Cost-Effectiveness Evaluation of Swiss Agri-Environmental Measures on Sector Level

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Abstract

This paper focuses on non-linear programming models and their suitability for ex-ante evaluations of agri-environmental policies on sector level. An approach is presented to compare organic farming payments as a multi-objective policy, with other, more targeted agri-environmental policies in Switzerland. The Swiss version of the comparative static sector-consistent farm group model FARMIS is able to group the sector's farms into organic and non-organic farms and optimise them separately. CH-FARMIS is expanded with three modules particularly for this study: a) allowing for the simulation of uptake; b) integrating life cycle assessment data for energy use, eutrophication and biodiversity; and c) estimating the policy and farm-group-specific public expenditure, including transaction costs. This paper illustrates the functions of the model, shows preliminary energy use calculations for the German Agricultural Sector and discusses the advantages and limitations of the approach.

Key words: positive mathematical programming, life cycle assessment, organic farming, environmental indicators, economic efficiency

1. Introduction and problem statement

The request for quantitative tools for ecological-economic impact assessment of agricultural policies has been increasing in recent years due to i) improved impact assessment and policy evaluation standards of the agricultural support schemes (European Commission, 2004) and ii) the improved methodological and technical potentials in the field of sector modelling (Heckelei, 2002).

The Swiss agricultural policy has been following a progressive ecological agenda since the introduction of direct payments in 1993. Full cross-compliance was introduced already in 1998 and additional ecological services were stimulated by targeted agri-environmental payments, including payments for organic management. Against the background of a limited budget, the considerations on cost-effectiveness play a fundamental role for a further development of the direct payment system.

In this context organic farming is of particular interest because in Switzerland as in most other countries, organic farms receive additional support payments for providing public goods, particularly of environmental nature (Stolze *et al.*, 2000). As this support made it economically more attractive for farmers to convert to organic agriculture (Lampkin *et al.*, 1999), the question of cost-effectiveness of the organic area payments is particularly relevant.

So far, agricultural economists have two differing views on the cost-effectiveness of organic farming support payments: One the one hand, von Alvensleben (1998) argues that the organic area payments are not cost-effective because the policy objectives could be achieved by flexible combinations of various agri-environmental measures more efficiently. The theoretical basis for this was laid by Tinbergen, who theorised that an efficient policy requires as many specific instruments as there are specific objectives (Tinbergen, 1956). On the other hand, the applicability of the Tinbergen rule might not be given fully in this case due to interactions between policies, conflicting objectives and a limited determinability of different kinds of objectives. Furthermore, the multi-purpose character of organic agriculture could increase its cost-effectiveness by lowering transaction costs as compared to specific, targeted agri-environmental measures (Dabbert *et al.*, 2004).

This problem has not been addressed in a quantitative way so far. The present paper introduces an approach to answer this question on sector level by adapting a sector-consistent farm group model.

2. Objectives of this paper

The objectives of this paper are to:

- explore the general suitability of static programming models as a tool to assess both economic and ecological impacts of single policy measures and complex schemes
- discuss an approach to quantify the economic and ecological effect of organic farming and alternative extensification policies and to determine the cost-effectiveness of these measures

3. Sector models for the evaluation of agri-environmental policy

The quality of agri-environmental policy evaluation largely depends on the availability of data on uptake rates, effects and expenses. Doing a simple ‘before-after-comparison’, i.e. comparing the situation before the introduction of a policy at T_0 and after the introduction T_1 or T_2, does not reflect excactly the additionality of the policy in question, because other changes might have occurred during that period and influenced the data to an unknown extent (see Fig. 1).

In order to derive the additionality, i.e. the extra effect of a particular policy measure or scheme, a ‘with-without-comparison’ has to be conducted (Osterburg, 2004; Pearce, 2004). However, if the policy has been implemented already (*ex-post* case), the situation without the policy is unknown. *Ex-ante* evaluations lack data of both cases (with and without). An additional shortcoming commonly faced by evaluators is insufficient longitudinal data. Either, in *ex-post* evaluations observations on short term (T_1) impacts are available only, or, in *ex-ante* evaluations there is no hard data of future years.

