ASSESSMENT OF ENVIRONMENTAL IMPACTS FOLLOWING ALTERNATIVE AGRICULTURAL POLICY SCENARIOS

Ilona Bärlund[1], Heikki Lehtonen[2] and Sirkka Tattari[1]

[1] Finnish Environment Institute (SYKE), PO Box 140, FIN-00251 Helsinki
[2] Agrifood Research Finland, Economic Research (MTT), PO Box 3, FIN-00411 Helsinki
ilona.barlund@ymparisto.fi, heikki.lehtonen@mtt.fi, sirkka.tattari@ymparisto.fi

ABSTRACT
Finnish agriculture is likely to undergo major changes in the near and intermediate future. The future policy context can be examined at a general level by strategic scenario building. Computer-based modelling in combination with agricultural policy scenarios can in turn create a basis for the assessments of changes in environmental quality following possible changes in Finnish agriculture. The analysis of economic consequences is based on the DREMFIA model, which is applied to study effects of various agricultural policies on land use, animal production, and farmers' income. The model is suitable for an impact analysis covering an extended time span – here up to the year 2015. The changes in land use, obtained with the DREMFIA model assuming rational economic behaviour, form the basis when evaluating environmental impacts of different agricultural policies. The environmental impact assessment is performed using the field scale nutrient transport model ICECREAM. The modelled variables are nitrogen and phosphorus losses in surface runoff and percolation. In this paper the modelling strategy will be presented and highlighted using two case study catchments with varying environmental conditions and land use as an example. In addition, the paper identifies issues arising when connecting policy scenarios with impact modelling.

Keywords : agricultural policy, eutrophication, economic modelling, nutrient leaching modelling

INTRODUCTION
Finnish agriculture is likely to undergo major changes in the near and intermediate future. The globalisation of food markets, expansion of the European Union, consumer and environmental demands, changes in policy priorities and the development of agricultural technology are important driving forces. A profound understanding of policy options and their consequences is essential, in particular, when the future of national agricultural policy and the European Common Agricultural Policy (CAP) are discussed. Sustainable agriculture is an overall objective of the CAP, but the dimensions of sustainability - ecological, economic and social - are potentially conflicting and may be differently interpreted at local, regional, national or global spatial scales. Due to their elevated concentration of total phosphorus (>35 μg/l) ca. 10% of Finnish lakes are classified as eutrophied. These are mainly situated in the southern and western coastal plains. Rivers are, with a few exceptions, all classified as eutrophied in these areas (Pietiläinen and Räike, 1999). In coastal waters of the Baltic Sea heavy fouling of fishing gear is the most acute problem caused by eutrophication to local fishery (Lappalainen and Pönni, 2000), as are unwanted species in the catch and occasional changes in fish community structure in lakes (Tammi *et al*., 1999). Cyanobacterial blooms are also common in the Baltic Sea (Kanoshina *et al*., 2003). Phosphorus is usually the limiting factor regulating growth of algae in fresh surface waters (Pietiläinen, 1997), whereas in the Baltic Sea nitrogen is reported to be the limiting factor throughout the productive season (Kivi *et al*., 1993). Agriculture comprises the highest single source of nutrients into surface waters. On the contrary to many regions in Europe, pollution of groundwater caused by agriculture is not an extensive problem in Finland (Valpasvuo-Jaatinen *et al*., 1997).

