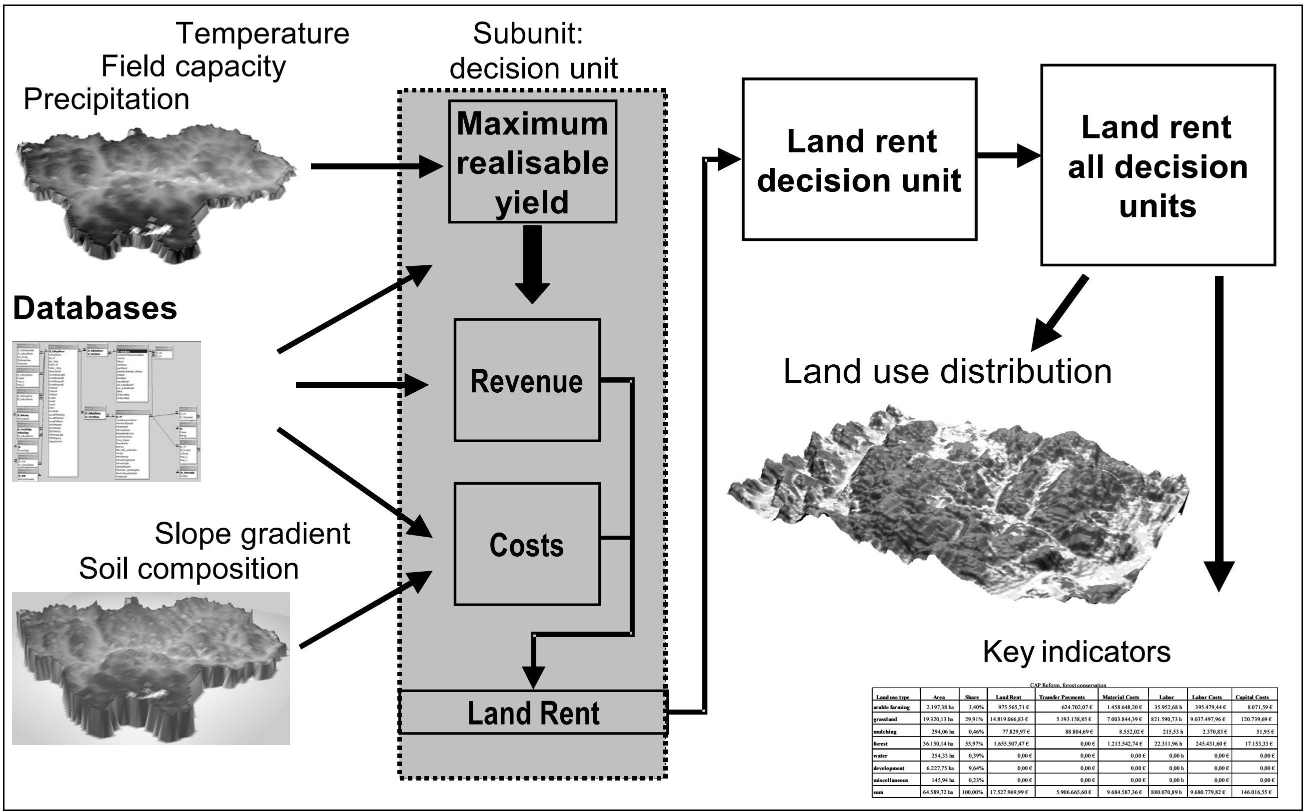
The mode of the CAP Reform implemented in Germany became effective in 2005. Key elements are the decoupling of transfer payments, requirements in terms of „Cross Compliance" and the redirection of funds from the First to the Second Pillar („Modulation") (BMVEL, 2005). By the year 2013, area payments for grass- and arable land will be integrated in a regional model, using a combinatory model as intermediate step.

Until the CAP Reform, key instruments employed in the First Pillar of CAP were coupled transfer payments such as market price support, direct payments for certain crops (mainly "grandes cultures") and animal premiums. Of course, these interventions influenced the economic decisions of land users with respect to the selection of land use systems.

