AgriBMPWater
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AgriBMPWater

Systems approach to environmentally acceptable farming

Guidelines to compare Best Management Practices at watershed scale

Concepts
Methods
Demonstration
Implementation

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Guidelines to compare Best Management Practices at watershed scale

Grassland under hazelnut trees on the Lake Vico watershed (*photo UTUV*)

The AgriBMPWater project developed an integrated framework that relies on hydrological modelling, on agronomic and environmental expertise and takes into consideration economic and social factors. This project fulfils the key-action 1 Sustainable Management and quality of Water and FP5 objectives of multidisciplinary research and demonstration efforts.

1 Introduction

1.1 Historical background

Because they had to deal with the increase in surface and groundwater pollution, EU Member States undertake policies aiming at reducing the negative impacts of the agricultural activities on water quality. These policies took various forms, from the promotion of "agri-environmental schemes" with the CAP, or the mandating of "good practices" according to the Nitrate Directive. These agri-environmental schemes and good practices have been designed by the Member States, validated by the EU and refined by local managers. The Water Framework Directive mandates the adoption of restoration plans by water sectors resulting in the fact that local managers have to design them and to choose to promote or mandate the most cost-effective modification of conventional practices. For the farmers, most of these changes consist in the adoption of Best Management Practices (BMPs), designed by technicians. There are hundreds of environmentally friendly practices for each Member State and there is a need to select among them the most cost-effective ones and those which are liable to be the most easy to adapt for the farmers.

Preliminary assessments of these programmes show that they have only little impact throughout Europe. The usual explanations of the farmers low commitment was that either the farmers resist or the BMPs are badly designed or insufficiently explained to the farmers.

The aim of the AgriBMPWater project was to improve the efficiency of BMPs designed to prevent or reduce Non Point Source (NPS) pollution from farms.

Experience showed that BMPs with low implementation rate encounters difficulties in the different phases of the policy implementation, from design to information dissemination. Because difficulties occurred more often during the integration, there is a need to create an integrated assessment framework for BMPs. The framework should take into consideration :

- firstly a cost/effectiveness approach to assess BMPs appropriateness to environmental and economic objectives ;
- secondly, an acceptability approach to estimate the potentiality of farmers joining BMPs;
- and finally an evaluation of the implementation practices, that should be initiated to ensure a better information of farmers.

Moreover, it was not rare that several BMPs would be implemented on the same area, with complementary or opposite objectives, leading to redundancy or cancellation of allowed supports. Lastly, alternative agri-environmental practices were proposed to farmers without considering the diversity of the watershed situations.

Thus, the integrated framework that the AgriBMPWater project proposes could improve the implementation of BMPs on critical areas so that they may be more efficient, at lower cost, and with a higher rate of acceptability.

Photo Cemagref

To reach these objectives, the AgriBMPWater project leans on technological and scientific developments:

- the increasing computer capacity developed over the past 20 years led to the improvement of spatially distributed hydrologic models. These models provide reliable results to estimate diffuse pollutant losses at the watershed scale when the input dataset is precise enough.;
- the literature on NPS pollution control has extensively addressed different

economically appealing instruments. These instruments consider the particularly challenging informational issues inherent in NPS pollution problems;

- the sociologic approaches focus on the analysis of social and institutional conditions for agri-environmental management and policies.

These guidelines provide **insights into different approaches to compare** BMPs in a 3 dimensional space defined by environmental effectiveness, economic consequences and social acceptability by farmers and land-users. These approaches have been developed and tested during the EU FP5 research project AgriBMPWater.

1.2 Objectives of the guidelines

The aim of the AgriBMPWater project is to describe a method allowing stakeholders to select, at a local scale and for a specific environmental concern, the most cost-effective Best Management Practices (BMPs) through their comparison in terms of hydrological effectiveness, costs for the farmers and society, and acceptability.

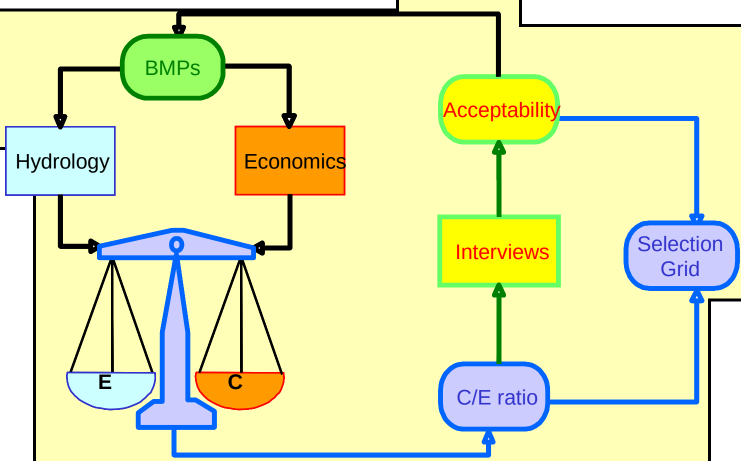
These guidelines are a summary of the analytical methods, empirical techniques, data sources and results that can assist in performing integrated analyses of environmental, agricultural, economic and social aspects of agri-environmental policy implementation and management.