Effects of environmental conditions and agricultural practices on nutrient leaching have been studied in several field trials in Finland (e.g. Puustinen, 1994; Turtola and Kemppainen, 1998). Due to complexity of soil-water-plant interactions, the direct up-scaling of results from singular field scale experiments to regional assessment of losses can be misleading. Therefore, mathematical modelling tools have been developed and modelling strategies set up to generalise the effect of environmental conditions and agricultural practices on nutrient losses on field and catchment scale. Models like SOIL/SOILN (Rekolainen and Leek, 1996), GLEAMS (Knisel and Turtola, 2000) and ICECREAM (Tattari *et al*., 2001) have been used to assess phosphorus and nitrogen losses from agricultural land in Finland. The ICECREAM and SOIL/SOILN models have been used to assess the effects of the Agri-Environmental Programme on nutrient loading (Rekolainen *et al*., 1999; Granlund *et al*., 2000). Results from the monitoring network on water quality will, in due time, give indication on the actual impacts of altered agricultural practices on river basin scale. The responses of water quality will, however, be slow and subject to high fluctuation in annual nutrient losses caused by varying climatic conditions. The use of models enables versatile testing of hypotheses of possible future development providing thus additional information to measured data.

Sector level economic analysis is needed when evaluating impacts of agricultural policy changes on agricultural production and farmers' income. In sector models of agriculture most important production lines and production areas are connected through prices and resources (most importantly the land available for agricultural production). Policy changes often influence relative differences in profitability between different production lines in agriculture. Such changes, in turn, influence quantity of agricultural production and income both at aggregate and at regional level. Rational economic behaviour gradually drives production to the areas in which the production is relatively most profitable. In this study the impacts of four different agricultural policies are analysed using dynamic regional sector model of Finnish agriculture (DREMFIA; Lehtonen, 2001).

The changes in land use, animal production and the use of production inputs, obtained from the DREMFIA model, are utilised in the ICECREAM model to evaluate field scale environmental impacts of different agricultural policies. Two catchments, which vary in their location and characteristics, have been selected for this study. This paper discusses the effort and the first experiences when connecting policy scenarios with impact modelling.

METHODS

The agricultural policy scenarios utilised within this work are Agenda 2000, Mid Term Review, Integrated Policy and Free Trade. The **base** scenario follows Agenda 2000 reform (CEC, 1999) which is assumed to stay unchanged until 2015. Producer price of milk would fall by 15% in Finland until 2008 from the average producer price of 1999-2001 (35.3 c/litre). LFA, environmental and national support stay at 2003 year level in 2004-2015. The **Mid Term Review (MTR)** scenario follows the EU Commission's agricultural policy reform proposal presented January 22nd 2003 (CEC, 2003). The commission proposes decoupling CAP support from production. CAP support based on 2000-2002 historical production levels would be paid in a single farm payment each year. The commission further proposes reduction of butter and milk powder intervention prices by 35% and 17.5%, respectively, until 2009. Consequently, the producer price of milk would fall by 28%. It is mentioned in the Commission proposal that LFA support could be increased if specific problems occur in less favoured areas. It is assumed that the increased LFA support is paid per bovine animal unit, and the support rate would increase linearly up to 300 euros per animal unit until 2009. National supports, which are production linked, are kept at base scenario. The **Integrated rural and environmental policy (INT)** scenario is built on the MTR scenario in such a way that environmental concerns and labour in rural areas are of particular emphasis level. This means that support for grass area is increased, and labour is supported by paying 4 euros per hour of work for farms which have bovine animals. Extra investment subsidy is paid for small farms, on the basis of labour to be used in agricultural production. LFA support is kept at the base scenario level. Prices of agricultural products, at the EU level, would be the same as in MTR scenario. Finally, the **Free trade** and full scale agricultural trade liberalisation **(LIB)** scenario means that all agricultural support is transformed into an area based flat rate support which is the same for all crops. The total sum of agricultural support is decreased by 10% until year 2014. Prices of agricultural products in the EU would be 5-10% lower than in MTR and INT scenarios.

The ICECREAM model (Tattari *et al*., 2001; Bärlund and Tattari, 2001), used for environmental impact assessment, is developed to simulate water, soil loss and phosphorus (P) and nitrogen (N) transport in the unsaturated soil of agricultural land. The model simulates on field scale 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). The model is based on the GLEAMS/CREAMS models developed in the US (Knisel, 1993). Water transport is described using the SCS method for surface runoff and water capacity type one-dimensional soil water movement. Soil erosion is calculated using a modified USLE. Transformations of N and P in soil include mineralisation, immobilisation and the flow between various inorganic and organic nutrient pools. Plant development is calculated using the degree day factor. Special attention in ICECREAM development has been paid on including management practices such as various tillage methods, fertilisation practices and land use options like vegetative strips.

