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Integrating Economic and Ecological Impact Modelling: Dynamic Processes in Regional Agriculture under Structural Change

Heikki Lehtonen

*MTT Agrifood Research Finland / Economics
Finland*

1. Introduction

Water quality has long been an important part of agricultural policy debate in Finland because agricultural activities are responsible for a significant part of nutrient load of surface waters. Changes in agricultural production, its input and land use intensity, as well as regional concentration of production, are seen as primary drivers of agricultural water pollution. Despite the theoretical fact that decreasing production linked agricultural subsidies should decrease input use intensity and volume of agricultural production, no or little decrease has been observed in agricultural water pollution in Finland during the last 15 years (Ekholm et al. 2007). This observation, despite the fact that nitrogen surplus has decreased by 42 % and phosphorous surplus by 65 % in Finland 1995-2006, has been a disappointment since ambitious targets have been set for water quality improvements and significant agri-environmental subsidies have been paid for farmers in order to reach the targets (Turtola, 2007). Ekholm et al. (2007) conclude that simultaneous changes in agricultural production (e.g. regional specialisation) and in climate may also have counteracted the effects of agri-environmental measures. The actions to reduce agricultural loading might have been more successful had they focused specifically on the areas and actions that contribute most to the current loading. Such conclusions and the apparent need for integrated modelling of agricultural economy, structural change in agriculture, and consequent impacts on nutrient leaching, are the main motivation for the modelling efforts presented and discussed in this study. Climate change concerns, both mitigation and adaptation, as well links between agricultural production, climate change and biodiversity, further increase the need for consistent integrated analysis. We present an approach designed for combined analysis of agricultural production and markets, nutrient leaching and water quality. While our emphasis here is in agriculture and water quality, the basic set-up, i.e. the relationship between changing agriculture (production) and environment is rather general.

Improvement in surface water quality has been so far the main objective of agri-environmental policy in Finland (Valpasvuo-Jaatinen et al. 1997). The quality of surface waters can be linked to agricultural production through estimating surplus of nutrients, which in turn provides indicator of potential runoff of nutrients. However, the actual nutrient runoff from a given parcel is only partly explained by estimated nutrient surplus in

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that parcel as there are many exogenous and stochastic factors which affect the amount of actual runoff including the weather, topography and soil characteristics.

Moreover, the relationship between nutrient surpluses and agricultural production is more complex than merely analysing individual farm management practices, such as fertilisation and crop yield levels for each crop. Changes in agricultural production may be linked to production specialisation, technological change and market feedback through prices, which also determines production intensity and the use inputs in production. Hence, if analysis focus only on individual crops or production lines then it may be difficult to identify important cause-effect linkages. There has been considerable changes in agricultural production, including the changing agricultural management practices, the increased use of fertilizers and pesticides, the increase of sub-surface drainage and enlarged field parcels, as well as the reduction of wintertime plant cover on farmland in the last 30–40 year (Tiainen & Pakkala 2000, 2001; Tiainen et al. 2004) Since grasslands providing wintertime plant cover have diminished, it is widely recognised that changes in livestock production are very decisive in terms of farmland biodiversity and nutrient runoff (Pykälä 2000). Hence, changes in nutrient runoff from agriculture seem to be linked to overall changes in agriculture.

Partial analyses focusing on individual production lines, which compete on the same regional land and labour resource, may not always provide a sound basis for policy recommendations. Especially regional changes in agriculture may not be driven by technical change and other (such as managerial abilities of farmers) developments in individual production lines alone, but also by comparative advantage of regions and farms. Hence a sector level analysis, entailing the overall change in agriculture, is needed when evaluating changes in the regional development of agricultural production, as well as when evaluating the potential to reduce nutrient runoff from agricultural sector. For example, the national supports and agri-environmental payments are very significant in Finland.

Aim in this paper is to show how the challenges of dynamic modelling of regional agricultural production and structures can be modelled in a way that not only provides (1) a consistent picture of agricultural changes with respect to overall markets and policies, but provides also (2) a major platform for integrated economic-ecological modelling of nutrient leaching impacts and for analysis how both agricultural production and nutrient leaching are impacted by agricultural and agri-environmental policies at regional scales.

We examine these modelling challenges by presenting and motivating the structure of a dynamic regional sector model of Finnish agriculture (DREMFIA; Lehtonen, 2001), which has been tailored to facilitate consistent integration between physical field scale and catchment scale nutrient leaching models. In addition to analyses of production and income effects of agricultural policies (Lehtonen 2004, 2007), this model has been earlier employed to assess the effects of alternative EU level policy scenarios on the multifunctional role of Finnish agriculture (Lehtonen et al. 2005, 2006). The integrated analysis of agricultural policy changes on agriculture, nutrient leaching and water quality have already been reported in Bärlund et al. (2005), Lehtonen et al. (2007), as well as in Rankinen et al. (2006). In this paper the role of economic modelling is given a particular emphasis and hence we approach the challenge of dynamic integrated modelling from the point of view of dynamic multiregional modelling of agricultural sector. In fact, we feel that the crucial role of economic modelling in the economy-ecology model integrations has not been sufficiently addressed in the literature, including the references mentioned above. For example, the capability of an economic model to take into account biological processes and physical

nutrient flows, consistently both at farm and sector level, are important. In other words, the consistent model integration seem to require validation of the economic models not only in terms of monetary values (as is the standard practice), but also in terms of nutrients, their flows and utilisation in agriculture.

The rest of this paper is organised as follows. In the following section some of the previous studies that have used economic modelling for analysing the cost-effectiveness of alternative policy measures to reduce nutrient runoff from agriculture are briefly reviewed. We then present the main challenges in dynamic modelling of regional agriculture and its nutrient leaching. This is followed by presentation of the agricultural sector model and its tailored features facilitating integrated modelling. Finally, we discuss and conclude on the theoretical consistency and empirical feasibility of the presented approach.

2. Review of literature

We start by reviewing briefly some recent studies that have analysed the effectiveness and cost-effectiveness of different policy measures to reduce nutrient runoff from agriculture.