1.3 Summary of the method

The comparison of different BMPs for a given watershed is built as a 6 steps framework:

step 1 : *description of watershed*: general problematic (including objectives of the different actors) and of the major water quality problems.

step 5 : *assessing the social acceptability* of the BMPs and agri-environmental policy.



step 2 : *description and computing of hydrology*: description of the model, calibration and validation of model, definition of critical areas and risk practices, assessment of their impact on total fluxes or concentrations, deduction of proposed BMPs, assessment of the *ex-ante* effectiveness of each BMP.

step 3 : *description of economics*: description of the diversity of farms, choice of the model to represent this diversity, results of model implementation (does this model provide an acute description of the baseline scenario ?), assessment of the consequences of introducing BMPs and *ex-ante* cost of this introduction.

step 4 : *assessing the results of steps 2 and 3* through a cost/efficiency ratio for each BMP.

step 6 : *collating cost/efficiency ratio and acceptability* to build a selection grid.

2 Definitions, concepts and methods

2 .1 Best management Practices

2.1.1 Definition

Agricultural BMPs can include fairly simple changes such as fencing cows off of streams, planting grass in gullies to reduce the amount of sediment transported by run-off water or ploughing reduction in fields with row crops to control soil erosion and related pollutant transfer.

Most BMPs concern farming practices at field scale, such as rate of manure spreading, or split application of fertilisers, mulching or specific irrigation techniques. Some of these BMPs are liable to greatly modify the production system because they may affect the crop yields or the forage production.

BMPs can also involve the building of structures such as large manure storage tanks that allow farmers to spread animal waste at appropriate periods.

> BMPs consist of all kinds of cropping method, fertiliser and pesticide application techniques or landscape structural fixture, which potentially reduces water pollution from agriculture; they is proposed on a contractual basis to farmers

2.1.2 Design of BMPs

Usually, the design of a restoration plan starts with the diagnosis of the watershed, including the different uses for water, its quality and available quantity depending on the different periods of the year. This diagnosis is often performed by consultants with few relationships with the other potential users on the watershed.

To improve the appropriation of diagnosis by all the actors on a watershed it is highly recommended to involve them at the earliest stages of the restoration plan. The design of BMPs can be a good step in the procedure to begin an active cooperation.

Many BMPs have already been tested and experienced in various watersheds throughout the European Union. Appropriate BMPs can be locally designed through interviews with administrations, professional advisors and elected representatives in order to describe the history of environmental measures tested on the watershed, share experience from other regions and define practices that could match the local situation.

Practical definition of BMPs on the Mincio watershed

The Mincio river basin was roughly divided into 4 hydro-geologic units or landscape units. The potential BMPs were suggested by experts from the faculty of Agronomy of Padua University based on their experience, each BMP being recommended for some or all the hydro-geological units:

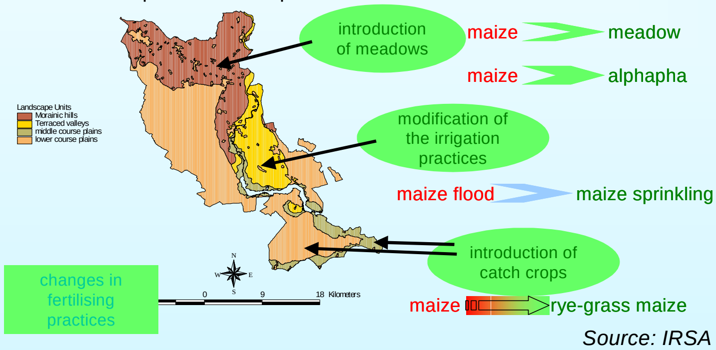
- changes in fertilising practices applicable to all the four hydro-geologic units;
- introduction of meadow has been estimated to be potentially applicable to hydro geologic unit 1 (the morainic hills);
- changes in the irrigation practices has been considered advantageous in the hydro-geological unit 2 (terraced valleys);
- cultivation of winter crops has been considered beneficial for both hydro-geological units 3 and 4 (plain areas of the middle and lower course of the Mincio river).

