Combining dynamic economic analysis and environmental impact modelling: Addressing uncertainty and complexity of agricultural development

Heikki Lehtonen a,*, Ilona Bärlund b, Sirkka Tattari b, Mikael Hilden b

a MTT Agrifood Research Finland, Economic Research, Luutnantintie 13, FI-00410 Helsinki, Finland
b Finnish Environment Institute, PO Box 140, FI-00251 Helsinki, Finland

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Abstract

In this study, the impacts of different agricultural policies on agricultural production and nutrient leaching from agricultural land are evaluated using the economic DREMFIA agricultural sector model and the field-scale nutrient transport model ICECREAM. DREMFIA simulates competitive markets of agricultural products and includes an evolutionary scheme of technology diffusion which explicitly considers farm investments, evolving farm size structure and technological change. The technology diffusion model allows self-enforcing patterns of technical change driven by the spread of information and farmers’ knowledge related to different technological alternatives. Hence, the long-term changes in agriculture due to policy changes may be essentially larger than those predicted by traditional static equilibrium models. Larger potential for changes in production provides a larger perspective for evaluation of environmental impacts. The modelled variables in ICECREAM are nitrogen and phosphorus losses in surface run-off and percolation. The considered environmental effect is eutrophication of surface waters. In this paper, the modelling strategy will be presented and highlighted using two case-study catchments with varying environmental conditions and land use.

Keywords: Agricultural policy; Economic modelling; Technical change; Nutrient leaching modelling

1. Introduction

Water quality has been a part of agricultural policy debate in Finland because agricultural activities are responsible for a significant part of nutrient load. At the same time, agriculture is under rapid structural change due to economic pressures. In this paper, we therefore combine analyses of long-term economic viability of agriculture, nutrient leaching and water quality. There are only few such studies, although it is obvious that agricultural policies probably have environmental effects which include impacts on nutrient leaching and water quality by influencing production intensity and/or production allocation between geographical areas.

We have approached this issue through modelling, using a strategy that integrates a national-level multi-regional agricultural sector model (Lehtonen, 2001, 2004) with a region-specific field-scale nutrient leaching model (Tattari et al., 2001). The chosen approach is challenging, because the agricultural production economy both at national and regional level has to be combined with sets of factors that influence water quality.

A similar, but not identical integrated agri-environmental modelling approach was used by Shou et al. (2000). They used a sector-level economic model in calculating economically rational changes in variable factors of production as a response to changing policy. The resulting prices and quantities of inputs and outputs were then utilised in different farm
level economic models and in nutrient leaching models in order to calculate nutrient loads and their abatement costs for different soil types. The approach was seen convenient in combining the strengths of detailed bottom-up-based environmental analysis with the opportunities of aggregate top-down-based policy descriptions and economic modelling of agricultural production. However, the econometric sector level model used was not considered appropriate in evaluating effects of relatively large changes in prices or policy. The farm-level models based on statistical databases were static in the sense that no long-term adjustment mechanisms, like technology-inducing effects of price changes, or potential for cost-saving in the longer run, were modelled.

The Dynamic Regional Sector Model of Finnish Agriculture simulates economically rational production decisions, and is used to evaluate the likely impact of agricultural policy change on agricultural production. In this model, the most important production lines and production areas are connected through prices and resources—most importantly, agricultural land. Changes in agricultural policy influence relative profitability between agricultural products. Rational economic behaviour gradually drives use of inputs and production to the products and areas in which the production is relatively most profitable. Concerning variable factors of production, all this is a common feature in many agricultural sector models.

What is not a common feature in agricultural sector models is that agricultural investments are modelled explicitly in DREMFIA. Investments in new production techniques have wide ranging consequences in the medium- and long-term by affecting technical and structural change in agriculture and accumulation of knowledge and skills of farmers. Such effects of agricultural policy changes have been little analysed in economic literature. For example, the proceedings of 65th European Association of Agricultural Economists (EAAE) seminar in 2000 (Heckelei et al., 2001) include few explicit examples of modelling agricultural investment and technical change on sector level, or applying such schemes in policy analysis. Also the impact analyses of the Mid-Term Review (MTR) proposals of the European Commission1 do not report effects on investments and technical change. The primary focus of the impact analyses seems to be short- or medium-term (up to 2009) impacts on agricultural production and income at the EU level. No structural or technical change is assumed in those analyses where production resources are assumed as given.