The decoupling of direct payments under the CAP Reform is an important modification regarding the comparative advantage of land use systems. The economic potential of systems which previously yielded the maximum land rent on a spatial unit only because of coupled animal and area payments has to be reassessed. Since decoupled transfer payments depend on payment entitlements and not on the production programme, the decoupled payments exert no influence on a land user's decision for a certain land use system. Coupled animal payments will also be replaced by homogeneous area payments, putting an end to an important incentive for beef, veal and lamb production. Alternative methods of arable and grassland farming which previously received no payments, become economically more attractive under the new policy scheme. Particularly cutting (mulching) of permanent grassland in order to keep it in "good agricultural condition" is a new land use alternative.

Considering the new payment criteria, a land user may choose among five options: (i) maintain the existing land use programme, (ii) maintain the land use category but switch to a different land use system, (iii) change the land

**Figure 2. Model structure**




Source: author

use category, for example from arable farming to grassland, and switch to an appropriate land use system, (iv) cease production and keep the fields in a "good agricultural and ecological condition" in accordance with the Cross Compliance requirements, (v) leave the fields to natural succession and waive the area payments.

## 3.1 Incorporating policy measures into ProLand

Variable options of market price support are incorporated for marketable cash crops and processed products such as milk and beef. These price structures can be entered and altered directly in the database.

Coupled, as well as decoupled payments are stored for every crop, respectively every decision unit. They are added to the monetary yields of the individual crop according to equation (2). Animal premiums influence the profitability of the respective animal production processes and thus affect the comparative advantage of fodder growing land use activities.

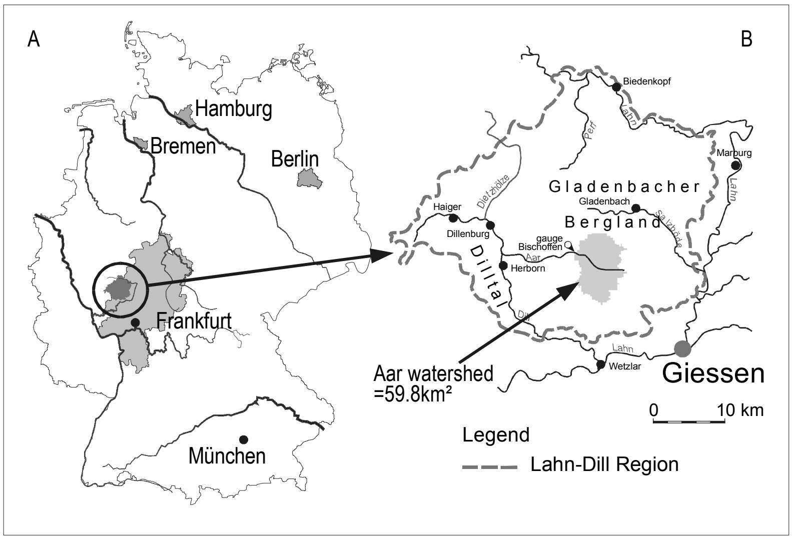
This structure enables simulations with spatially referenced coupled and decoupled animal premiums and area payments. On the other hand, integrating individual transfer payments at the farm level, and simulating the effects is not possible or only for the region in its entirety, due to the spatial rather than farm based approach.

## 3.2 Region of interest

The Lahn-Dill region, located in the central part of Hesse, Germany (compare figure 3), is a heterogeneous, low mountain region with unfavourable production conditions caused by low yields and small agrarian structure, i.e. a typical less favoured region.

The region comprises a total area of 1,100 km$^2$ with an average elevation of 380 m above sea level and 900 mm/a average precipitation. The share of plots with a low field capacity (below 100 mm) is almost 70%. More than 50% of the area is forest, whereas grassland takes a 20% share and a minor part of 6% is used for arable farming.

**Figure 3. Location of the investigated region in Germany. (A) dark coloured the German state Hesse and the study area Lahn-Dill hill country**




Source: author

### 3.3 Scenario description

The general political conditions of the region correspond to those in the state of Hesse. The baseline scenario reflects the political conditions under the Agenda 2000. The CAP Reform scenario differs only in the transfer payment scheme. Table 1 lists the different transfer payments in the Agenda 2000 and CAP reform scenarios.