Mincio watershed: 750 km^2; nitrates ; arable crops (mostly maize)

The second step of the design was to split each BMP into agricultural techniques.

The last step consisted in combining the elementary BMPs into composite BMPs that have been introduced into the models.

Unit BMPs split into techniques



Source: IRSA

2.1.3 Example of potential BMPs

For all watersheds analysed during the AgriBMPWater project, the diagnosis suggests that some specific agricultural practices could be modified to improve the water quality. Thus, most of the tested BMPs have been designed on a technical basis. Of course, this can help designing policies too.

Improving the fertilisation practices:
· Application of all the manure produced within the watershed, then adjustment of inorganic fertilization to meet crop needs,
· Decrease of mineral nitrogen amounts,
· Use of fertilisation guidelines to adapt the amount of spread nutrient closely to the plants requirements;

Modification of rotation:
· Local crop rotation with additional catch crops during winter period,
· Green fallow,
· Change from maize to meadow, alfalfa or ryegrass-maize rotation,

Modification of soil structure and porosity to reduce erosion and P transfer:
· Catch crop implementation,
· Mulching on maize fields,
· Grass under permanent cultures and vegetative filter strips (VFS);

Improving drainage water quality on acid sulphate soils::
· control drainage,
· lime filter drainage;

Improving the pesticides management:
· Weed control by a combination of mechanical and chemical measures,
· Implementation of warning system and purposeful selection of fungicides and dosages,
· Application of herbicides in the rows and mechanical weeding between the rows,
· Insect pest control related to population level,
· Use of models to select the less harmful pesticide for the environment depending of the on-field condition;

Composite BMPs:
· improvement of cattle feeding to reduce the amount of nutrients in their effluents plus amount of fertilisers brought to the plants close to plants requirements,
· Specific technical BMPs targeted to each kind of soil;

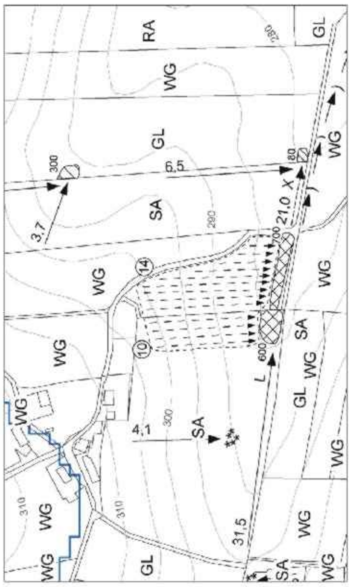
Economic policies:
· Increase of rye grass and clover instead of corn silage to optimise gross margin,
· Tax on mineral nitrogen,
· Modification of milk quota,
· Mandatory quota of bought mineral nutrients,
· Optimally differentiated policies on production level.

2.2 Critical areas

2.2.1 Definition of critical area

The Water Framework Directive requests the identification of Heavily Modified Water Bodies, where more emphasis should be put on restoration measures. The concept of critical areas developed here is different. Even for slightly modified water bodies, it is obvious that all the components of the watershed do not contribute at the same level to the NPS pollution process. Besides, the least costly way for the economy (or for specific economic sectors, here the agriculture) to achieve well-defined environmental objectives for water resource often requires to target the measures to specific areas where they may be more effective, or cheaper to implement.

At this stage of a cost-effectiveness analysis, it is really important that physicists, economists, sociologists and stakeholders agree on a common definition for these priority zones, named “critical areas”. This definition will strongly depend on the aim of the study. If only physicists are involved in the river basin management plan, the study will have a natural science theoretical aim and a critical area can be defined as “the minimum area, where feasible measures can be applied, needed to reach the desired quality standard of the considered pollutant at the receptor (outlet or pumping station). When many stakeholders participate in the diagnosis, an operational definition can be adopted and the critical areas are “the sets of areas where feasible measures can be applied needed to reach the



Example of mapped soil erosion pattern at Grub watershed.
Numbers indicate the eroded/deposited soil volume

desired quality standard of the considered pollutant at the receptor." More often, physicists, stakeholders and economists are involved in the restoration plan. In this case, critical areas can be defined as "the set of areas where feasible measures can be applied to reach the desired quality standard of the considered pollutant at the receptor at the least social cost."