When evaluating environmental effects of agricultural policies, both regional and dynamic aspects are relevant. The regional dimension is vital in any deeper analysis of environmental effects which are often regionally specific and varying. Dynamics is important because of technical and structural change, and because of re-allocation of production between regions over time.

Two catchments, which vary in their location and characteristics but represent two rather typical agricultural production regions in Finland, have been selected for this study. Production in both areas is influenced by production in other areas in Finland because of the balance between total supply and demand. Our purpose is to show how integration of dynamic economic and environmental modelling can be carried out in practice, and to discuss some of the challenges.

2. Methods

2.1. The sector model

DREMFIA is a dynamic recursive model and includes 17 production regions. The model provides effects of various agricultural policies on land use, animal production, farm investments and farmers’ income. The model consists of two major parts: (1) a technology diffusion model which determines sector level investments in different production technologies, and (2) an optimisation routine which determines annual production decisions (within the limits of fixed factors) and price changes, i.e., supply and demand reactions, by maximising producer and consumer surpluses subject to regional product balance and resource (land and capital) constraints (cf. Fig. A1 in Appendix A).

In the DREMFIA model, annual land use and production decisions from 1995 to 2020 are simulated by an optimisation model which maximises producer and consumer surplus subject to regional product balance and resource (land) constraints. Products and intermediate products may be transported between the regions. The optimisation model is a typical spatial price equilibrium model (see e.g. Cox and Chavas, 2001), except that no explicit supply functions are specified (i.e., supply is a primal specification). Furthermore, foreign trade activities are included in DREMFIA. The Armington assumption (Armington, 1969), which is a common feature in international agricultural trade models but less common in one-country sector models, is used. Imported and domestic products are imperfect substitutes, i.e., endogenous prices of domestic and imported products are dependent. There are 18 different processed milk products and their regional processing activities in the model.

Four main areas are included in the model: Southern Finland, Central Finland, Ostrobothnia (the western part of Finland), and Northern Finland. Production in these areas is further divided into sub-regions on the basis of the support areas. In total, there are 17 different production regions. This allows a regionally disaggregated description of policy measures and production technology. The final and intermediate products move between the main areas at certain transportation costs.

Technical change and investments, which imply evolution of farm size distribution, are modelled as a process of technology diffusion. Investments are dependent on economic conditions such as interest rates, prices, support, production quotas and other policy measures and regulations imposed on farmers. The model of technology diffusion follows the main lines of Soete and Turner (1984).

Two crucial aspects about diffusion and adaptation behaviour are included: first, the profitability of a new technique, and second, the risk and uncertainty involved in adopting a new technique. The information about and likelihood of adoption of a new technique will increase as its use becomes widespread.

To cover the first aspect, the likelihood of adoption of a new technique \( f_{a,b} \) is made proportional to the fractional rate of profit increase in moving from technique \( a \) to technique \( b \), i.e., \( f_{a,b} \) is proportional to \( \left( r_a - r_b \right) w_a \), where \( r_a \) is the rate of return for technique \( a \) and \( r_b \) is the rate of return for technique \( b \). The second aspect is modelled by letting \( f_{a,b} \) be proportional to the ratio of the capital stock in \( b \) technique \( (K_b) \) to the total capital stock \( K \) (in a certain agricultural production line), i.e., \( K_{b}/K \). The total investments to \( \alpha \) technique, after simplification, is where

\[ I_\alpha = \sigma (Q_\alpha - wL_\alpha) + \eta (r_\alpha - \bar{r}) K_\alpha \]  

\( \sigma \) is the savings rate (proportion of economic surplus re-invested in agriculture), \( \eta \) is the farmers’ propensity to invest in alternative techniques, \( Q_\alpha \) is

the total production-linked revenue for technique \( a \), \( w \) is a vector of input prices, \( L_a \) is a vector of variable production factors of technique \( a \), and \( r \) is the average rate of return on all techniques.