The DREMFIA model (Lehtonen, 2001) used in the economic analysis is dynamic recursive and includes 17 production regions. The model provides effects of various agricultural policies on land use, animal production, farm investments and farmers' income. Endogenous investments in different production techniques are modelled using the concept of technology diffusion. Investments to efficient technology is dependent on general economic conditions of agriculture such as prices, support, production quotas and other policy measures. Changing agricultural policy will result in different patterns of technical change. Annual land use and production decisions are simulated by an optimisation model which maximises producer and consumer surplus subject to regional product balance and resource (land) constraints. The optimisation model is a typical spatial price equilibrium model (see e.g. Cox & Chavas, 2001), except that foreign trade activities are included in DREMFIA.

The two catchments selected for this study vary in their location and characteristics (Tables 1 and 2). Yläneenjoki catchment is situated in the coastal plains of south-western Finland. Its total area is larger but its field percentage smaller than of the Taipaleenjoki catchment, which is situated in eastern Finland. The main line of production in Yläneenjoki is spring cereals whereas in Taipaleenjoki it is dairy production, which also explains the higher share of grassland in this area. In this study the development of the agricultural sector is simulated with DREMFIA from 1995 to 2015. Yläneenjoki and Taipaleenjoki catchment areas are both relatively small production areas compared to other regions in DREMFIA. The final result of the DREMFIA model is an annual distribution of the field crops (Table 3), which forms the land use input to the ICECREAM model.

Table 1 Variables describing the Yläneenjoki (YLA) and Taipaleenjoki (TAI) catchments.

	YLA	TAI	Data source
average annual air temperature [^oC] annual precipitation sum [mm]	4.2 719	2.5 781	FMI database 1981-1990
total catchment area [km^2] field percentage [%]	227 35	27 50	(Palva *et al.*, 2001)
mean total P conc. [µg/l] at catchment outlet mean total N conc. [mg/l] at catchment outlet	37 (n = 36) 1.9 (n = 345)	17 (n = 29) 2.4 (n = 109)	SYKE database 1981-2003 (P) 1995-2003 (N)

FMI: Finnish Meteorological Institute; SYKE: Finnish Environment Institute; n: number of samples

Table 2 Dominant crops, soil types and field slopes according to the year 1995 survey, and their share of the total agricultural land area.

	Yläneenjoki	Taipaleenjoki
dominating crop types	spring barley (37 %), oats (17 %)	grass (45 %), oats (27 %)
dominating soil types	sandy loam (44 %), clay (32 %)	silt loam (60 %), sandy loam (17 %)
median field slope	1 %	0 %
range of field slopes	0-10 %	0-4 %

To assess the environmental impacts of the agricultural policy scenarios, the results of the field scale simulations with ICECREAM are up-scaled. The relevant soil-crop-slope combinations form a simulation matrix of 6 soil types, 11 crop types and 9 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 DREMFIA model is gained weighing the ICECREAM matrix by the percentage of each soil-crop-slope combination in each catchment for each particular year.

RESULTS AND DISCUSSION

In the Yläneenjoki region grain area increases and grass and fallow areas decrease slightly in the base scenario until 2015. This is because Yläneenjoki region is one of the best grain production areas in Finland. In the MTR scenario, however, grain and grass areas decrease slightly while set aside areas increase up to 11% of the total area. This is since CAP support is decoupled from production and dairy herd declines in the Yläneenjoki region. In INT and LIB scenarios, where LFA support is lower than in MTR scenario, set aside areas are even higher in 2015. It is remarkable that even if the aggregate grain area in Finland decreases drastically in the LIB scenario, grain area does not change much in the Yläneenjoki region in this scenario.