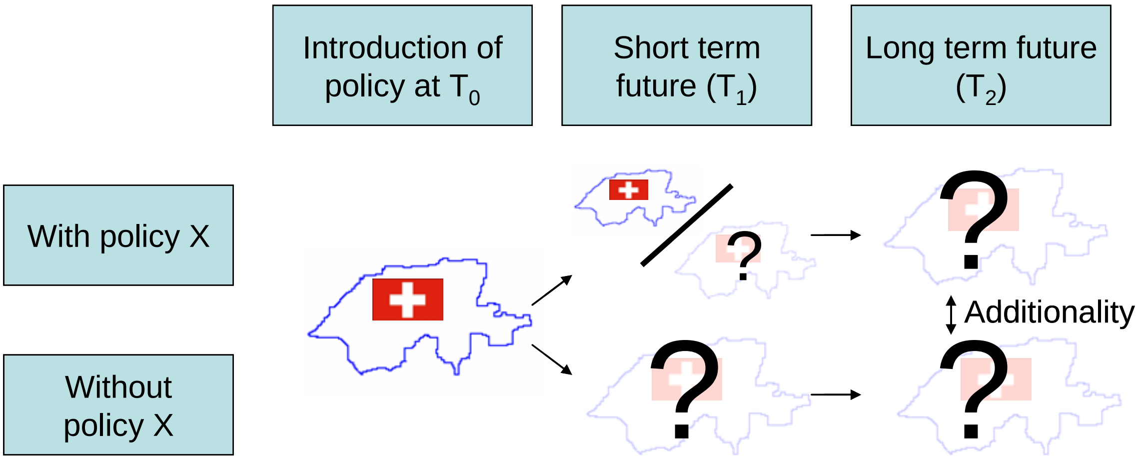

Fig. 1 Data availability for the evaluation of an agri-environmental policy measure in an *ex-ante* and an *ex-post* evaluation

Here, policy impact models come into play, since they are able to forecast responses of the farm sector or simulate reactions to hypothetical situations. Hence, models can substitute empirical data, however, modelled data cannot entirely substitute empirically measured data because models rely on assumptions to simplify reality. Nevertheless, models can provide data in case empirical data is not available (Kleinewefers and Jans, 1983).

Because agri-environmental policies are aimed to have a beneficial impact on the environment, the analysis of its effects requires the coverage of these impacts by the models either in physical or monetary terms. In recent years sector models have been equipped with environmental indicators using a variety of different concepts but mostly building on normative data or data derived from ecological models (Julius *et al.*, 2003; LEI *et al.*, 2003; Sattler and Zander, 2004; Schmid and Sinabell, 2006). Such approaches can then be used to relate the environmental effects that result from the modelled decisions of farms in physical terms to the adherent costs. According to Salvatici et al. (2000), there are three model classes used for impact assessments on the agricultural sector:

Mathematical programming models are most frequently used to include environmental parameters. In the 6th Framework Programme of the EU, several projects were launched to link environmental indicators to programming models (e.g. SEAMLESS, SENSOR, MEA-Scope). In total, 14 European programming models which integrated environmental concerns were found, thereof 7 Positive Mathematical Programming (PMP) models and 5 Linear Programming (LP) models. Only one relevant approach was found with respect to multifunctionality or environmental indicators, using **general equilibrium model** (Cretegny, 2002), while **econometric model** approaches were found to address only specific questions with regard to sector modelling and environmental assessments.

Due to this dominant role of PMP models, the following comparision is limited to this model type comparing the relevant characteristics of the models in place (Table 1). LP approaches are disregarded here due to lack of space, although there are relevant LP approaches available (Jayet, 1997; Pacini *et al.*, 2004; Sattler and Zander, 2004).

Concerning the geographical scope, except CAPRI all models work on national level. The calibration is done according to supply elasticities for the activities in all models, while CAPRI follows an econometric calibration of land use activities, according to Heckelei (2002). While all models are capable of representing regions, only FARMIS and PROMAPA.G are able to specify according to different farm types. Currently, FARMIS is the only model which can separately optimise organic and non-organic farms. All models are static, while both CAPRI and SILAS currently work on a dynamisation. Site specific characteristics are taken into account by endogenously RAUMIS, while CAPRI considers soil types within the results calculation.