Mapp et al. (1994) analyse regional water quality impacts of limiting nitrogen use by broad versus targeted policies in five regions within the Central High Plains. Broad based policies analysed include: (i) limitations on the total quantity of nitrogen applied (total restriction) and (ii) limitations on per-acre nitrogen applications (per-acre restriction). Targeted policies analysed include: (iii) limits on the quantity of nitrogen applied on soils prone to leaching (soil targeted restriction) and (iv) specific irrigation systems (system-targeted restriction). Their results show that targeted policies provide greater reduction in environmental damage for each dollar reduction in net farm income, that is, targeted policies are more cost-effective than broad policies. Among the targeted policies nitrogen restrictions differentiated on production systems outperform nitrogen restrictions on soil types.

Vatn et al. (1997) developed an interdisciplinary modelling approach named ECECMOD to analyse the regulation of non-point source pollution from agriculture. They analyse the impacts of following policy scenarios on losses of nitrogen, phosphorus and soil: (i) 100% tax on nitrogen in mineral fertilisers, (ii) 50% arable land requirement on catch crops/grass cover, and (iii) a per hectare payment for spring tillage. The nitrogen tax induces both reduced fertiliser levels, more clover in the leys and better utilisation of nitrogen in manure. However it does not have any effect on soil or phosphorus losses. Requirement for catch cropping reduces all categories of losses and losses of nitrates are reduced twice as much as in the tax regime. Subsidising spring tillage has a stronger effect on soil losses than the catch crop regime, but it has insignificant effect on nitrate leaching. Tax on nitrogen is the least costly measure per ha and per kg reduced N leached, catch crops are more costly but they have positive effects on erosion and phosphorus losses as well. If the focus is exclusively on erosion then spring tillage is the least costly measure.

Johansson and Kaplan (2004) investigate the regional interaction of agri-environmental payments and water quality regulation (a carrot-and-stick approach) in animal and crop production setting by using the U.S. Regional Agricultural Sector Model (USMP), which maximises profits from livestock, poultry and crop production in the presence of agri-environmental payments and nutrient standards. Crop and animal production choices are linked to edge-of-field environmental variables using the Environmental Policy Integrated Climate Model (EPIC). The results show that meeting nutrient standards would result in decreased levels of animal production, increased prices for livestock and poultry products,

increased levels of crop production, and water quality improvements. The impacts of nutrient policies are not homogeneous across regions; in regions with relatively less cropland per ton of manure produced these impacts are more pronounced. Moreover, their results indicate that there may be important environmental trade-offs relating to nutrient standards. For example, by requiring the spread of manure at no greater than agronomic rates result in increased leaching of nitrogen to groundwater as well as increased runoff of soil particles and pesticides to surface water in some areas.

Our approach here is a modelling strategy that integrates a national-level multi-regional agricultural sector model (Lehtonen 2001, 2004) with a region-specific field-scale or catchment scale nutrient leaching models (Tattari *et al.* 2001, Rankinen *et al.* 2006). The integrated analysis is challenging, because the agricultural production and its economy both at national and regional level has to be combined with sets of factors that influence water quality. Hence the policy relevant objective of this kind of modelling is to show to which extent different policies, both agricultural and environmental, may influence nutrient leaching which is determined at the practices and processes at the local level.

A similar, but not identical integrated agri-environmental modelling approach was used by Schou *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.

3. Challenges in modelling technical and structural changes in multi-regional economic models

The literature reviewed above suggests that both regional and dynamic aspects are relevant when evaluating environmental effects of agricultural policies. 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 significant re-allocations of production between regions over time.

Modelling investments and technical change in sector level models, however, is difficult due to farm heterogeneity. Applying explicit farm level dynamic optimisation on many representative farms located in a number of regions with distinct support levels and other characteristics, for example, would be a difficult task, especially if the investment decisions are linked to product price changes. Various difficulties of explaining aggregate level investments using (stochastic) farm level dual dynamic models of investment (which address both uncertainty and irreversibility simultaneously) becomes clear in the studies of Pietola (1997) and Sckokai (2004), for example. Hence alternative approaches trying to combine the most relevant drivers of structural change may provide valuable aspects and viewpoints.

Activity analysis is a traditional and straightforward practice of modelling endogenous technical change in optimisation models: introduce alternative production activities with different linear (or why not non-linear) input-output-combinations and then let the model endogenously choose the optimal technique (Hazell & Norton 1986, p. 149). However, there are reasons which make such bottom-up approach problematic in analysis of structural change. First, free choice of technology means that farmers are assumed to be perfectly informed on the production techniques and capable of selecting and adopting the most profitable technique. This is an over-optimistic assumption given the diversity of Finnish farms in terms of production costs and the fact that large scale production techniques have been adopted only recently. Furthermore, if only few representative farms are used as supplying agents in the model, the linear activity analysis approach, which selects always a single most profitable technique, fails to explain co-evolution of several competing techniques. In reality, several techniques co-exist since one technique does not fit all farms.

Activity analysis rules out sunk cost behaviour and out-of-equilibrium movements typical for agriculture. Irreversibility of investments as well as uncertainty and sunk costs make it problematic to assume sudden shifts in technology, or shifts independent of earlier investments, in response to changes in economic conditions. Applying activity analysis in a sector model simulating competitive markets means that maximisation of consumer and producer surplus directly steer the technology choices of representative farms. Since large scale production techniques have been used only by a small sub-set of farms in Finland, such an assumption must be considered an exaggeration of the common knowledge and the efficiency of the markets. The same kind of problems are related to different non-linear specifications, such as smooth nested production functions (such as CES) specifying substitution between labour and capital at macro level (top-down approach). One may put under question the empirical content and validity of the calibrated substitution elasticities, and the assumption that they stay constant over time. Advantages and shortcomings of the bottom-up and top-down-approaches are obvious and well known, as well as the difficulties in combining the both approaches (Frei et al. 2003 and Sue Wing 2006).