Table 3 Distribution of crops [% of cultivated area] simulated by ICECREAM according to the 1995 survey and estimated by DREMFIA for the four scenarios BAS (Agenda 2000), MTR (Mid Term Review), INT (Integrated Policy) and LIB (Free Trade) in 2015.

	Yläneenjoki					Taipaleenjoki				
	1995	BAS	MTR	INT	LIB	1995	BAS	MTR	INT	LIB
oats	17	22	27	27	29	27	31	13	9.8	1.9
barley	37	57	45	40	39	14	0.68	0.37	0.11	0.20
s_wheat	11	2.4	2.8	2.3	3.6	1.9	0.013	0.013	0.013	0.013
oilseeds	4.1	1.0	1.4	0.97	1.8	0.95	0.0063	0.0063	0.0063	0.0063
w_wheat	4.6	1.1	1.2	1.0	1.6	0	0	0	0	0
rye	4.2	0.97	1.1	0.93	1.5	1.8	0.012	0.012	0.012	0.012
s_beet	2.3	0.54	0.62	0.51	0.80	0	0	0	0	0
potato	1.4	0.31	0.36	0.30	0.47	0.72	0.0048	0.0048	0.0048	0.0048
grass	7.7	6.4	4.8	3.5	4.8	45	64	82	85	39
g_fallow	8.3	4.3	11	19	14	3.9	4.4	4.4	4.4	58
b_fallow	1.0	0.23	0.27	0.22	0.34	3.4	0.023	0.023	0.023	0.27

s_wheat: spring wheat; w_wheat: winter wheat; s_beet: sugar beet; g_fallow: green fallow; b_fallow: bare fallow

In the Taipaleenjoki region grass area increases and grain area decreases significantly (from the 1995 level) in the base scenario until 2015. This is because Taipaleenjoki region is already dominated by dairy production and grain production concentrates to more feasible regions. In the MTR scenario, however, the decline of milk prices (-28%) and decoupled compensatory payments would result in very extensive grass cultivation. Grass areas would increase significantly despite the fact that dairy herd would decline. The extensification of grass area and the decrease of grain area is a rational consequence of low milk price and decoupled CAP payments, since costs of grain cultivation are much higher than the costs of grass. In the LIB scenario the dairy herd declines drastically because of no national support for milk, and set aside becomes the relatively most profitable use of land.

The baseline ICECREAM simulation results show that the average simulated annual sum of total runoff (269 mm in Yläneenjoki and 363 mm in Taipaleenjoki) is in accordance with long-term (1961-1990) measured runoff values in the areas: 242 mm and 365 mm, respectively (Hyvärinen *et al*., 1995). The main difference between the areas affecting total runoff is the higher amount of snow in Taipaleenjoki. Simulated soil loss in Yläneenjoki is five times higher than that in Taipaleenjoki. This is a result of many factors: soil type, higher field slopes and smaller area of grass. The average simulated annual sum of soil loss from fields in Yläneenjoki (1188 kg ha^{-1} a^{-1}) is within the range of soil loss measured from small catchments in south-western Finland (55-1860 kg ha^{-1} a^{-1}; Puustinen, 1999). The average simulated annual sum of total P in total runoff from agricultural land in Yläneenjoki (1.7 kg ha^{-1} a^{-1}) is clearly higher than in Taipaleenjoki (0.75 kg ha^{-1} a^{-1}). This difference is reflected by the measured average total P concentrations in these areas (Table 1) and is mainly due to differences in soil loss. Total P losses from three small agricultural catchments in south-western Finland over three 5-year monitoring periods show a range of 0.43-1.6 kg ha^{-1} a^{-1} (Vuorenmaa *et al*., 2002). The average simulated annual sum of total N in total runoff from agricultural land in Yläneenjoki (19 kg ha^{-1} a^{-1}) is slightly smaller than in Taipaleenjoki (20 kg ha^{-1} a^{-1}). This difference is reflected by the measured average total N concentrations in these areas (Table 1) and is mainly due to surface applied fertilisation for grass. Total N losses from the three 5-year monitoring periods ranged between 8 and 21 kg ha^{-1} a^{-1} (Vuorenmaa *et al*., 2002).