There are various environmental indicators covered in the different models, however, there are large differences in the way how the environmental indicators are modelled. E.g. nutrient balances or biodiversity can be modelled in very different ways, depending on the model structure and the available data in the specific case. The limited information that is available in publications currently and the high levels of complexity of these models does not allow for a comparison of these implementations.

On the one hand, the high number of PMP and LP models with environmental indicators suggests a general suitability of static programming models for analysing environmental effects of policies on sector level. On the other hand, however, the model comparison illustrates that each of the seven reviewed PMP models has its advantages and limitations against the chosen criteria, hence, there is no model which has all capabilities that were desirable for the evaluation of agri-environmental policies.

Table 1 Overview of reviewed PMP models and their characteristics

Model	Main publication referred to	Geographic scope	Calibration	Regional representation	Farm type representation	Static/dynamic	Site specificity	Coverage of environmental indicators
CAPRI	LEI et al., 2003	EU-level, NUTS 1, NUTS 2	Econometric for plant activities supply elasticity for animal activities	YES	indirect representation	Static (dynamisation in progress)	NO (but soil types considered in results calculation)	N, P, K balances, Ammonia output, Global warming emissions Water balances
DRAM	Helming, 2005	The Netherlands	Supply elasticity	YES	NO	Static	NO	Ammonia emissions, Nitrogen surplus
FARMIS	Bertelsmeier, 2004	Selected EU member states and Switzerland	Supply elasticity Intensities based on Röhm-Dabbert-Approach	YES	YES	Static	NO	Energy use, Eutrophication with N and P Biodiversity (CH)
PASMA	Schmid & Sinabell, 2006	Austria (national)	Röhm-Dabbert-Approach, linear approximation	YES	NO	Static	NO	Fertilizer balances, Transport matrix, Para-agricultural activities
PROMAPA.G	Júdez et al., 2006	Spain	Optional econometric calibration	YES	YES	Static	NO	Nutrient balances
RAUMIS	Julius et al., 2003	Germany, differentiation up to NUTS 3 level	Supply elasticity	YES	NO	Static	YES (differentiation according to soil type classification)	Nutrient balances, NH3 emissions, Pesticide risk, Crop diversity
SILAS	Mack et al., 2007	Switzerland	Supply elasticity	YES	NO	Static (dynamisation in progress)	NO	Energy use, Eutrophication, GHG potential, Pesticide risk

4. Analytical approach

The evaluation approach is based on the comparative static farm group model FARMIS. FARMIS was adapted to the Swiss policy context and extended with a representation of the agricultural sector based on differentiation by farming system (Sanders, 2007). Accordingly, the model (henceforth called CH-FARMIS) is able to assess the impact of agricultural policies on different farm groups that can be defined in a flexible way. By default, a differentiation is made between different farm types, geographic regions and farming systems.

CH-FARMIS is primarily based on farm accountancy data and distinguishes between 30 plant production activities and 15 animal production activities. Positive Mathematic Programming (PMP) facilitates exact reproduction of the Swiss agricultural sector, compared to standard linear programming models (Howitt, 1995). CH-FARMIS is calibrated on the basis of supply elasticities as described in Bertelsmeier (2004).

However, in order to assess both economic and ecological impacts on sector level and to evaluate the cost-effectiveness of specific direct payment designs a model extension of CH-FARMIS is required concerning the intensity levels of activities, environmental indicators and public expenditure calculations, incl. transaction cost estimations. These extensions will be illustrated in the following sections.

4.1. Management Intensity Module (MIM)

Management intensities are differentiated as sub-activities corresponding to defined policy measures, similar to the approach developed by Röhm et al. (2003). Besides the support payments for organic farming, two types of grassland extensification payments as well as the extensification of wheat and rape are implemented in the model. For the activity wheat, for instance, three optional intensity levels are defined: integrated intensive production[1], integrated extensive production according to defined extensification restrictions, and organic production. Since each activity level of each activity is equipped with Input/Output factors, the optimisation process simultaneously considers the different activity intensity levels.