Without going to the very details in the reasoning of technical change in economics, it is merely stated here that the dynamic reality of structural change in agriculture is poorly represented by static models, independent if they include bottom-up or top-down specifications of technical change. In a dynamic context one alternative to activity analysis approach and to macro-level substitution-based production functions is the concept of technology diffusion. Models of technology diffusion describe the progressive distributional change in the spread of different production techniques (Hagedoorn 1989, p.120, Karshenas & Stoneman 1995, p.263), i.e. the process how the most profitable techniques become widespread over time. The pattern of diffusion follows the description of the process of innovation and imitation with a few originators and a growing number of imitators or followers. This pattern of diffusion is generally pictured as a sigmoid (S-curve). In the early phase of the diffusion number of users of the new technique (or share of capital stock embodied in the new technique) increases rather slowly. There may be practical and technical difficulties related to the adoption of the new technique. If the first adopters are able to solve the problems and find the technique relatively profitable compared to the other techniques, other firms get interested in the adoption and the number of adopters increase. This, in turn, results to a spread of information and knowledge of the new technique, and

the number of adopters will grow faster. Those firms which gain the greatest benefits of the new technique most probably make the first investments in the new technique. In the later phase of the diffusion process, however, the growth rate in the number of adopters decreases because not all potential adopters have the same incentives (the profit motive) or costs of adoption. Some potential adopters remaining face relatively severe constraints for adoption and thus the rate of growth in the number of adopters decreases (Hagedoorn 1989, p. 121).

Sue Wing & Anderson (2007) model accumulative gains and dynamics of capital and economic growth in a dynamic recursive multi-regional computable general equilibrium model. Even though the general equilibrium set-up of recursive dynamic modelling includes a larger number of dimensions (such as migration) they conclude environmental applications, such as economic analysis related greenhouse gas emission abatement, as one of the most promising application areas of the model. Hence modelling the dynamics and drivers of regional economic changes are likely to provide useful analysis and insight in a number of issues related to interrelationships between economic dynamics and environment.

4. Economic model

4.1 General features

The dynamic regional sector model of Finnish agriculture (DREMFA) is a dynamic recursive model simulating the development of the agricultural investments and markets from 1995 up to 2020 (Lehtonen 2001, 2004). The underlying hypothesis in the model is profit maximising behaviour of producers and utility maximising behaviour of consumers under competitive markets. According to microeconomic theory, this leads to welfare maximising behaviour of the agricultural sector. Decreasing marginal utility of consumers and increasing marginal cost per unit produced in terms of quantity lead to equilibrium market prices which are equal to marginal cost of production on competitive markets. Each region specialises to products and production lines of most relative profitability, taking into account profitability of production in other regions and consumer demand. This means that total use of different production resources, including farmland, on different regions are utilised optimally in order to maximise sectoral welfare, taking into account differences in resource quality, technology, costs of production inputs and transportation costs (spatial price equilibrium; Takayama & Judge 1971, Hazell & Norton 1986).

The model consists of two main parts: (1) a technology diffusion model which determines sector level investments in different production technologies; and (2) an optimization routine simulates annual price changes (supply and demand reactions) by maximizing producer and consumer surplus subject to regional product balance and resource (land and capital) constraints (Fig. 1). The major driving force in the long-term is the module of technology diffusion. However, if large changes take place in production, price changes, as simulated by the optimization model, are also important to be considered. The investment model and resulting production capacity changes is however closely linked to market model determining production (including land use, fertilisation, feeding of animals, and yield of dairy cows, for example), consumption and domestic prices. Our market model is a typical spatial price equilibrium model (see *e.g.* Cox & Chavas 2001), except that no explicit supply functions are specified, *i.e.* supply is a primal specification).

Fig. 1. Basic structure of DREMFA sector model

Contrary to comparative static models, often used in agricultural policy analysis, current production is not assumed to represent an economic equilibrium in the DREMFA model. The endogenous investments and technical change, as well as the recursive structure of DREMFA model implies that incentives for changes in production affect production gradually in subsequent years, i.e. all changes do not take place instantaneously. The current situation in agricultural production and markets may include incentives for changes but these changes cannot be done immediately due to fixed production factors and animal biology. Hence, the continuation of current policy may also result in changes in production and income of farmers. However, the production in DREMFA model will gradually reach a long-term equilibrium or steady state if no further policy changes take place.

Four main areas are included in the model: Southern Finland, Central Finland, Ostrobothnia (the western part of Finland), and Northern Finland. Production in these is further divided into sub-regions on the basis of the support areas. In total, there are 18 different production regions (Fig. 2), including 3 small catchment areas, of size 4 – 6 000 hectares, which match exactly the spatial aggregation of the bio-physical nutrient leaching models (see ch. 5 below). 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 cost. The most important products of agriculture are included in the DREMFA model. Hence, the model provides a complete coverage of land use and animal production, which compete on production resources.

Fig. 2. Regional disaggregation of the DREMFA sector model. There are 4 main regions split up by subsidy zones (A, B, C2-C4) and small catchments.

4.2 Technology diffusion, investments and technical change

The purpose of the technology diffusion sub-model is to make the process of technical change endogenous. This means that investment in efficient technology is dependent on the economic conditions of agriculture such as interest rates, prices, support, production quotas and other policy measures and regulations imposed on farmers. Changing agricultural policy affects farmers' revenues and the money available for investment. Investment is also affected by public investment supports. The model for technology diffusion and technical change presented below follows the main lines of Soete & Turner (1984). The choice of this particular diffusion scheme is further motivated in Lehtonen (2001). While the set-up of Dremfia model is rather neo-classical (competitive markets simulated by maximisation of consumer and producer surplus), the model of technology diffusion allows at least temporary movements out of equilibrium path and can be therefore considered close to the core of evolutionary economics paradigm (Nelson & Winter 2002).