**Table 1. Comparison of transfer payments for Agenda 2000 and CAP Reform scenarios in the state of Hesse**

| payment | unit | Agenda 2000 | CAP 2013 |
|---|---|---|---|
| Coarse grains | €/ha | 347 | 302 |
| Grassland | €/ha | 0 | 302 |
| Oil seeds | €/ha | 347 | 302 |
| Set aside | €/ha | 347 | 302 |
| Slaughter premium male cattle | €/head | 210 | 0 |
| Suckler cow premium | €/head | 200 | 0 |
| Suckler sheep premium | €/head | 26 | 0 |
| Milk premium | €/kg FCM | 0 | 0,035 |

Source: compiled by author, based on BMVEL, 2002a, 2002b, 2005

Transfer payments are decoupled according to the German CAP implementation. Payments from conservation programmes, the sugar market organisation, and the milk quota system are not altered. Time series data of farm gate prices for all relevant marketable agricultural products are derived from data provided by the "Central Market and Price Reporting Agency" (ZMP, 2002a-2004a; ZMP, 2002b-2004b). Prices for agricultural products and production factors are kept constant over time.

Factor prices for labour and capital are fixed in both scenarios of this example. The opportunity costs of labour are set to 11 € per hour, the opportunity costs of equity to 3.5% of the principal. In general, of course, they are variable exogenous inputs to the model ProLand.

Legal constraints, such as the prohibition of converting forest to cultivated land, are taken into account. Conversion of grassland to arable land is possible, but converted sites receive no area payments in the Agenda 2000 scenario.

Analyses are performed ceteris paribus, i.e. all other political, socio-economic, technological, and natural variables are kept constant in order to analyse the effects of the policy measures only.

### 3.4 Results

The results are evaluated by using the variables land rent, area shares of the different land use categories, amount of employed labour as well as amount of animal premiums and area payments (for details see figure 4 and table 2). Additional landscape functions and ecological indicators are not presented. The collaborative research centre SFB 299 at the Justus Liebig University has developed and continues to develop appropriate models which are linked to ProLand and provide the corresponding information (MÖLLER et al., 2002).

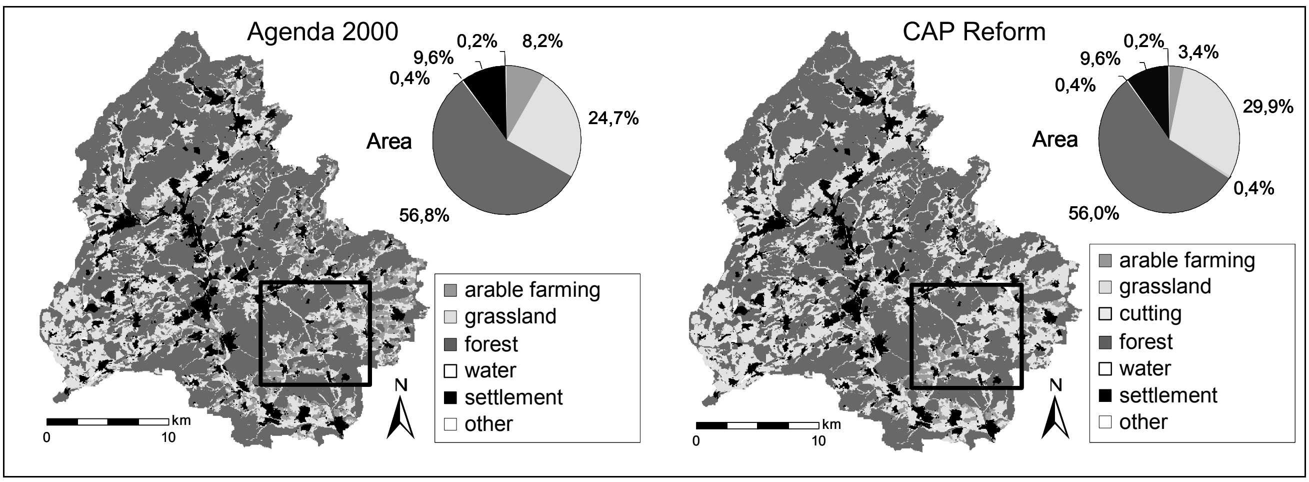
Figure 4 shows the endpoints of land use adaptation processes in the Lahn-Dill region for both, Agenda 2000 and CAP Reform, as simulated by ProLand. As only agricultural and silvicultural land uses are modelled, developed area remains constant, as do other non-agricultural land uses. Forested area shows only a marginal difference, mainly attributable to the strict legislative protection of forests. Grassland area in the CAP Reform scenario is about 5% larger, while arable farming area is about 5% smaller than under Agenda 2000 conditions.