2.2.2 Characterizing methods

Although linearly presented, the analysis is iterative: initial analysis is based on existing information, and will be upgraded as new information and knowledge are gathered.

The use of a spatialised hydrologic model is of importance to select, among all the watershed areas, some of them where the implementation of BMPs is expected to be more efficient. These models need to be calibrated first on a baseline scenario (see sections 2.3 and 3 for a description of the use of hydrological models). Of course, no hydrological model will provide immediate delineation of critical areas. There is a need to rank the specific pollutant loads from each unit area with respect to the others. A sensitivity analysis will provide great help at this stage for the interpretation of ranking the different areas according to their potential effect on the BMP effectiveness. Once the different unit areas from watershed are ranked, their specific simulated effectiveness has to be combined, so that each BMP delineates the areas defined as critical according to the natural science definition.

To go further in the delineation of critical areas, the stakeholders and firms interests can be taken into consideration. The areas where potential BMPs are modelled to be most effective may differ from the areas where the same BMPs are more liable to be implemented (see sections 2.5 for concepts related to the BMPs acceptability). Then, the different areas have to be ranked according to both effectiveness and acceptability criteria, before delineating the "critical areas" according to the operational definition.

The same procedure can be applied to design critical areas according to the welfare economic definition, the candidate areas being ranked according to a cost-effectiveness ratio, their potential acceptability being also considered.

Note that the delineation of critical areas according to the two last definitions is an iterative process which is often time consuming. Most studies use the physical definition of critical areas only.

Case study: Lake Vico (Italy)

The presented approach aims at assessing the phosphorous supply to lake Vico (Italy) due to agriculture activities around the lake. It is based on field scale runs of model GLEAMS and developed in 3 steps.

Firstly, phosphorus yield is evaluated by GLEAMS. As “slope” is the main parameter influencing the processes, a simple slope-based regression model was built. The regression equation is:

$$P_{conv} = 13{,}42\, x^{0,23}$$

where ***P*** is phosphorus export (kg/ha/year), *x* is the slope.

This simple formula allows to extent GLEAMS results to the basin, using a GIS and a digital terrain model (Fig. 1).

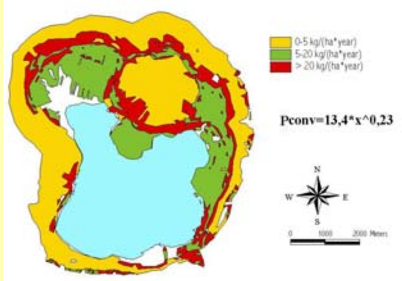


Fig. 1: GLEAMS simulated phosphorus yield

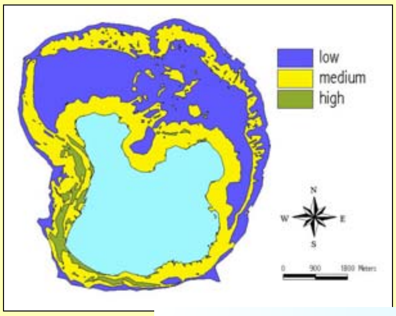


Fig. 2: Translocation capability of phosphorus

However, these first results regard P yield for each cell and not the export into the lake. So the concept of translocation capability (Fig. 2) of sediment and phosphorus has been introduced considering distance to waterways, distance to lake perimeter and slope length.

Finally, the combination of translocation capability and critical areas produce the real impact of land use on the lake.

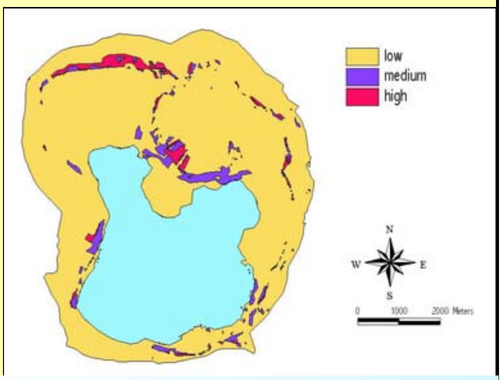


Fig.3: Critical areas obtained by matching phosphorus yield and translocation capability

2.3 Environmental effectiveness of BMPs

2.3.1 Definition of the environmental effectiveness

The environmental effectiveness of a given BMP is defined within the AgriBMPWater project as the evolution of water quality led from the BMP implementation on a watershed or on some specific areas within this watershed.

Basically, implementing a BMP on a given area will have short term and long term consequences on water quality, while modifying specific discharge, pollutant pathways, nutrient cycles and so on. The effectiveness should be considered as the difference between the baseline scenario and the modified scenario, each system being in equilibrium.