Let us assume that there is a large number of farm firms producing a homogenous good. Different technologies with different production costs are used and firms can be grouped on the basis of their technology. The number of technologies is N . Each technology uses two groups of factors of production, variable factors, such as labour (L), and fixed factors, such as capital (K). Variable factors of production may also include land rent, particularly if agricultural land can be rented on a short-term basis, or opportunity cost of land, so that

crucial issue of competition for land can be included in the analysis. A particular production technique is labelled α . The rate of return on capital for firms using the α technique, under assumption of fixed exogenous input prices (w), is

$$r_{\alpha} = \frac{Q_{\alpha} - wL_{\alpha}}{K_{\alpha}}. \quad (1)$$

The surplus available for investment— $Q_{\alpha} - wL_{\alpha}$ (Q_{α} is the total revenue on the α technique)—is divided between all firms using the α technique. $f_{\beta\alpha}$ is the fraction of investable surplus transferred from α technique to β technique. This transfer will take place only if the rate of return on the β technique is greater than the rate of return on the α technique, i.e. $r_{\beta} > r_{\alpha}$. The total investable surplus leaving α technique for all other more profitable techniques is

$$\sum_{\beta: r_{\beta} > r_{\alpha}} f_{\beta\alpha} \sigma r_{\alpha} K_{\alpha}, \quad (2)$$

where $\sigma < 1$ is the savings ratio (constant). To make the model soluble, a form of $f_{\beta\alpha}$ has to be specified. Two crucial aspects about diffusion and adaptation behaviour are included: first, the importance of the profitability of the new technique, and secondly, the risk, uncertainty and other frictions involved in adopting a new technique. The information about and likelihood of adoption of a new technique will grow as its use becomes more widespread with a growth in cumulated knowledge of farmers.

To cover the first point, $f_{\beta\alpha}$ is made proportional to the fractional rate of profit increase in moving from technique α to technique β , i.e. $f_{\beta\alpha}$ is proportional to $(r_{\beta} - r_{\alpha}) / r_{\alpha}$. The second point is modelled by letting $f_{\beta\alpha}$ be proportional to the ratio of the capital stock in the β technique to the total capital stock (in a certain agricultural production line), i.e. K_{β} / K . If β is a new innovation then K_{β} / K is likely to be small and hence $f_{\beta\alpha}$ is small. Consequently, the fraction of investable surplus transferred from α to β will be small. Combining these two assumptions, $f_{\beta\alpha}$ can be written as

$$f_{\beta\alpha} = \eta' \frac{K_{\beta}}{K} \frac{(r_{\beta} - r_{\alpha})}{r_{\alpha}}, \quad (3)$$

where η' is a constant. A similar expression can be written for $f_{\alpha\beta}$. The total investment to α technique, after some simplification, is

$$I_{\alpha} = \sigma r_{\alpha} K_{\alpha} + \eta(r_{\alpha} - r)K_{\alpha} = \sigma(Q_{\alpha} - wL_{\alpha}) + \eta(r_{\alpha} - r)K_{\alpha} \quad (4)$$

where r is the average rate of return on all techniques. The interpretation of this investment function is as follows. If η were zero then (4) would show that the investment in the α technique would come entirely from the investable surplus generated by the α technique. For $\eta \neq 0$ the investment in the α technique will be greater or less than the first term, depending on whether the rate of return on the α technique is greater than r . This seems reasonable. If a technique is highly profitable, then it will tend to attract investment and conversely if it is relatively less profitable, investment will decline.

Assuming depreciations, the rate of change in capital invested in α technique is

$$\frac{dK_{\alpha}}{dt} = [\sigma r_{\alpha} + \eta(r_{\alpha} - r) - \delta_{\alpha}]K_{\alpha}, \quad (5)$$

where δ_{α} is the depreciation rate of α technique. If there is no investment in α technique during some time period, the capital stock K_{α} decreases at the depreciation rate. To summarise, the investment function (4) is an attempt to model the behaviour of farmers whose motivation to invest is greater profitability but nevertheless will not adopt the most profitable technique immediately, because of uncertainty and various other retardation factors. Total investment is distributed among the different techniques according to their profitability and accessibility. The most efficient and profitable technique, which requires a large scale of production, is not equally accessible for all farmers and, thus, farmers will also invest in other techniques which are more profitable than the current technique. When some new and profitable technique becomes widespread, more information is available about the technique and its characteristics, and farmers invest in that technique at an increasing rate.

Three dairy techniques (representing α techniques) and corresponding farm size classes have been included in the DREMFLA 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). Let us briefly show the calibration of the diffusion model to the official statistics of farm size structure. Parameter σ has been fixed to 1.07 which means that an 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 η (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 σ and η (1.07:0.77) is unique because it calibrates the farm size distribution to the observed farm size structure in 2003 (a new combination is chosen each year when new information on farm size structure has been obtained). Choosing larger σ and smaller η exaggerates the investments on small farms, and choosing smaller σ and larger η exaggerates the investments on large farms. Choosing smaller values for both σ and η result in too low investment and production levels, and choosing larger values for both σ and η results in overestimated investment and production levels, compared to the ex post period. 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 Heikkilä *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 empirical findings.

4.3 Recursive programming model

The optimization routine is a spatial price equilibrium model which provides annual supply and demand pattern, as well as endogenous product prices, using the outcome of the previous year as the initial value. Production capacity (number of animal places available, for example), which is an upper boundary for each production activity (number of animals) in each region, depends on the investment determined at a sub-model of technology diffusion.

The use of feed is a decision variable, which means that animals may be fed using an infinite number of different (feasible) feed stuff combinations. This results in non-linearities in balance equations of feed stuffs since the number of animals and the use of feed are both decision variables. There are equations ensuring required energy, protein and roughage needs of animals, and those needs can be fulfilled in different ways. The use of concentrates and various grain-based feed stuffs in dairy feeding, however, is allowed to change only 5–10 % annually due to biological constraints and fixed production factors in feeding systems. Concentrates and grain based feed stuffs became relatively cheaper than silage feed in 1995 because of decreased grain prices and CAP payments for grain. The share of concentrates and grain has increased, and the share of roughage, such as silage, pasture grass and hay, has gradually decreased in the feeding of dairy cows. There has also been substitution between grain and concentrates (in the group of non-roughage feeds), and between hay, silage and pasture grass (in the group of roughage feeds). The actual annual changes in the use of different feed stuffs have been between 5–10%, on the average, but the overall substitution between roughage and other feed stuffs has been slow: the share of concentrates and grain-based feed stuffs in the feeding of dairy cows has increased by 1% annually since 1994.