Although these differences appear small compared with the overall ratio of land use systems, they may be more pronounced in certain sub-regions. As figure 4 shows, some areas exhibit small differences, for example the south-western corner, while others show significant variation, such as the eastern part of the study area.

Figure 5 is a magnification of the rectangular area marked in figure 4. It serves to demonstrate that the two simulated policies result in different land uses and thus in a changed landscape in this sub-region. Arable farming systems would account for around 59.4% of cultivated land, grassland systems for about 40.6% in the Agenda 2000 scenario. Note that arable farming systems are found throughout the sub-region illustrated in figure 5, i.e. also in the south-western and north-eastern corner.

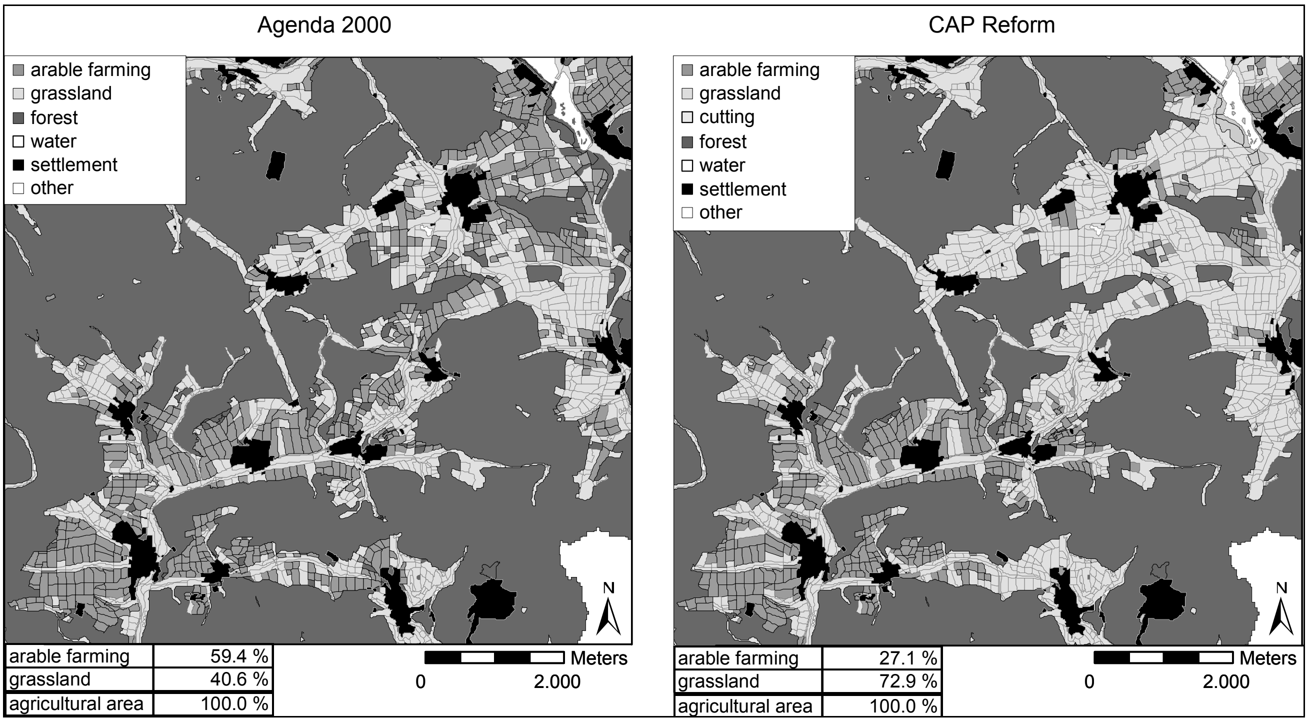
In the CAP reform scenario, arable farming retreats mainly to the south-western corner and is replaced by grassland

**Figure 4. Land use for Agenda 2000 and CAP Reform scenarios**




Source: author, based on ProLand results

**Figure 5. Land use for Agenda 2000 and CAP Reform scenarios – detail**




Source: author, based on ProLand results

systems in the north-eastern part. Arable farming systems account for only 27.1% of the cultivated area, grassland systems for 72.9%. An inspection of the natural conditions reveals lower temperature sums and more abundant plant available water in the north-eastern part of the sub-region compared with the south-western part.