Once again, uncertainty analysis should provide the possible uncertainty existing in the estimation of effectiveness.

2.3.2 Assessment method

Effectiveness can be estimated through the introduction in previously validated models of pre-designed BMPs as alternative practices. Each BMP effectiveness can be determined as the ratio between the initial state and the estimated state after BMP implementation, both systems being in equilibrium. Effectiveness is calculated as:

$$\text{effectiveness}\ (\%) = \left| \frac{\text{VAR}_{\text{BMP}} - \text{VAR}_{\text{ref}}}{\text{VAR}_{\text{ref}}} \times 100 \right|$$

where VAR_{BMP} is a variable measured in a test field or simulated with a specific BMP implemented and VAR_{REF} is measured in the reference plot or simulated with ordinary practice.

2.3.3 Choosing a model to assess the effectiveness

Even though distributed, physically-based models do not in principle require lengthy hydro-meteorological records for their calibration, but they do require considerably more input parameters than the simpler lumped models. Again in theory, the parameters and their spatial distributions could be measured in the field, but the expense of such a survey is obviously not realistic and would prohibit practical implementation of the models. It is therefore necessary to reduce the number of direct measurements and to employ more indirect evaluations readily available from field studies. As the parameter values should be characteristic for the spatial resolution used in the model, the sampling and evaluating of the parameters represent a supplementary difficulty. Many hydrological measurements, for example, are made at the point scale (i.e., of the order of a meter) and may or may not be representative of conditions at the grid scale used in the distributed models. In this regard, parameter evaluation from data provided by remote sensing techniques or satellite information is potentially of great help. However, while these techniques can currently give surface distributions of watershed properties such as topography, land use or vegetation, they do not provide information on soil type and subsurface soil conditions.

Against the above assessment on some of the major difficulties associated with data provision, it is clear that the choice of a model is directly conditioned by the way in which the problem of data provision is handled. Precise guidelines should therefore be specified right at the beginning of the coding effort, rather than in the process of development. As the reality shows that most natural watersheds are often poorly defined in data, three avenues are chosen for the data provision and the type of model chosen:

- The first concerns the need to reduce the number of system parameters to a strict minimum. Even though this point seems obvious, still too many simulation codes suffer from the problem of over-parametrization. The construction of multi-purpose models such as integrated hydrological modelling systems is often based on the coupling of two or more pre-existing models. The single models are in principle validated on an individual basis. However, when the single models are used in a combined mode, problems may occur due to the fact that the underlying concepts and parametrization techniques used for each of the individual models are mutually incompatible. A classical example is the sometimes viciously hidden interdependence of system parameters. Overlooking this problem, unavoidably leads to an over-parametrized modelling system.

- The second data provision criterion concerns the structural flexibility of the modelling code. The model should be able to match the sophistication of the solution with the specific project requirements or the availability of data. In this regard, two categories of input data should be considered, i. e., those data which are absolutely necessary to drive the modelling system, and those data which are useful in the sense that their knowledge improves the precision of simulation. Moreover, the flexibility of the model architecture should be able to accommodate different parameter evaluation techniques. As the parameter values are estimated from either direct or indirect measurements, the code should be capable of running the specific configuration out of a wide class without any need for work at the level of the software.

- The last point of importance for a sound data provision strategy concerns the pre-processing of the rough field data. The pre-processor of the modelling code should include tools which are capable of aggregation, disaggregation and/or interpolation (in space and time) of various hydrological and hydro-meteorological input data. When kriging techniques are used, the specifications of the variogram parameters and the choice of the specific variogram model should be defined as a function of the project requirements (e.g., the variograms used for the interpolation of rainfall data change as a function of the geographical project location). As it is often observed that lack of data does not prevent planning or development decisions from being made, supplementary statistical routines should be included that are able to accommodate the partial lack of input data (e.g., incomplete time series of rain data).

Illustration of the environmental effectiveness: some results

BMP	Watershed	VAR $_{REF}$	VAR $_{BMP}$	Effectiveness
Composite BMP 3	Mincio (Italy)	8748 t N	1726 t N	80.3 %
Weeds under trees and reduction of tillage simulated on 100 % of the critical area	Lake Vico (Italy)	4876 kg P	1719 kg P	64.7 %
Pesticide treatment strategy for cabbage	Heiabekken	EIQ value 172	EIQ value 120	30.0 %
BMP soil erosion	Grub	250 kg soil/ha	5 kg soil/ha	97.9 %
Control drainage + lime filter drainage	Rintala polder	9684 t SO_4-S	7583 t S-SO_4	21.6 %

2.4 Costs associated with the BMPs implementation

The Water Framework Directive integrates economics into water management and water policy decision making. We shall restrict the economic approach to the assessment of the costs associated with the implementation of BMPs, even though the WFD requests wider economic analysis. For more information on the economic analysis in the WFD, please refer to the guidance document “economics and the environment, the implementation challenge of the WFD” provided by the European Union.