Feeding affects the milk yield of dairy cows in the model. A quadratic function is used to determine the increase in milk yield as more grain is used in feeding. Genetic milk yield potential increases exogenously 110–130 kilos per annum per cow (depending on the region). Fertilization and crop yield levels depend on crop and fertilizer prices via empirically validated crop yield functions.

There are 18 different processed milk products, many of which are low fat variants of the same product, in the model as well as the corresponding regional processing activities. There are explicit skim milk and milk fat balance equations in the model. In the processing of 18 milk products, fixed margins representing the processing costs are used between the raw material and the final product. This means that processing costs are different for each milk product, and they remain constant over time in spite of gradually increasing inflation. In other words, it is assumed that Finnish dairy companies constantly improve their cost efficiency by developing their production organisation, by making structural arrangements (shutting down small scale processing plants) and substituting capital for labour (enlarging the processing plants), for example. Such development has indeed taken place in Finland in recent years.

All foreign trade flows are assumed to be to and from the EU. It is assumed that Finland cannot influence the EU price level. Armington assumption is used (Armington 1969). The demand functions of the domestic and imported products influence each other through elasticity of substitution. Since EU prices are given the export prices are assumed to change only because of frictions in the marketing and delivery systems. In reality, exports cannot grow too rapidly in the short run without considerable marketing and other costs. Hence, the transportation costs of exports increase (decrease) from a fixed base level if the exports increase (decrease) from the previous year. The coefficients of the linear export cost functions have been adjusted to smooth down the simulated annual changes in exports to the observed average changes in 1995–2004. In the long-term analysis the export costs play little role, however, since they change only on the basis of the last year's exports. Hence the exports prices, (the fixed EU prices minus the export costs), change only temporarily from

fixed EU prices if exports change. This means that Finland cannot actually affect EU price level. In fact the export specification is asymmetric to the specification of import demand. Export prices may be only slightly and temporarily different from EU average prices while the difference between domestic and EU prices may be even significant and persistent, depending on the consumer preferences. According to Jalonoja and Pietola (2004), there seems to be a significant time lag before Finnish potato prices move close to steady state equilibrium after shocks in EU prices. A unit root of domestic price process was found to be statistically significant which indicates that domestic price changes are rather persistent.

The export price changes due to changing export volume are relatively small and temporary compared to changes in domestic prices which are dependent on consumer preferences. In terms of maximizing consumer and producer surplus, this means that exports may fluctuate a lot and cause temporary and relatively small changes in export prices (through export costs), while the difference between domestic and average EU prices may be more or less persistent, depending on the consumer preferences. Hence, in addition to the import specification, the export specification explains why the domestic prices of milk products, as well as the producer prices of milk, remain at a higher level than the EU average prices even if Finland is clearly a net exporter of dairy products.

4.4 Links between technology diffusion and land use competition

Let us briefly discuss the role of land competition here since agricultural land is almost always required if livestock investments are to be made. Already nitrate directive of the European Union restricts the amount of nitrogen fertilisation to the maximum value of 170 kg N/ha per year. Environmental permits, required for large scale livestock production units, may pose more stringent conditions for a farm, implying more land area for manure spreading. Agri-environmental subsidy scheme in Finland poses significantly stricter requirements for manure spreading since not only nitrogen fertilisation level but also phosphorous fertilisation is given upper limits, as a condition for agri-environmental subsidies. This phosphorous fertilisation limit is particularly compelling for pig and poultry farms since the phosphorous content of manure of pigs and poultry animals is significantly higher than that of bovine animals.

The price of land, affected consistently by all production activities regionally, is provided as shadow values of the regional land resource constraint. In earlier years land competition was not very intense in Finnish agriculture due to abundance of farmland with respect to the quantity of regional animal production, i.e. due to low level of regional concentration of animal farms and animal numbers. However in the last 10 years land competition has intensified, especially in areas where animal production has significantly increased (Lehtonen & Pyykkönen 2005). For this reason coupling the technology diffusion model with market simulating optimisation model provides a consistent treatment of land resource competition. When shadow price of regional land resource constraint is fed as an input price to the technology diffusion model, profitability of livestock investments decrease in those regions where land price (endogenous to the programming model) is high, while livestock investments become relatively more profitable in regions where land prices are low. Such connections to factors market, often demanded by agricultural economists in recent years (Chavas, 2001), provide an explanation why the increase in intensive animal production regions have decelerated due to land scarcity and high land prices, while animal production

still exist in less productive regions. In technology diffusion model one may also include technological variations (biogas plants and methods how to fraction phosphorous out of manure to be spread on farmland) which may change the relative profitability of investments in different production techniques. This kind of options have not been included in the Dremfia model yet. Implementing a link between land prices between technology diffusion model and programming model however provides one more possibility to validate the simulated development path of regional animal production and land use to the observed ex-post development. Furthermore, regional feed use of animals, also endogenous in the programming model affects the land area required by animal production, hence a part of land scarcity costs can be avoided by changing feed use.

4.5 Trade of milk quotas

Milk quotas are traded within three separate areas in Finland. Within each quota trade area the sum of bought quotas must equal to the sum of sold quotas. In the model the support regions A, B and BS is one trade area (Southern Finland), support region C1 and C2 another trade area (Middle Finland – consisting of both Central Finland and Ostrobothnia regions in the model), and support areas C2P, C3 and C4 constitute a third region (Northern Finland). The price of the quota in each region is determined by the shadow value of an explicit quota trading balance constraint (purchased quotas must equal to sold quotas within the quota trading areas consisting of several production regions in the model, defined separately for each quota trading area. A depreciation period of five years is assumed, i.e. the uncertainty of the future economic conditions and the future of the quota system rule out high prices. Additional quotas and final phase-out of the EU milk quota system can be taken into account in a straightforward manner.

4.6 Risk specification

Ignoring risk-averse behaviour in farm planning models often leads to results that bear little relation to the decisions farmer actually makes (Hazell & Norton, 1986: 80). In studying climate change impacts on agricultural production it is essential to implement risk into the optimization models, rather than operate them assuming risk neutrality. Furthermore, including risk in optimisation models is relatively straightforward technically.