An important component of land rents are transfer payments. Of course, they influence the land users' allocation decisions. The example illustrates the distorting effect of coupled transfer payments in the Agenda 2000 scenario as arable farming is more profitable than grassland at cooler sites with comparably good water availability. This distortion is removed by the CAP reform, hence the corresponding differences between land use patterns as shown in figures 4 and 5.

Objectives of the CAP reform include redirecting transfer payments into less favoured areas, removing production distorting components, increasing or stabilizing the area share of grassland, and providing rural employment opportunities. The first three objectives are clearly accomplished in this example of a less favoured region as table 2 and figures 4 and 5 indicate.

The share of grassland increases as does the land rent. Transfer payments are redirected into the region, the simulated increase amounts to 111%. Labour demand and the remaining indicators show no considerable difference.

The CAP reform is more successful than the Agenda 2000 in terms of achieving the stated objectives for the investigated region, given the general conditions as specified in the scenarios. Of course, results may be different for regions with intensive agricultural production, especially arable farming.

## 4. Discussion

The major objectives of this paper were to outline ProLand's methodology and to present a brief application. More specifically, the impact of decoupled Pillar One payments under ceteris paribus conditions is assessed. Therefore, results for two scenarios are presented. Effects of price structure changes, technological improvements, and socio-economic developments etc. are not considered here.

The predicted effects aggregated over the entire region are small. These developments were expected, given the already large share of grassland and the strict legislative protection of forests. More importantly, the model confirmed that effects are spatially variant. Identifying locations with differing reactions is a key objective of ProLand.

**Table 2. Area of land use categories and economic indicators for Agenda 2000 and CAP reform scenarios**

| | Scenario | |
|---|---|---|
| | Agenda 2000 | CAP reform |
| Agricultural and forest area [ha] (= 100%) | 57,971 | 57,971 |
| Arable farming [%] | 8.2 | 3.4 |
| Grassland [%] | 24.7 | 29.9 |
| Forest [%] | 56.8 | 56.0 |
| Cutting [%] | 0.0 | 0.5 |
| Land rent [€] | 14,068,657 | 17,527,970 |
| Land rent [€/ha] | 243 | 302 |
| Transfer Payments [€] | 2,802,697 | 5,906,666 |
| Transfer Payments [€/ha] | 48 | 102 |
| Material costs [€] | 10,542,433 | 9,684,587 |
| Material costs [€/ha] | 182 | 167 |
| Labour [h] | 872,823 | 880,071 |
| Labour [h/ha] | 15 | 15 |

Source: author, based on ProLand results

Obviously, a comprehensive impact assessment should be based on multiple simulation runs including structural as well as technological changes in order to estimate the long term consequences on the land use distribution and the associated quantitative indicators. In this context, ProLand can be employed as a decision support system.

The results have to be interpreted considering model assumptions, the comparative-static approach and scenario definitions. Certain possible developments regarding land use change are constrained by scenario specifications.

## 5. Summary

This paper presents the bio-economic simulation model ProLand employed for spatially explicit projections of land use. The model operates at the level of decision units that can be raster or vector elements of discretionary size such as individual fields. ProLand's fundamental assumption is that land users show land rent maximising behaviour and select the land use alternative which generates the highest possible land rent on a decision unit. The model uses site specific data on annual precipitation, temperature sum, and usable field capacity to predict maximum realisable yields and, based on these, revenues. Site specific production costs are calculated considering slope, field size, and soil composition. The resulting data are used to determine the land rent of agricultural and silvicultural land use systems.

The consequences of fully decoupled transfer payments are simulated for a less favoured region in Hesse, Germany. The results confirm that the CAP Reform removes production distorting effects of coupled transfer payments. The extent and direction of land use changes are spatially variant. Sites with relatively low temperature sums and high precipitation levels farmed as arable land in the scenario of coupled payments (Agenda 2000) are mostly farmed as grassland in the scenario of decoupled payments (CAP Reform). Overall, the reform increases the total land rent generated by agriculture in the region, due mainly to substantially increased transfer payments.

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