For a competitive market, consumer plus producer surplus is maximised at a market equilibrium and at a Pareto optimum. But it is well known that environmental protection often requires government intervention to correct market failures and one of the primary tools for deciding of the appropriateness of this intervention in the economy is the benefit cost analysis. The basic idea of this analysis is very simple: find the project that leads to the largest surplus. In general a surplus maximum is equivalent to a Pareto optimum.

Implementing this very simple idea is far from being simple. The usual problem is the difficulty to quantify some of the benefits or some of the costs. Efficiency calls for emissions that balance the costs of emissions control with the damage from ambient pollution and fully takes into consideration the complex relations between emissions and damage. When this is not practical, goals or targets are established regarding desired levels of ambient concentrations. These goals may be only imperfectly related to the efficient levels of pollution because these efficient levels may vary through time and space.

Establishing ambient targets is usually a compromise that sacrifices efficiency in pollution control. But even with such a target there are both good ways and less desirable ways of regulating emissions to achieve the target. If a set of environmental measures achieves the target at the lowest cost, the regulation is **cost-effective**: even though efficiency is not attainable for many regulations, cost-effectiveness is attainable.

Basically, the WFD requires the basin management plans to support the selection of a programme of measures for each river basin district on the basis of cost-effectiveness criteria.

2.4.1 Definition of the costs

The cost of a set of measures is the difference in the total surplus between the baseline scenario and the modified situation. The total surplus is the producers’, plus the consumers’, plus the tax payers’ surplus. The producers can belong to the regulated sector (agriculture) or to other sectors of the economy.

Within the AgriBMPWater project, we distinguished two parts in this difference of surplus:

- the surplus variation that is directly related to the introduction of the measure, named “direct costs”. These costs include the variation of the regulated producers’ surplus, the amount of subsidy borne by the tax-payers and the variation of consumers’ surplus related to the production variation. For example, subsidising the dairy farms to help them reduce their emissions may induce a welfare variation for milk drinkers (if the milk production is sufficiently modified to affect the milk price), has a cost for the tax payers and may modify the dairy farmers’ surplus.
- the surplus variation borne by other components of the economy but the agricultural sector are named "indirect costs". There are several reasons why such indirect costs are likely to appear. On the one hand, would farmers try to compensate for direct costs induced by BMPs implementation, then either they would raise their output prices so that agricultural goods would be more expensive for intermediate and final consumers or, if they cannot do so, they would switch to more profitable products. On the other hand, some public institution may want to be the one who compensates for farmers direct losses in order to promote BMPs adoption; then, either it will have to levy a specific tax somewhere to finance the new incentive scheme, or it should redirect subsidies previously granted to somebody else towards the benefit of farmers who implement BMPs. In any case, if a sufficiently large number of farmers do implement BMPs, agricultural and other markets may be therefore affected together.

2.4.2 Which measure for which cost?

In any case, the cost is measured as a surplus variation between the baseline scenario and the modified situation. Depending on the size of the watershed and on the candidate BMP, consumers, tax-payers, regulated producers and producers belonging to other sectors of the economy may be affected or not and therefore the expression of the surplus variation may be simplified.

Obviously, implementing BMPs on very large watersheds or nationwide leads to a surplus variation for all the components of the economy. For a watershed size close to a river basin district, the production variation induced by the environmental policy is small enough to have no effect on the price, and the consumers’ surplus variation can be neglected when assessing the direct costs associated with this policy.

When implementing BMPs on a small watershed (less than 100 km^2), the indirect effects on the other sectors of the economy can be neglected. If the BMP is associated with a subsidy that compensates the producers’ profit losses, then the cost of the BMP is related to the tax-payers’ profit variation only.

2.4.3 How to choose an economic model for this measure?

The choice of an economic model is strongly related to the surplus variations that have to be estimated. When all the components of the economy can be affected by the BMP, only a computable general equilibrium model can estimate the associated costs.