Several techniques have been developed to incorporating risk-averse behaviour in mathematical programming models. We adopted the mean-variance analysis with dynamic recursive sector model to explicitly include crop risks into estimates of land use changes in Finland. In classical mean-variance-model we maximize the utility function with positive risk aversion coefficient. If X is a vector of the different activities (amount of n), the vector of the land use of different crops is $(x_1, x_2, \dots, x_n)$ and P is vector of the prices of different crops $(p_1, p_2, \dots, p_n)$.

The model maximizes the utility function:

$$\text{Max } u = E[PQ] - cX - \Phi V[PQ]^{1/2}, \quad (6)$$

where $E[PQ]$ is the expected profit (price vector multiplied with quantity vector Q), c is the unit cost of the activity (e.g. euros/ha), Φ is the positive risk averse parameter and V the variance operator. This can be written:

$$\text{Max } u = P^* E[y]X - cX - \Phi[X'\Omega X]^{1/2}, \quad (7)$$

where P^* is the expected price, y yield, Ω is covariance matrix between profits of the different activities. The target function u is maximized with resource constraint as matrix A contains the resource use, like availability of land and working ours at peak working period:

$$AX \leq b \quad (8)$$

If the expected return per hectare is denoted:

$$r^* = P^* E[y] \quad (9)$$

we have:

$$\text{Max } u = r^*X - cX - \Phi[X'\Omega X]^{1/2} \quad (10)$$

In the optimum, the utility gained from the additional unit of activity equals with marginal costs. For a risk-averse farmer the possibility for the lower profits than expected is the additional cost. Increasing the activity produces additional costs determined by the risk parameter. These costs are positive if the profit of the activity correlates positively with the profits of the other activities and negative if the profit of the activity correlates negatively with the profits of the other activities. For example if the profit of certain crop correlates negatively with the profits of other crops, the variance of the total profit decreases.

The empirical estimation of the risk attitude parameters is difficult. Quadratic utility functions can't be summed up, so we are not able to calculate the mean value of the risk attitude parameters measured from different entrepreneurs and the groups of entrepreneurs. In addition the values of the risk attitude parameters depend substantially on definition of the optimization model and the mean prices. In empirical work the values of the risk attitude parameters are often calibrated so that the resulting model outcome is close to the realized production. The problem is that realized situation in a certain year or mean of the several years may not necessarily represent the economical equilibrium (Hardaker & Huirne, 1997:187-189; Coyle, 1992).

The variance-covariance matrixes of the crop contribution margins are calculated on the regional basis since there are 18 production regions in the DREMFIA model. We have used the regional data of crop yields from 1995 - 2006, product and input prices and agricultural subsidies from the official statistics. The use of inputs per hectare in different regions is already defined and validated to farm taxation data and farm level production costs calculations made by rural advisory services¹. Hence the variance-covariance matrices we have produced fit the DREMFIA -model specifications but may not be usable in a context of some other input specification and aggregations. For example, we have fully included labour costs of farm family to production costs, which is more appropriate in long-term analysis than in short-term analysis.

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¹ We have used input specification and aggregation of Pro Agria -organisation (www.proagria.fi) which is a central coordinating body of rural advisory services in Finland.

The calculation of matrixes shows that wheat, rye, malt barley and oilseeds have higher own variances than barley, oats and mixed grain which are mainly cultivated for feed use. The variances of wheat, rye, malt barley and oilseeds further grow towards the north. These crops of high variances also correlate positively with each other. This is understandable since feed crops are substitutes and also global cereals markets usually change cereals prices in the same direction. Also if crop yields are low due to weather, pests etc., the yield reducing factors tend to have similar impacts on all cereals. However, there tend to be large intra-annual variations in weather and yields between different regions, while the input and output prices are largely uniform since they are determined at global and EU markets. Consequently, while profitability covariance terms differ, they are almost all positive, there are only few negatively correlating crops in the northern areas of Finland, but areas under these crops are quite insignificant. Clearly positive covariance terms mean that risks cannot be significantly lowered through multicropping. However, the risk specification can provide an endogenous explanation for the fact that some crops are not only cultivated in southern most favourable regions but also in few other regions as well. Most importantly the risk terms in the objective function mitigate the tendency of the programming model to over-specialisation (discussed by Hazell & Norton 1984). Hence corner solutions typical for linear programming can be avoided², i.e. land use is not sensitive for small differences in prices, which is important when evaluating land use and environmental impacts, such as nutrient leaching of policies. The robustness of the policy impacts however should be routinely tested for sensitivity for input and output prices.

Risk aversion behaviour of farmers as well as changing patterns of crop and revenue risks are increasingly relevant in the changing climate. Simple expansion of risk based on observed covariance matrices (for example, by changing the risk aversion coefficient in eq. (7) and (10) may produce misleading results. Crop growth simulation models (Boogard et al. 1998) and their new versions tailored for climate change simulations could serve to create artificial realisations of crop yields and hence covariance matrices. Such a work, however, is computationally demanding in time scales of 50 or more years.

5. Integration to field scale and catchment scale nutrient leaching models

The outcome of the Dremfia model, i.e. numbers of animals, their manure to be spread on fields, chemical fertilisation, as well as land use variables (hectares of different crops) can be fed in physical field (Tattari et al. 2001) and catchment scale models – in a relatively straightforward way.

However, the field scale nutrient leaching models are rich in biophysical detail. The field scale nutrient leaching model ICECREAM (Tattari et al. 2001), for example, 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

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² While corner solutions are not possible for feed crops (due non-linear relations between feeding, meat and milk yields, market prices affected by Armington –specification and regional balance equations, the risk terms essentially eliminate the possible sensitivity of bread grain and malting barley production, not strongly affected by non-linearities in the model, on exogenous input or output price changes.

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, for example, the results of the field-scale simulations with ICECREAM have been up-scaled (Lehtonen et al. 2007). 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 model response to the (land use, fertilisation) input from the DREMFIA model is obtained by weighing the ICECREAM matrix by the percentage of each soil-crop-slope combination in each catchment for each year.