The interpretation of the investment function is as follows. If the value of \( \eta \) were zero, then (1) would show that the investment in a technique would come entirely from the investable surplus generated by \( \alpha \) technique. For \( \eta \neq 0 \), the investment in a technique will be greater or less than the first term on the right-hand side, depending on whether the rate of return on \( \alpha \) technique is greater or less than the average rate of return on all techniques (\( \bar{r} \)). This seems reasonable.

If a technique is highly profitable, it will tend to attract investments and, conversely, if it is relatively less profitable, investments will decline. If there are no investments in \( \alpha \) technique at some time period, the capital stock \( K_0 \) decreases at the depreciation rate. To summarise, the investment function (1) is an attempt to model the behaviour of farmers whose motivation to invest is greater profitability but who, nevertheless, will not adopt the most profitable technique immediately because of uncertainty and other retardation factors.

The investment function (1) shows that the investment level is strongly dependent on capital already invested in each technique. This assumption is consistent with the conclusions of Rantamäki-Lahtinen et al. (2002) and Heikilä et al. (2004), i.e., farm investments are strongly correlated with earlier investments, but poorly correlated with many other factors, such as liquidity or financial costs. Other common features, except for the level of previous investments of investing farms, were hard to find. Hence, the assumption made on cumulative gains from earlier investments seems to be supported by the findings of Rantamäki-Lahtinen et al. (2002) and Heikilä et al. (2004). Three dairy techniques (representing \( \gamma \) techniques) and corresponding farm size classes have been included in the DREMFA model: farms with 1–19 cows (labour intensive production), farms with 20–49 cows (semi-labour intensive production), and farms with 50 cows or more (capital intensive production). The parameter \( \sigma \) has been fixed at 1.07 which means that the initial value 0.85 (i.e., farmers re-invest 85% of the economic surplus on fixed factors back into agriculture) has been scaled up by 26% which is the average rate of investment support for dairy farms in Finland. The value of \( \eta \) (fixed to 0.77) is then used as a calibration parameter which results in investments which facilitate the ex post development of dairy farm structure and milk production volume. The chosen combination of the parameters \( \sigma \) and \( \eta \) (1.07:0.77) is unique in the sense that it calibrates the farm size distribution to the observed farm size structure in 2002 (Farm Register, 2002). Choosing larger \( \sigma \) and smaller \( \eta \) exaggerates the investments on small farms, and choosing smaller \( \sigma \) and larger \( \eta \) exaggerates the investments on large farms. Choosing smaller values for both \( \sigma \) and \( \eta \) result in too low investment and production levels, and choosing larger values for both \( \sigma \) and \( \eta \) results in overestimated investment and production levels, compared to the ex post period.

Use of variable inputs, such as fertilisers and feed stuffs, are dependent on agricultural product prices and fertiliser prices through production functions. The nutrients from animal manure were explicitly taken into account in the economic model. Feeding of animals may change in the short-term within certain bounds imposed by fixed production factors and animal biology, provided that nutrition requirements are fulfilled. Specific production functions are used to model the dependency between the average milk yield of dairy cows and the amount of the grain based feed stuffs used in feeding. The yield of dairy cows responds to price changes of milk and feed stuffs. Time series of the model outputs include number of animals, areas of different crops and feeding of animals.

Milk quotas, which constrain milk production at farm and country level, are traded within three separate areas in the model. Within each quota trade area, the sum of bought quotas must equal the sum of sold quotas. The price of the quota is the weighted sum of the shadow values of an explicit quota constraint.


2.2. The nutrient leaching model

The ICECREAM model (Tattari et al., 2001; Bärlund and Tattari, 2001) has been developed to simulate water, soil loss and phosphorus (P) and nitrogen (N) transport in the unsaturated soil of agricultural land. The model is based on field scale simulations, but the model results have been aggregated using typical soil—crop—slope combinations to small catchment scale to describe transport from agricultural land (Rekolainen et al., 2002).