On river basin districts, computable general equilibrium models are relevant when the BMP may affect largely the non-agricultural sector of the economy. When the variability of the farms is large, this parameter has to be included in the modelling. This can be done by splitting the watershed into distinct sub-regions where the farming activity can differ. Another way to include the farms variability into the modelling is to use a Principal-Agent model. The farmers are represented as a continuum characterized by a one-dimensional parameter representing their private information. This kind of model allows the design of optimally differentiated policies while providing a menu of contracts adapted to each kind of farm and the associated variation of producers’ plus tax-payers’ surplus variation.

When only the tax-payers’ surplus variation has to be estimated, linear programming model can be used. These models are built at the farm level. The farmer is a profit-maximizer that “adopts” a given BMP when the associated subsidy is high enough to ensure him at least the same profit as the baseline scenario. When associated with a typology of farms within the watershed, these linear programming models can easily compute the tax-payers' surplus variation led by the implementation of any BMP. Note that these models are easier than the others to connect with hydrological models when they explicitly represent on-field agricultural practices.

Photo Cemagref/Gilard O.

2.5 Acceptability

2.5.1 Definition

The agri-environmental schemes are based on individual farm-level contracts, which are often voluntary in nature. However, in order to diminish diffuse pollution, a BMP applied in one individual farm is not necessarily enough, In fact, they should be targeted at critical areas and to a group of farms. This requires actions from a number of actors and institutions and at the same time raises collective action problems.

The problem of low implementation rates of BMPs is still too often explained by the resistance of farmers only. However, experience has shown that problems also occur in the various phases of the policy implementation and in the dissemination of information.

In order to increase our understanding of the social factors that contribute to the acceptability of the BMPs and agri-environmental policy, more attention has to be paid to the implementation practices at the local and farm level. This means giving due consideration to the role of farmers in the agri-environmental management and policy implementation practices. The evaluation of the institutional setting is of uttermost importance, when the social acceptability of the BMPs and agri-environmental policy is assessed.

2.5.2 Method

The study of the social acceptability can vary from a survey of willingness to contract to an extensive study of the implementation practices. In the AgriBMPWater project our studies on social acceptability were based on the following methods:

Simplified case studies, which determined the social factors affecting the "willingness to contract", main barriers in contracting, legitimacy of the agri-environmental policy and farmers attitudes towards environmental issues in general. The empirical material was gathered with surveys and focus group studies. The surveys focused on the following issues:

- changes in the environmental management practices,
- acceptability of the agri-environmental policy model and its future development
- information channels,
- specific questions on BMP contracts (impact on farm management and environment, the level of compensation),
- local environmental problems and actions.

Extensive case study, which examined the implementation practices of the agri-environmental policy at the local and farm level. The study was focused on the analysis of the practices of different actors and interplay between the agri-environmental implementation and farming practices. Special attention was put on the dynamics of translating policy goals into farming practices and arising intermediary mechanisms. The empirical material was gathered with thematic interviews, observation and surveys.

3.1 Nitrate problem

What type of hydrological model should be used to achieve assessment of effectiveness of BMPs related to nitrate leaching concern? Even though there appears to be a certain degree of consensus at the theoretical level regarding the potential of the distributed physically based models for nitrate leaching valuation, the right hydrological modelling system should garanty sufficient flexibility in matching the sophistication of the solution with the project requirements or the availability of data.

3.1.1 Possible models

A large number of modelling tools is available today, depending on the objectives and scales of space and time that are addressed (see also others FP5 FP6 related projects to control diffuse loads from Agricultural Land: Euroharp …). The following models permit to obtain interesting results, the data they require and their implementation do not bring major difficulties.

SWAT
The SWAT (*Soil and Water Assessment Tool*) is a continuous time and space distributed model, which includes hydrological, sedimentary and chemical processes in river basins. The model is based on a routing command language which allows definition of how the water budget moves inside the catchment, relating spatially the different considered units (i.e. sub-basins, reservoirs, ponds, river reaches). SWAT is a basin-scale, spatially distributed watershed delivery model developed by the Agricultural Research Service (ARS) at the US department of Agriculture (USDA). Its purpose is to simulate water, sediment and chemical yields on large river basins and possible impacts of land use, climate changes and watershed management. Outputs from SWAT can be daily, monthly or yearly, but in all cases are based on a daily model time step. SWAT can be applied in watersheds up to 1000s of km^2, using a two-level disaggregation scheme.