While the ways to integrate Dremfia output to nutrient leaching models depend on the technical set-up as well as the problem (i.e. unique solutions may not exist), one should note that the deeper integration of the models is done already inside Dremfia. In fact, the actual municipality (catchment) level disaggregations of the nutrient leaching model ICECREAM is introduced in Dremfia, which means that extra regions are added to the DREMFIA model. In this the rich datasets of cultivation and land use history of the region, collected for the validation of the nutrient leaching models such as ICECREAM or INCA (Rankinen et al.), can be utilised. For example, in Lehtonen et al. (2007) some penalty functions were developed for wheat yields in Yläneenjoki catchment, if wheat area exceeded the historical maximum. However individual soil types and field slopes, included in the nutrient leaching models, cannot be included in Dremfia except further increasing the number of dimensions and decision variables in the optimisation model. That, in turn, increases computational burden, and is also rather demanding in terms of crop fertilisation response functions included in Dremfia: not the same type of response functions can be assumed for crops on all soils. Crop growth simulation models (Boogard et al. 1998) could serve in creating artificial response functions. Such an approach, however, requires a considerable simulation work already in the case 5-10 few crops and soil types.

6. Conclusion

The presented research method is crucially based on the cumulative gains in the process of gradually increasing farm size at the local level. Small initial farm size, or any significant interruption in the process of farm size growth and improved labour efficiency, may lead to increased regional concentration of production over time. This means that agriculture at weaker agricultural areas will deteriorate while production at the national level can be considered more competitive if the concentration development is not intervened. The multi-regional sector model presented and discussed in this study explains increasing concentration of production in some particular areas. This development is confirmed by observed patterns of production concentration.

It must be recognised that the production development, and hence the development of regional production level and structure as well, 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.

One can conclude that the diffusion models combined with recursive-dynamic optimisation model of agricultural sector provide analytically simple but not easily applicable approach in modelling aggregate investments and technical change. In principle the combination of the models provides a dynamic view of agricultural development and structural change without many complications prevalent in econometric approaches resulting from dynamics and a large number of dimensions in regional sector level models. However, the difficulty lies in the combination and coupling between diffusion and optimisation models. Concerning the particular diffusion scheme one can find a unique set of parameter values which explain ex- post structural development. However, since changes in market prices affect investments, the parameters of the diffusion models are conditional on the particular market module specification and its regional dis-aggregation and cannot be validated independently. Nevertheless the overall direction and magnitude of the production changes seem to be robust to minor changes in the diffusion model parameters.

On the other hand the optimisation approach employed in the market model facilitate explicit treatment of physical quantities, description of inputs (kg/ha, animal), and their substitution (such as imperfect substitution between chemical fertiliser and manure used as fertiliser; utilisation for plants). This makes the approach suitable for integrations and interdisciplinary research. Furthermore, the richness of the optimisation approach also lies in duality, i.e the use of dual variables (shadow prices) of explicit resource constraints and balance equations (interpreted as prices). Hence the approach taken can be made efficient in terms of utilisation of different kind of data used in validation. In practical terms, the model and its components need to be tuned to the data, and there are many options for that in optimisation approach.

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 farm level bookkeeping data, the future production levels, regional concentration of production, and environmental effects are underestimated.

7. References

- Boogaard, H. L., C.A. van Diepen, R.P. Rötter, J.M. Cabrera, and H.H. van Laar, 1998. User's guide for the WOFOST 7.1 crop growth simulation model and Control Center 1.5, Alterra, Wageningen, The Netherlands, 143 pp.

- Bärlund, I., Lehtonen, H. & Tattari, S. 2005. Assessment of environmental impacts following alternative agricultural policy scenarios. *Water Science and Technology*, vol. 51, issue 3-4 (March-April 2005) pp. 117-125.
- Cox, T.L. & Chavas, J.-P. 2001. An Interregional Analysis of Price Discrimination and Domestic Policy Reform in the U.S. Dairy Sector. *American Journal of Agricultural Economics* 83: 89-106.
- Chavas, J-P. 2001. Structural Change in Agricultural Production. In: B. Gardner and G. Rausser (editors.). *Handbook of Agricultural Economics*, Vol. 1, Ch. 5, 263-285, Elsevier Science B.V.
- Coyle, B. 1992. Risk Aversion and Price Risk in Duality Models of Production: A Linear Mean-Variance Approach. *American Journal of Agricultural Economics*, Vol. 74, No. 4 (Nov., 1992). P. 849-859.
- Ekholm P., Granlund, K., Kauppila, P., Mitikka, S., Niemi, J., Rankinen, K., Räike, A., Räsänen, J. 2007. Influence of EU policy on agricultural nutrient losses and the state of receiving surface waters in Finland. *Agricultural and Food Science* Vol. 16 (2007), No. 4, p. 282-300. <http://www.mtt.fi/afs/pdf/mtt-afs-v16n4p282.pdf>
- Frei, C.W., Haldi, P-A and Sarlos, G. (2003). Dynamic formulation of a top-down and bottom-up merging energy policy model. *Energy Policy* 31, 1017-1031
- Hagedoorn, J. (1989), *The Dynamic Analysis of Innovation and Diffusion*. Pinter Publishers 1989. 197 p.
- Hardaker, J., Huirne, R., Anderson, J. & Lien, G. 1997: *Coping with Risk in Agriculture*. Second edition. CAP Publishing. USA.
- Hazell, P. & Norton, R. 1986. *Mathematical programming for economic analysis in agriculture*. MacMillan, New York, USA. 400 p.
- Heikkilä, A-M, Riepponen, L. & Heshmati, A. 2004. Investments in new technology to improve productivity of dairy farms. Paper presented in 91st EAAE seminar "Methodological and Empirical Issues of Productivity and Efficiency Measurement in the Agri-Food System", Rethymno, Greece, September 24-26, 2004.
- Jalonoja, K., Pietola, K. 2004. Spatial integration between Finnish and Dutch potato markets. *Acta agriculturae Scandinavica*. Section C Food economics 1, 1, April 2004: 12-20.
- Johansson, R.C. and Kaplan, J.D. 2004. A carrot-and-stick approach to environmental improvement: marrying agri-environmental payments and water quality regulations. *Agricultural and Resource Economics Review* 33: 91-104.
- Karshenas, M. and Stoneman, P. 1995, Technological Diffusion. In: Stoneman, P. (ed.), *Handbook of the Economics of Innovation and Technological Change*, p. 265-297.
- Lehtonen, H. 2001. Principles, structure and application of dynamic regional sector model of Finnish agriculture. Academic dissertation. MTT Publications 98. Helsinki, Finland.
- Lehtonen, H. 2004. Impacts of de-coupling agricultural support on dairy investments and milk production volume in Finland. *Acta Agriculturae Scandinavica, Section C: Food Economics* 1: 46-62.
- Lehtonen, H., Aakkula, J. & Rikkonen, P. 2005. Alternative Policy Scenarios, Sector Modelling and Indicators: A Sustainability Assessment. *Journal of Sustainable Agriculture*, Vol. 26: Issue 4 (August 2005).