To assess the environmental impacts of the agricultural policy scenarios, the results of the field-scale simulations with ICECREAM have been up-scaled. The relevant soil—crop—slope combinations form a simulation matrix of six soil types, 11 crop types and nine field slopes, i.e., 594 single simulations. These results are averages of annual sums of, e.g., leached nitrate-N over the simulation period, here 10 years. The parameters to characterise soil properties and crop development are equal in both simulated areas, but the meteorological conditions are typical for each region. The response to the results from the DREMFA model is gained by weighing the ICECREAM matrix by the percentage of each soil-crop-slope combination in each catchment for each year.

2.3. Catchment areas

The two catchments selected for this study vary in their location and characteristics. Yläenejoki catchment is situated in the coastal plains of southwestern Finland (Fig. A2 in Appendix). Its total area is larger (227 km²) but its field percentage smaller (35%) than those of the Taipaleenjoki catchment (27 km²; 50%) which is situated in eastern Finland. The main line of production in Yläenejoki is spring cereals, whereas in Taipaleenjoki it is dairy production, which also explains the higher share of grassland in this area. Taipaleenjoki, however, is not among the most intensive and efficient dairy production areas in Finland. Yläenejoki region, on the other hand, is strong in pork and poultry production. Yläenejoki is relatively one of the best grain production areas in Finland. The yields of wheat and malting barley, in particular, are higher than average yields in Finland. Farms having dairy and beef cattle are of the same size in both Yläenejoki and Taipaleenjoki areas, but pork and poultry farms in Yläenejoki area are significantly larger and more specialised.

2.4. The policy scenarios

The base (BAS) scenario follows the Agenda 2000 reform (agreed in Berlin 1999; CEC (1999)) which is assumed to stay unchanged until 2020. It is assumed that producer price of milk would fall by 15% in Finland until 2008 from the average producer price of 1999—2001 (0.353 euro/litre). Hence, the producer price of milk would be 0.3001 euro/litre in 2008—2015 in the base scenario. LFA, environmental and national support, mainly paid per hectare of different crops, is assumed to stay at 2003 level till 2020. Investment support (aids ranging between 15 and 50% of the total value of farm investment projects; the average aid level is 20%) is assumed to stay at the 2002 level until 2020.

The mid-term review (MTR) scenario, ranging to year 2020, is the EU Commission’s agricultural policy reform proposal (CEC, 2003) presented on 22 January 2003. All CAP support is paid in a single farm payment each year. A uniform area payment is assumed, which means that all farms which keep their land in good condition are eligible for CAP support regardless of their current and historical production.

Producer price of milk falls by 28% in the EU until 2008. This price cut is considered permanent because, according to the EU Commission impact analysis, the supply of milk in the EU will remain at the quota level. Hence, there will be little chance for any recovery of producer prices of milk. In Finland, such a change means that the average producer price of 1999—2001 (0.353 euro/litre) is reduced to 0.254 euro/litre in 2008. If the milk production volume in Finland decreases due to this, the domestic milk price (endogenous in the DREMFA model) may, however, recover to a level which is closer to 0.30 euro/litre than to 0.25 euro/litre. The milk price cut is compensated by payments per quota tonne. The payment goes to 41 euro per tonne (prior to 2001; 0.30 euro/litre than to 0.25 euro/litre. The milk price cut is compensated by payments per quota tonne. The payment goes to 41 euro per tonne (prior 5% modulation) and becomes de-coupled from milk quotas in 2008.

An increase in LFA support is assumed. The increase of LFA support would be directed for milk and cattle farms. The support rate per bovine

animal unit would increase linearly to 300 euro per bovine animal until 2008. Overall, this would mean a 25% increase in the total LFA support. National supports and supports for investments are kept at the base scenario level. The integrated rural and environmental policy (INT) scenario is built on the MTR scenario in such a way that environmental concerns and employment in rural areas are of particular emphasis. This means that support for grass area is increased, and labour is supported by paying 3 euro/h of work for farms which have bovine animals. It is assumed that 50% of investment supports is transformed into labour support specifically directed to small bovine animal farms. The goal of the labour support is to foster socially and environmentally friendly small-scale dairy and beef production.