The Röhm-Dabbert-Approach (2003) allows for a more realistic model behaviour by defining the intensity levels as ‘similar acitivites’. Without the definition of similar acitivites, all activities can be exchanged in a similar way, although in reality farmers may be able to easily switch between different intensity levels without replacing their whole machinery or other farm processes. Switching e.g. from wheat production to grassland, requires many changes on the farm, which go along with massive costs for the farms that are not explicitly considered in the model. These differences are taken into account in the objective function which in its expanded version reads as follows:

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[1] In Switzerland, more than 95 % of the farms cultivate their land according to cross-compliance conditions, which require minimum ecological standards regarding nutrient balance, livestock density, and rotation). Thus, integrated intensive farms represent the reference group in Switzerland.

$$\max \boldsymbol{Z}_n = \sum_j \sum_k \boldsymbol{p}_{njk} \boldsymbol{Y}_{njk} - \sum_i \sum_k \boldsymbol{c}_{nik} \boldsymbol{X}_{nik} + \sum_i \sum_k \boldsymbol{dp}_{nik} \boldsymbol{PX}_{nik} - \sum_u \boldsymbol{r}_{nu} \boldsymbol{U}_{nu} -$$

$$\sum_v \boldsymbol{r}_{nv} \boldsymbol{V}_{nv} - \sum_l \boldsymbol{r}_{nl} \boldsymbol{LAND}_{nl} - \sum_i \boldsymbol{\delta}_{nik} \boldsymbol{X}_{nik} - 0.5 \sum_i \boldsymbol{\omega}_{ni1} \boldsymbol{X}_{nik}^2 - 0.5 \sum_i \sum_w \boldsymbol{\omega}_{ni2} \boldsymbol{X}_{niw}^2 \qquad \forall \boldsymbol{n}$$

$X_{ni}, PX_{ni}, U_{nu}, V_{nv} > 0$

where:

Indices:

n = index for farm groups
i = index for production activities
j = index for output products
k, w = index for intensity levels
l = index for land type
u = index for labour
v = index for fertilisers

Variables:

Z_n = objective (profit per farm group)
Y_n = sales of agricultural products
X_n = level of activities
PX_{ni} = level of activities eligible for direct payments
U_{nu} = level of labour input/requirements
V_{nv} = level of fertiliser input/requirement
$LAND_{nl}$ = level of rented UAA

Parameters:

P_{nj} = prices for agricultural products
C_{ni} = activity-specific costs
dp_{ni} = activity-specific direct payments
r_{nu} = labour costs
r_{nv} = expenditures for fertilisers
r_{nl} = rental costs for UAA
δ_{ni} = parameter for linear hidden cost
ω_{ni1} = parameter for quadratic hidden cost
ω_{ni2} = parameter for quadratic hidden cost (depending on the alternative int. levels)

4.2. Environmental Indicator Module (EIM)

On the basis of the Driving-force-pressure-state-impact-response (DPSIR) indicator framework (EEA, 1999) the environmental indicators were selected against their relevancy, information value, data availability and data validity.

While some response and driving force indicators can be derived endogenously from the CH-FARMIS optimisation (organic farm incomes, consumption of mineral fertiliser and pesticides, etc.), others are covered using the MIM described above (area under agri-environmental support and area under organic farming, intensification/extensification).

Additional state and impact indicators are covered by linking data from Life Cycle Assessments (LCA) to the model activities. The SALCA life cycle assessment data by *Agroscope Reckenholz-Tänikon (ART)* (Nemecek *et al.*, 2005) will be used as a comprehensive data pool, while data gaps will be filled with by expert assessments. Direct and indirect energy use, nitrogen and phosphorus eutrophication and biodiversity (in terms of habitat quality) are integrated as three impact indicators for each activity and management intensity in CH-FARMIS.

For the modelling of **energy use**, we base our analysis on ECOINVENT / SALCA data (Nemecek *et al.*, 2005). Both direct (i.e. fuel, gas, electricity) and indirect energy use (i.e. seeds, plant protection, fertiliser, feedstuffs, machines, buildings) are modelled.