- Lehtonen, H., Pyykkönen, P. 2005. Maatalouden rakennekehitysnäkymät vuoteen 2013 (Structural change in Finnish agriculture up to 2013). MTT:n selvityksiä 100: 40 s., 1 liite. An English abstract is included.
<http://www.mtt.fi/mtts/pdf/mtts100.pdf>
- Mapp, H.P., Bernardo, D.J., Sappagh, G.J., Geleta, S. and Watkins, K.B. 1994. Economic and environmental impacts of limiting nitrogen use to protect water quality: a stochastic regional analysis. *American Journal of Agricultural Economics* 76: 889-903.
- Nelson, R.R., Winter, S.G., 2002. Evolutionary theorizing in economics. *The Journal of Economic Perspectives* 16 (2), 23-46.
- Pietola, K. 1997. A generalised model of investment with an application to Finnish hog farms. Agricultural Economics Research Institute, Finland. Publications 84. 113 p.
- Rankinen, K., Kenttämies, K., Lehtonen, H. & Nenonen, S. 2006: Nitrogen load predictions under land management scenarios for a boreal river basin in northern Finland. *Boreal Environment Research* 11: 213-228.
- Rantamäki-Lahtinen, L., Remes, K. & Koikkalainen, K., 2002. The investment and production plans in Finnish bookkeeping farms. Agrifood Research Finland, Economic Research (MTTL), Working Papers 4/2002, 6-40.
- Rekolainen S., Salt C.A., Bärlund I., Tattari S. and Culligan-Dunsmore M., 2002. Impacts of the management of radioactively contaminated land on soil and phosphorus losses in Finland and Scotland. *Water, Air, Soil Pollut.*, 139, 115-136.
- Shou J.S., Skop E. and Jensen J.D., 2000. Integrated agri-environmental modelling: a cost-effectiveness analysis of two nitrogen tax instruments in the Vejle Fjord watershed, Denmark. *J. Environ. Manage.*, 58, 199-212.
- Sckokai, P. 2004. Modelling impacts of agricultural policies on farm investments under uncertainty: The case of arable crop regime. Paper presented in OECD workshop on de-coupling in Paris 3-4 June 2004.
<http://www.oecd.org/dataoecd/14/27/34996395.pdf>
- Soete, L. and R. Turner. 1984. Technology diffusion and the rate of technical change. *Economic Journal* 94: 612-623.
- Sue Wing, I. 2006. The synthesis of bottom-up and top-down approaches to climate policy modelling: Electric power technologies and the cost of limiting US CO₂ emissions. *Energy Policy* 34:3847-3869.
- Sue Wing, I., & W.P. Anderson 2007. Modeling Small Area Economic Change in Conjunction with a Multiregional CGE Model, in R.J. Cooper, K.P. Donaghy and G.J.D. Hewings (eds.), *Globalization and Regional Economic Modeling*, Springer-Verlag (Advances in Spatial Science).
- Tattari S., Bärlund I., Rekolainen S., Posch M., Siimes K., Tuhkanen H.-R. and Yli-Halla M., 2001. Modelling sediment yield and phosphorus transport in Finnish clayey soils. *Trans. ASAE*, 44 (2), 297-307.
- Tiainen, J. & Pakkala, T. 2000. Population changes and monitoring of farmland birds in Finland. In: *Linnut-vuosikirja 1999*. BirdLife Suomi. Helsinki, Finland. p. 98-105.

- Tiainen, J. & Pakkala, T. 2001. Birds. In: Pitkänen, M. and Tiainen, J. (eds.). *Biodiversity of Agricultural Landscapes in Finland. BirdLife Finland Conservation Series* (No3.). Helsinki, Finland. p.33-50.
- Tiainen, J., Kuussaari, M., Laurila, I.P. & Toivonen, T. (eds) 2004. *Elämää pellossa – Suomen maatalousympäristön monimuotoisuus*. Edita Publishing Oy, Helsinki. 366 p.
- Turtola, E. 2007. Preface. *Agricultural and Food Science* Vol. 16 (2007), No. 4, p. 279-281. http://www.mtt.fi/afs/pdf/mtt-afs-v16n4p279_preface.pdf

Dynamic Modelling

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When talking about modelling it is natural to talk about simulation. Simulation is the imitation of the operation of a real-world process or systems over time. The objective is to generate a history of the model and the observation of that history helps us understand how the real-world system works, not necessarily involving the real-world into this process. A system (or process) model takes the form of a set of assumptions concerning its operation. In a model mathematical and logical assumptions are considered, and entities and their relationship are delimited. The objective of a model – and its respective simulation – is to answer a vast number of “what-if” questions. Some questions answered in this book are: What if the power distribution system does not work as expected? What if the produced ships were not able to transport all the demanded containers through the Yangtze River in China? And, what if an installed wind farm does not produce the expected amount of energy? Answering these questions without a dynamic simulation model could be extremely expensive or even impossible in some cases and this book aims to present possible solutions to these problems.

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Phone: +86-21-62489820
Fax: +86-21-62489821

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