The CAP extensification premium is not de-coupled from production. LFA support is kept at the base scenario level. The EU price level of agricultural products is the same as in the MTR scenario.

Free trade scenario, full-scale agricultural trade liberalisation (LIB), includes the most drastic changes. All agricultural support is transformed into an area-based flat rate support which is the same for all crops and is de-coupled from production. This transformation would be complete in 2010. The total sum of agricultural support is decreased by 15% by year 2014. Prices of agricultural products in the EU are 5–20% lower than in MTR and INT scenarios.

3. Results

3.1. Production development in Ylänneenjoki and Taipaleenjoki regions

The development of dairy cattle numbers in both Ylänneenjoki and Taipaleenjoki regions (Table 1) is similar to that of the whole country. Since the milk yield per dairy cow increases by 20–25% (depending on the changes in feeding practices) in time period 2002–2015, the milk production volume in the base scenario still increases slightly until 2015 despite the decreasing number of dairy cows. However, dairy production decreases significantly in the MTR, INT and LIB scenarios because of lowered profitability of investments. Especially small dairy farms allocate land to set-aside instead of investing in dairy production.

Incentives for dairy investments decrease most dramatically in the INT and LIB scenarios. Hence, dairy capital decreases, through reduced investments and capital depreciation, drastically in the INT and LIB scenarios till 2015. In the INT scenario, the labour support, which in fact should reinforce supply in static constant technology analysis, ceteris paribus, makes investments in large production units relatively less profitable. This inhibits the development of competitive farm structures in the long-term. Taking into account the relatively high opportunity cost of labour in the Finnish national economy, it is logical that the lowered milk price, de-coupled CAP payments, and labour support efficiently reduce investments in large-scale production units.

The decrease in investments and dairy capital is less drastic in the MTR scenario because of higher investment supports (which were partly transformed to labour supports in the INT scenario) increased LFA support for bovine animals. In

<table>
<thead>
<tr>
<th>Ylänneenjoki</th>
<th>Taipaleenjoki</th>
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<tbody>
<tr>
<td></td>
<td>2001</td>
</tr>
<tr>
<td>Dairy cows</td>
<td>1.56</td>
</tr>
<tr>
<td>Suckler cows</td>
<td>0.40</td>
</tr>
<tr>
<td>Sows</td>
<td>6.65</td>
</tr>
<tr>
<td>Pigs</td>
<td>39.1</td>
</tr>
<tr>
<td>Hens</td>
<td>246.8</td>
</tr>
<tr>
<td>Other poultry</td>
<td>519.7</td>
</tr>
</tbody>
</table>

Fig. 1. Land use (% of total agricultural land) in Taipaleenjoki region in Base scenario.
any case, supply of milk will gradually decrease in the MTR scenario due to lower milk prices and de-coupled CAP payments.

Suckler cow numbers, however, increase in the base scenario in both areas, especially in Taipaleenjoki region. This is due to considerable national support for grass area, while beef prices and production linked supports keep up production. Grass area increases and grain area decreases significantly (from the 1995 level) in Taipaleenjoki region already in the base scenario until 2015 (Fig. 1). This is partly due to the fact that Taipaleenjoki region is not among the most efficient dairy production regions in Finland, while yields of dried hay, used for horses and breeding bulls, are relatively high in Taipaleenjoki region. Hence both dairy production and grain areas decrease in Taipaleenjoki region in all policy scenarios. In Figs. 2–4, one can see that Taipaleenjoki catchment becomes even more dominated by grass production in any scenario.

In the MTR scenario, suckler cow numbers at whole country level increase only slightly because increased LFA support is outweighed by de-coupled CAP support. However, in Taipaleenjoki region the number of suckler cows increases even in the MTR scenario because there is a strong incentive for extensive grass cultivation. The dairy production is partly replaced by very extensive suckler cow production and grass cultivation. This is a rational consequence of low milk price and decoupled CAP payments, and increased flat rate LFA payments. In the LIB scenario, however, the dairy herd declines drastically due to full de-coupling of all agricultural support and set-aside areas increase dramatically.