The simulated average annual amount of soluble P (DPr) in surface runoff is higher from the agricultural land in Taipaleenjoki reflecting the surface applied fertilisation of grass (Figure 1), whereas the particulate bound P (PP) is higher in Yläneenjoki due to higher amounts of eroded soil material. No substantial differences were simulated in the percolated nitrate N (percNO_3).

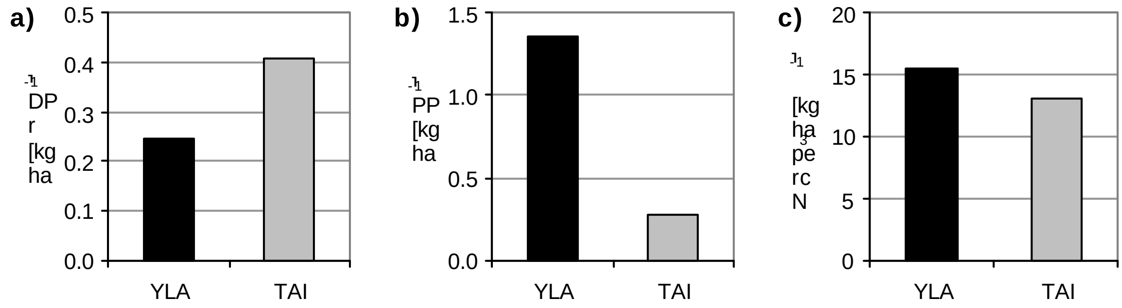

Figure 1 *Simulated average annual sum of soluble (DPr, a) and sediment bound (PP, b) P in surface runoff and nitrate N in percolation from root zone (percNO_3, c) from arable land over the 10-year simulation period in Yläneenjoki (YLA) and Taipaleenjoki (TAI) catchments.*

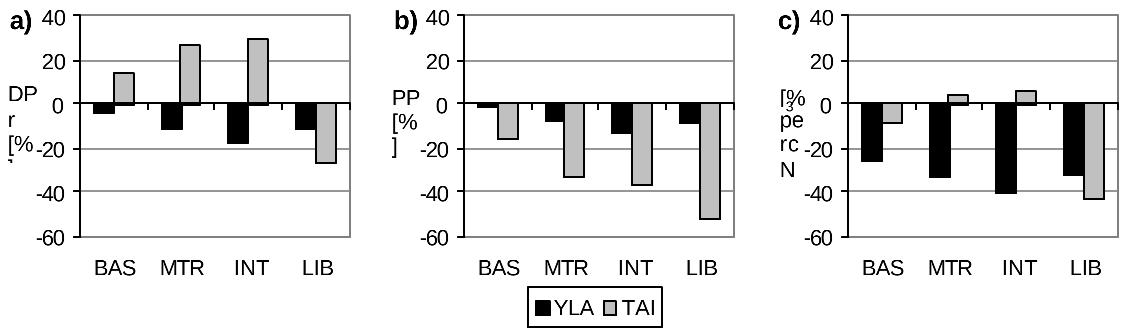

Figure 2 *Simulated change in average annual sum of soluble (DPr, a) and sediment bound (PP, b) P in surface runoff and nitrate-N in percolation from root zone (percNO_3, c) from arable land in 2015 relative to the situation in 1995 in Yläneenjoki (YLA) and Taipaleenjoki (TAI) catchments.*

The change in nutrient leaching from agricultural land in Yläneenjoki and Taipeleenjoki catchments due to agricultural policy scenarios applied was derived from DREMFIA simulation results on crop distribution changes by 2015. The ICECREAM results are relative changes in regard to the situation at DREMFIA simulation start in 1995. The results indicate that the effect on nutrient leaching is dependent both on the policy scenario applied and the nutrient leaching variable studied (Figure 2).