Of all nutrients, **nitrogen and phosphorus** have most harmful **eutrophication** effects for the environment, if they are used excessively. Within CH-FARMIS there will be a normative link of the

SALCA eutrophication data to CH-FARMIS. Simultaneously, CH-FARMIS calculates nutrient balances and relates them to the calculated normative values. This double procedure of an input and an impact indicator aims to provide more reliable information on these criteria.

The more intensive agriculture is practiced the more **biodiversity** decreases (Faucheux and Noël, 1995). While the conversion of less intensive systems into more intensive systems is seen as economically advantageous locally, the character of the externality appears to be global in the significant decrease of biodiversity (Faucheux and Noël, 1995). To take into account biodiversity effects of agricultural management within economic models has been tried in many studies, some of which attempted to monetarise various aspects (OECD, 2002).

The SALCA biodiversity indicator expresses the habitat quality for groups of species. Groups with high ecological requirements amphibians, spiders, and carabid beetles receive a special emphasis. Further groups of indicator species are flora on arable land, flora on grassland, birds, small mammals, molluscs, butterflies, bees and locusts. The value for total biodiversity expresses a weighed mean of all groups, with weightings according to their specific importance in the food chain of a habitat (Jeanneret *et al.*, 2006).

4.3. Public Expenditure Module (PEM)

While the effects of the activities and their intensity levels are calculated within the Environmental Indicator Module, the costs are considered in the public expenditure module. Costs of policies are calculated summing up the payments to the beneficiaries plus the transaction costs connected with a certain uptake of a policy. To these costs on farm level, transaction costs on cantonal and national level are added.

Transaction cost data is derived from latest Swiss and international studies (Buchli and Flury, 2006; Rørstad, 2007), missing data is generated by polling a set of experts.

$$PE = \sum_{n} \sum_{i} \sum_{k} \left(PC_{nik} + TC_{FARM_{nik}} + TC_{VAR\,nik} \right) + TC_{FIX}$$

where:

n = index for farm group

i = index for production activities

k = index for intensity level

PE = total public expenditure for a policy

P = payments to beneficiaries (farmers)

TC_{FARM} = transaction costs on farm level

TC_{VAR} = variable transaction for public administration

TC_{FIX} = fixed transaction costs for public administration

5. Potential applications of the model

Currently, CH-FARMIS enables to assess the economic performance per farm type and region as shown for organic and non-organic farms. After the full implementation of the three modules, CH-FARMIS can be used as an assessment and cost-effectiveness evaluation tool because the farm groups can be defined specifically to the research question. Cost-effectiveness analyses with FARMIS can be conducted on three levels:

- **farm group level**, i.e. distinguishing by farming system (organic/non-organic), region (e.g. valley, hills, mountains), farm type (e.g. arable, mixed, dairy farms)
- **for single measures**, i.e. variations of payment designs of single meausres under *ceteris paribus* conditions
- **for policy scenarios**, developing complete scenarios, including variations in payment levels, prices and technical coefficients.

To derive cost-effectiveness evaluations, the results of the three modules are interlinked as graphically shown in Fig. 2. The north-eastern quadrant shows the relation between public expenditure and the payment levels for a policy measure. The courve is s-shaped because small payment levels will not lead to a significant uptake of farms, while those farms with very high opportunity costs need disproportional high payment levels to take up the measure. Assuming an almost linear relation between uptake and effect, the north-western quadrant illustrates the effects on environmental indicators as a funtion of the payment level. Finally, the cost-effectiveness function, i.e. the sector-level effects on habitat quality, energy use and eutrophication as a function of public expenditure, is illustrated in the south-western quadrant. Thus, by modelling the uptake rates of policies in connection with the area-related effects and costs with CH-FARMIS, the cost-effectiveness of policy measures can be derived. The optimal payment level in terms of cost-effectiveness regarding the minimisation of energy use, theoretically lies somewhere between PL_1 and PL_2 because according to Fig. 2, payment levels smaller than PL_1 only cause minimal effects and the additional effects of payment levels beyond PL_2 lead to unproportional high costs.