In Yläneenjoki region, the milk production reduces only slightly in the MTR scenario (Table 1). In any scenario, Yläneenjoki region will lose some pig production (Table 1) while increases in poultry meat production may be considerable, if no major agricultural trade liberalisation will take place. Since Yläneenjoki area is one of the relatively best grain production areas in Finland, incentive for extensive grass cultivation is not as strong as in Taipaleenjoki area. In the MTR scenario grain and grass areas decrease slightly in Yläneenjoki region while set-aside areas increase to 11% of the total area. In the INT and LIB scenarios, set-aside areas are even larger in 2015. It is remarkable that even if the total grain area in Finland decreases drastically in the LIB scenario, grain area does not change much in Yläneenjoki region.

![Fig. 2. Land use (% of total agricultural land) in Taipaleenjoki region in MTR scenario.](image)

![Fig. 3. Land use (% of total agricultural land) in Taipaleenjoki region in INT scenario.](image)
Fig. 4. Land use (% of total agricultural land) in Taipaleenjoki region in LIB scenario.

Fig. 5. Simulated change in average annual sum of soluble (DPr, a) and sediment bound (PP, b) P in surface run-off and nitrate-N in percolation from root zone (percNO3, c) from arable land in 2015 relative to the situation in 1995 in Ylänneenjoki (YLA) and Taipaleenjoki (TAI) catchments.

Table 2
Distribution of crops (% of cultivated area) simulated by DREMFIA for the four scenarios BAS (Agenda, 2000), MTR (mid-term review), INT (integrated policy) and LIB (free trade) in 2015

<table>
<thead>
<tr>
<th></th>
<th>Ylänneenjoki</th>
<th>Taipaleenjoki</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1995 BAS MTR INT LIB</td>
<td>1995 BAS MTR INT LIB</td>
</tr>
<tr>
<td>Oats</td>
<td>17 22 27 27 29</td>
<td>27 31 13 9.8 1.9</td>
</tr>
<tr>
<td>Barley</td>
<td>37 57 45 40 39</td>
<td>14 0.68 0.37 0.11 0.20</td>
</tr>
<tr>
<td>s_wheat</td>
<td>11 2.4 2.8 2.3 3.6</td>
<td>1.9 0.013 0.013 0.013 0.013</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>4.1 1.0 1.4 0.97 1.8</td>
<td>0.95 0.0063 0.0063 0.0063 0.0063</td>
</tr>
<tr>
<td>w_wheat</td>
<td>4.6 1.1 1.2 1.0 1.6</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td>Rye</td>
<td>4.2 0.97 1.1 0.93 1.5</td>
<td>1.8 0.012 0.012 0.012 0.012</td>
</tr>
<tr>
<td>s_beet</td>
<td>2.3 0.54 0.62 0.51 0.80</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td>Potato</td>
<td>1.4 0.31 0.36 0.30 0.47</td>
<td>0.72 0.0048 0.0048 0.0048 0.0048</td>
</tr>
<tr>
<td>Grass</td>
<td>7.7 6.4 4.8 3.5 4.8</td>
<td>45 64 82 85 39</td>
</tr>
<tr>
<td>g_fallow</td>
<td>8.3 4.3 11 19 14</td>
<td>3.9 4.4 4.4 4.4 58</td>
</tr>
<tr>
<td>b_fallow</td>
<td>1.0 0.23 0.27 0.22 0.34</td>
<td>3.4 0.023 0.023 0.023 0.27</td>
</tr>
</tbody>
</table>

s_wheat, spring wheat; w_wheat, winter wheat; s_beet, sugar beet; g_fallow, green fallow; b_fallow, bare fallow.
3.2. Environmental implications

What then are the corresponding changes in the analysed environmental variables? According to the ICECREAM model, the change in annual sum of soluble phosphorus (DPr) and sediment bound phosphorus (PP) due to the base scenario is close to no change in Yläneenjoki region (Fig. 5a,b). All other scenarios would lead to a small reduction of both variables. For DPr, this is due to reduction of grass and increase of green fallow, and for PP, the main reason is the reduction of bare fallow and winter cereals in the catchment (Table 2), both land use types having relatively high PP loss values. Grass is the only crop receiving surface applied fertilisation and, thus, a decrease in the grass area reduces DPr losses effectively. The rather high reduction of nitrate-N in percolation from root zone (percNO₃) (Fig. 5c) can be explained by a smaller area of oilseeds and winter cereals. Both crop types have rather high N fertilisation compared to simulated crop uptake, which explains losses in percolated water.