In Yläneenjoki the change in DPr and PP due to the base scenario is close to no change. 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, both land use types having relatively high PP loss values. The rather high reduction of percNO_3 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 Taipaleenjoki the relative change in P leaching is higher than in Yläneenjoki and for DPr an increase is indicated for all scenarios except LIB. 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. The change in grass and green fallow area explains also the reduction of PP for all scenarios. The results for percNO_3 for MTR and INT scenarios can be interpreted as no change. 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.

The use of relative changes is the first step of the analysis of the policy scenario effects since it indicates differences between the scenarios and areas but does not consider the actual magnitude of change in relation to the present ecological status of the receiving waters. This is needed in order to assess the real effect of changes in nutrient loading in regard to eutrophication. The Yläneenjoki area is more susceptible to eutrophication due to natural conditions and loading history but it has to be investigated what the predicted change would mean in Taipaleenjoki conditions over a longer time period. Therefore, future analysis on the effect of predicted actual nutrient load change on variables describing eutrophication (e.g. Secchi depth) is needed.

One continuous point of criticism in modelling studies is the ability of the models used to reproduce natural conditions. It could be shown in the present study that the general level of water balance variables, soil loss and total nutrients gained using ICECREAM matched the measured values on small catchment scale. In the ICECREAM modelling the emphasis was, however, on agricultural land neglecting channel processes. Lacking field scale data to validate the model over a wide range of soil-crop-slope combinations under same environmental conditions, e.g. the modelled strong influence of grass due to surface applied fertilisation cannot be actually validated. Single field scale studies prove merely that leaching of nutrients, especially in surface runoff, can be higher from grass than cereals when using mineral fertilisation (Turtola and Jaakkola, 1995).

The combination of the two modelling types meant simplifying both approaches due to different levels of aggregation. Shou *et al.* (2000) have reported similar necessities when the nutrient transport model resulted in being more detailed than the economic model utilised. In this study the regional DREMFIA model does not include variation in soil type or crop yield level within each region, i.e. land quality is homogenous within each region. Therefore, the magnitude of land use change is probably exaggerated, but the direction of change correct. The DREMFIA simulation was continuous with an annual time step whereas the ICECREAM modelling strategy was based on weighing 10-year averages, not on continuous modelling over the same time period. This might lead to overestimation of the effect of crop distribution and underestimation of the effect of soil processes such as the P budget in soil. Due to this simplified approach the output of DREMFIA was, however, directly usable as input to ICECREAM, enabling direct model coupling.

In this study the agricultural area was assumed to remain unchanged. It has been stated that the greatest threats to rural landscapes in Finland are caused by discontinuing cultivation, depopulation of rural areas and closing of the open cultivated landscape (Valpasvuo-Jaatinen *et al*., 1997). It is a further task to investigate how the changes in environmental impacts are considered in comparison with other future possibilities and threats facing agriculture in Finland. This discussion will be an additional test on the usability of economic and environmental modelling results in policy dialogue.

CONCLUSIONS

The coupled use of the economic model DREMFIA and the environmental model ICECREAM enabled to test the effect of four different agricultural policy scenarios on nutrient leaching in two Finnish catchment with varying characteristics. The combination of the models required simplification of both approaches due to different levels of aggregation. The results indicated that the relative change in nutrient leaching was dependent on the policy scenario applied, the nutrient leaching variable studied and on the catchment chosen. In the Yläneenjoki catchment in south-western Finland a reduction of all variables presented would be expected, whereas in Taipaleenjoki in eastern Finland especially soluble P in surface runoff might be increasing even if prices of agricultural products were reduced and subsidies were decoupled from production. This result challenges a common view that lower product prices and decoupled subsidies imply less environmental harm. In order to utilise the results in policy dialogue, further refinement of the results is needed in order to quantify the effect in each particular area and to link the nutrient load from agriculture to the eutrophication potential.

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