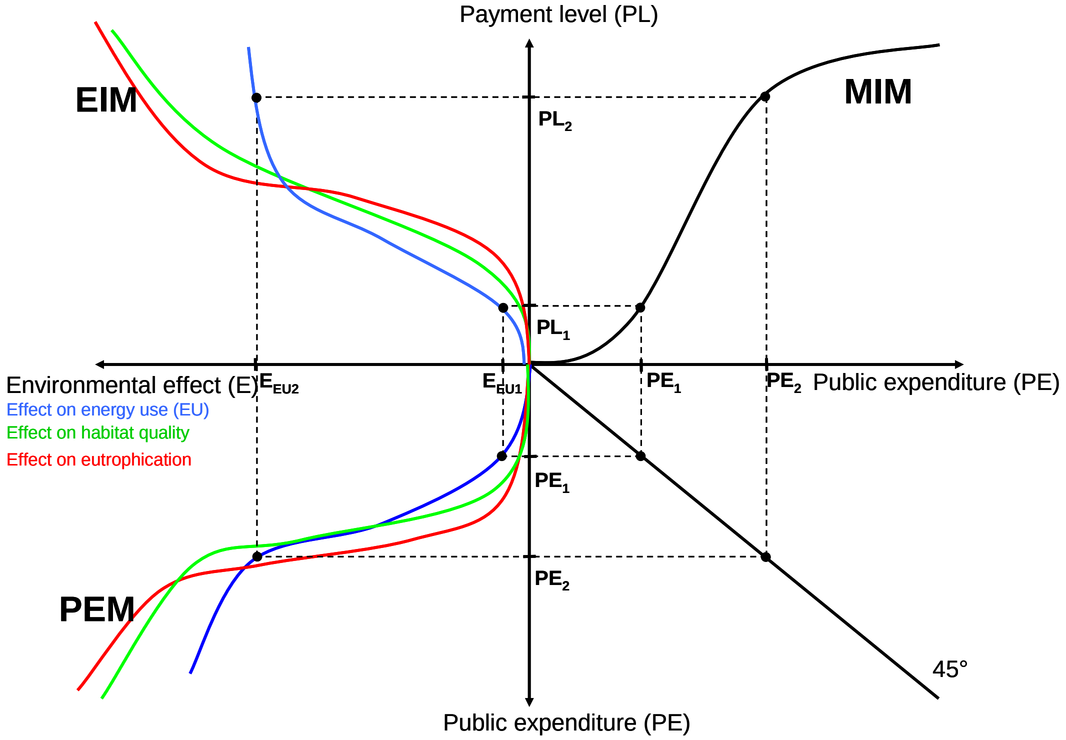

Fig. 2 Graphical derviation of the cost effectiveness on sector level for single policy measures by using the three modules EIM, MIM, and PEM

In Fig. 3 preliminary results for direct and indirect energy use in the German agricultural sector for a base year and a Mid Term Review (MTR) scenario are shown. While the differences among the farm groups are significant in absolute and relative terms per energy components, the differences between base year run and MTR scenario are small. The insignificancy of the differences between the scenarios may be attributed to the fact currently intensity levels do not differ in energy use according to the ecological data, secondly, differences in the use of energy components balance out. For example, the major source of direct energy, fuels, decreases, while the major indirect energy carrier, nitrogen fertiliser, increases due to extended cereals cultivations.