In Yläneenjoki region, the relative change in P leaching is higher than in Yläneenjoki, and for DPr, an increase is indicated for all scenarios except for LIB (Fig. 5a). For DPr, the main reason would be the larger area under grass in 2015 compared to 1995. The DPr decrease under the LIB scenario is explained by the extremely high increase in green fallow area (Table 2). The change in grass and green fallow area explains also the reduction of PP for all scenarios (Fig. 5b). The results for percNO₃ for the MTR and INT scenarios can be interpreted as no change (Fig. 5c). The reduction for the other scenarios is a combination of an increase in the area of oats (BAS) and green fallow with very low nitrate leaching and reduced area of oilseeds and winter cereals with high nitrate leaching potential.

In summary, from the point of view of nutrient load, the results indicate a weakly positive or stable development in Yläneenjoki, whereas the development in Taipaleenjoki is mixed. Further research may reveal to what extent these changes in load would also lead to observable changes in the state of the water courses. The waters in Yläneenjoki area are eutrophic due to natural conditions and nutrient load history and it is unlikely that the simulated changes would make a difference. The waters in Taipaleenjoki are mainly oligotrophic and the potential changes in load are sufficiently large to merit further analysis of effects in the watercourses.

4. Discussion and conclusions

The coupled use of the economic model DREMFIA and the environmental model ICECREAM provided opportunities to test the effect of four different agricultural policy scenarios on agricultural production and nutrient leaching in two Finnish catchments with different characteristics.

According to Shou et al. (2000), such an integrated modelling is problematic if the databases of two models operating at different spatial aggregation do not match. For example, it is important to take into account the value of manure at local scale in economic analysis. Also the lack of dynamics, i.e., the fixed distribution of farm types and production facilities, were considered a restriction in integrated modelling.

In this study, however, Yläneenjoki and Taipaleenjoki regions were explicitly modelled as sub-regions in a national level DREMFIA model which includes 17 regions in total, with unique sets or production variables in each region. Also the extensive regional databases of Yläneenjoki and Taipaleenjoki regions, gathered for environmental models, were utilised in the economic model. The nutrients from animal manure were explicitly taken into account in the economic model. On the other hand, economic decisions were not modelled separately for farms operating at different soil types in this study. Soil types were explicitly taken into account in the nutrient leaching model but only implicitly in the economic model which has no explicit production variables for each soil type separately. However, time series data of land and fertiliser use and crop yields on the catchment areas were utilised in deriving expected crop yields. The time series data showed that expanding the crop area to relatively less favoured soil types clearly reduced the crop yield level. Explicit farm level modelling was out of the scope of this study which assumed increasingly flexible production arrangements and investments over time hence providing a logical basis for evaluating long-term implications.

According to the modelling results, large reductions in milk price and a simultaneous de-coupling of CAP payments are likely to cut dairy investments considerably. This would slow down the ongoing farm size growth and production specialisation on Finnish dairy farms.³ Many dairy farms would refrain from investment and allocate land to set-aside. Milk and beef production volumes would decrease. Effects on pork and poultry production would be marginal, however.

In regions specialised in dairy and beef production, but which are not the most intensive and efficient production regions (like Taipaleenjoki region), the low milk and beef prices and de-coupled payments may lead to extensive grass cultivation. In the most intensive dairy production regions, this may not be the case, however. But in Taipaleenjoki region, the grass area increases despite the decreasing number of animals when support becomes more de-coupled from production. This is partly due to the fact that soil types relatively well suitable for grass cultivation in Taipaleenjoki region may be used increasingly for dry hay production for horses (which is the most profitable use of land after milk price cuts) instead of silage grass. On the other hand, the relatively high yields and suitable soil types for malting barley and wheat in Yläneenjoki region will keep up grain production almost irrespective of future agricultural policy, provided that the land is kept in good condition in order to receive the de-coupled subsidy.