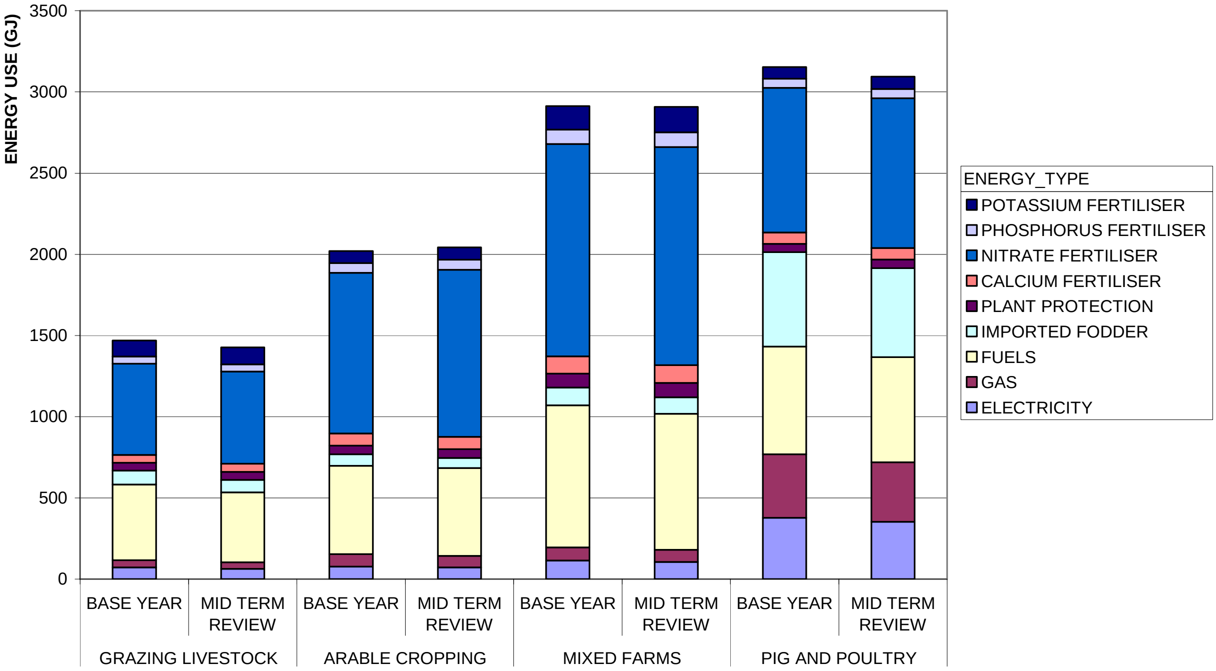

Fig. 3 Illustration of model reactions for exemplary, preliminary results for energy use of representative farms for four farm types of the German Agricultural Sector (own calculation with EU-FARMIS[2]).

6. Discussion of the approach

Static programming models are a suitable option for assessing the cost effectiveness of agricultural policies on sector level. The model comparison showed that currently, static PMP models are the most widespread sector modelling approach integrating environmental concerns. The way coverage and the data origin of the environmental indicators are supposed to vary among the approaches; however, detailed information can hardly be derived from publications.

The approach outlined in this paper has some advantages and limitations, which are discussed below. By employing CH-FARMIS for the evaluations, sector-level results can be generated differentiating between farm types and farming systems and regions. On the other hand the model can only indirectly take into account structural change and conversion to organic agriculture.With the PMP calibration,

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[2] within EU-SVAPPAS (Sustainable value analysis of policy and performance in the agricultural sector) based on EU-FADN – DG AGRI G-3 and energy use data by Schmidt and Osterburg (2005)

hidden costs can be considered within the objective function, on the other hand the PMP calibration relies on assumptions regarding supply elasticities and the validity of dual values in the target years. The flexible grouping of the farms allows for differentiated assessments, particularly the distinction between organic and non-organic farms has not been implemented in comparable sector models, which might be a difficulty when transferring the approach to other EU Member States. However, flexible grouping requires the same data structure for the ecological data. Furthermore, the model only works with broad averages, e.g. an average value for energy use in nitrogen fertiliser per ha of extensively managed wheat, although empirical farm level analyses show a high variation. This insufficiency can only be overcome by integrating ecological indicators into the FADN system.

The approach is targeted to analyse agri-environmental policies and the design of the three modules have been specifically developed for this analysis. An interpretation of the ecological results may be difficult, particularly for eutrophication and biodiversity, because there might not be a non-linear relationship between uptake rates and effects. Furthermore, particularly the aggregation of these effects may be problematic because site-specific characteristics like soil types and slopes cannot be considered at this macro-level. Lastly, the approach does not allow for efficiency calculations in a macro-economic sense, as markets and impacts on other sectors are not considered. Nevertheless, since the approach is able to take into account transaction costs for different policies, a comprehensive cost comparison of policies is possible and the question of cost-effectiveness of the organic farming support payments could be answered.

Given that relevant ecological data is available, further research questions may be addressed. CH-FARMIS may be equipped with different indicators than in stage. This may enable researchers to conduct assessments and *ex-ante* evaluations for multifunctional impacts of agricultural production.

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