³ Such effects are not taken into account in standard economic tools. For example, Jensen and Frandsen (2003) report no change in Finnish dairy production, but a remarkable increase in beef production due to 2003 CAP reform.
The relative change in nutrient leaching depends on the policy scenario applied, the nutrient leaching variable studied and on the catchment chosen. In the Ylänneenjoki catchment in south-western Finland, some reduction of leaching would be expected. However, the leaching was found to be rather stable considering the width of the agricultural policy scenarios analysed. This means that significant reductions in nutrient leaching would require radical policy reforms that take land out of production.

In Taipaleenjoki in eastern Finland, reductions in some (namely, the sediment-bound phosphorus and nitrate percolation from root zone) nutrient leaching levels are likely to be relatively large due to policy changes. What is remarkable, however, is that specialisation in extensive cattle and grass production may result in increasing soluble P in surface run-off in Taipaleenjoki region despite decreasing product prices and de-coupled subsidies. This challenges the common view that lower prices and decoupled subsidies always imply less environmental harm.

It must be recognised that the model outcomes are specific to the chosen regions and models used in the analysis. The production development is dependent on the exogenous parameters of the DREMFIA model, like the opportunity cost of labour, inflation of input prices, and general interest rate. Since the exogenous variables are the same in all policy scenarios, however, they are not likely to affect the relative changes in production development between the policy scenarios.

This study shows that increasing model complexity and size by including endogenous investments and technical change in the economic model does not necessarily obscure economic logic. Rather, such an approach may provide a better understanding of dynamics and directions of future development.

Nevertheless, one needs to keep in mind the simplification made in the construction of the technology diffusion model. The fact that current investments are best explained by previous investments is a major determinant of the model results. This simplification made it possible to employ a simple model of technology diffusion and keep the model structure clear and understandable.

If it turns out in the future that the earlier investments do not lower the threshold of new investments, or that only little economies of scale will be attained when enlarging farm size, then the self-enforcing pattern of technical change is overestimated in the DREMFIA model. In that case the future production development is less dependent on agricultural policy than outlined in this study. On the other hand, if the economies of scale will be higher than anticipated on the basis of bookkeeping data, this study underestimates the future production levels, regional concentration of production, and environmental effects.

Acknowledgements

The financial support of the SUSAGFU project through the Academy of Finland (contract 76724) is gratefully acknowledged.

Appendix A

The basic structure of the DREMFIA model is shown in Fig. A1 and the location of the catchment areas studied is shown in Fig. A2.

<table>
<thead>
<tr>
<th>Optimisation</th>
<th>Policy scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX: producer and consumer surplus</td>
<td></td>
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<tr>
<td>- annual market equilibrium</td>
<td></td>
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<tr>
<td>- different yields and inputs in regions</td>
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<tr>
<td>- feed use of animals changes endogenously</td>
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<tr>
<td>- constraints on energy, protein and roughage needs of animals</td>
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<tr>
<td>- non-linear milk yield functions for dairy cows</td>
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<tr>
<td>- domestic and imported products are imperfect substitutes</td>
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<tr>
<td>- processing activities of milk and sugar</td>
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<tr>
<td>- export cost functions</td>
<td></td>
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<tr>
<td>Results/Initial values</td>
<td>Crop yield functions</td>
</tr>
<tr>
<td>production</td>
<td>- optimal level of fertilisation</td>
</tr>
<tr>
<td>prices</td>
<td>- different yields and inputs in regions</td>
</tr>
<tr>
<td>land use</td>
<td>- feed use of animals changes endogenously</td>
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<tr>
<td>consumption</td>
<td>- constraints on energy, protein and roughage needs of animals</td>
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<tr>
<td>imports</td>
<td>- non-linear milk yield functions for dairy cows</td>
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<tr>
<td>exports</td>
<td>- domestic and imported products are imperfect substitutes</td>
</tr>
<tr>
<td>transportation</td>
<td>- processing activities of milk and sugar</td>
</tr>
</tbody>
</table>

Fig. A1. Basic structure of the DREMFIA model.
References