Gleams
GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) is a field scale model developed by the Agricultural Research Service of the U.S. Department of Agriculture. The model takes into account the complex interactions among soils, plants, agrochemicals, management practices and the climate, with the aim to assess the impacts of the management of the agricultural land on edge of the field and bottom of the root zone in terms of water, sediment, nutrients and pesticides mobilization. The model has to be used to make comparative analyses that is, to compare different crops, different soils and different management schemes in terms of nitrogen and phosphorus compounds and of pesticide loading in the runoff and in the leachate and it is not intended for absolute predictions of nutrients and pesticide concentrations in water bodies. GLEAMS consists of four components or sub-models operating simultaneously: hydrology, erosion/sediment yield, plant nutrients and pesticides.

BMP1Top
BMP1top is an agro-hydrological multi-scale model spatially distributed coupled with GIS databases. The model is developed by the Rennes Cemagref to study the relations between agricultural land uses, farming practices and flows and concentrations of nitrogen in water at the watershed outlet. The model works on homogeneous agro-hydrological units defined with GIS tools by intersecting maps of land use, Digital Elevation Model and soil and databases of agricultural practices. In addition to the possible reduction of nitrogen fluxes by denitrification in the top of soils, it makes it possible in particular to model the effects of the interaction between groundwater and soil in the wetlands and buffer zones. Lastly, the model takes into account the effects of the spatial distribution of various elements in the landscape (cultivated fields, hedges, wetland …) in the catchment area. The step of computing time is classically the day.

STOTRASIM / SIMWASER

STOTRASIM/SIMWASER is a field scale model for one-dimensional vertical flow of water and nitrate-nitrogen within a soil profile, neglecting interflow and preferential flow. Soil water fluxes and plant growth are calculated with the deterministic model SIMWASER. Nitrogen dynamics in the soil are calculated using STOTRASIM. Main attention is addressed to the amount of water and nitrogen leaching to the groundwater. SIMWASER calculates the water balance and the crop yield of any number of crop rotations and years on daily basis. The water balance and the growth of plants are interrelated by the physiological interaction of assimilation and transpiration. At the soil surface, precipitation and irrigation act as input while evaporation and transpiration act as output. Interception is also taken into account. Water fluxes in the soil are calculated according to Darcy's law. The lower boundary of the soil profile must be outside the influence of plant roots or is given by the groundwater level. Either capillary rise or seepage are the results there. STOTRASIM calculates a daily nitrate-nitrogen balance for a soil profile.

POWER

POWER is an acronym that stands for *Planner Oriented Watershed modelling system for Environmental Responses*. It is a software package developed within the Department of Hydrology of LTHE, aimed at the simulation of integrated flow systems of stream and overland flow, soil water and solution movement (e.g., fertilizer and pesticides) in the unsaturated and saturated aquifer zones combined with plant root uptake. The modelling system is meant as a tool for integrated hydrological studies, suitable for coupling with planner oriented models allowing for impact studies in agriculture and land management. The model structure is designed in an evolutive way such that it supports collaborative modelling with plant growth and/or economic modules which may be coupled to atmospheric models, at a later stage.

POWER uses specific space and time scales for all different flow processes and is operational with a minimum of calibration parameters, hence, reducing the risk of over-parametrization and relaxing the constraints when limited input-data are available. The model structure is object oriented which makes it sufficiently flexible as to match the sophistication of the solution with the project requirements.

3.1.2 Requested data to run a hydrological model

Topography	- Digital Elevation Model	
Climate	- Climatic data - soil evaporation compensation factor - precipitation amount - air temperature (7^{oo}, 14^{oo}, 19^{oo}, max, min) - relative humidity (7^{oo}, 14^{oo}, 19^{oo}) - averaged wind velocity - sum of global radiation	
Soil	- Soil textural properties - Available water capacity - rate factor for humus - biological mixing efficiency parameter - N-NO3 (mg/kg) - Organic matter (mg/kg) - soil depth (RD) - field capacity (FC) - potential yield. (PY) - water retention characteristic	- sequence of soil layers - thickness of soil layers - bulk density - humus content - C/N-ratio of the humus - initial values of: NO_3-N-content NH_4-N-content content of fresh organic matter (FOM) C/N-ratio of FOM - amount of NO_3-N, NH_4-N, N_{org}
Agricultural practices	- crop rotations - daily loads, annual biomass produced by each crop - dates of fertiliser application - kind and amounts of fertilisers - dates and kinds of crop management operations - dates and daily amounts of irrigation - dry matter (g/kg) for the whole plant	- carbon content - type of crop - date of sowing - date of harvest - NO_3-N-, NH_4-N-content of irrigation water - date of ploughing, grubbing and similar - depth of ploughing, grubbing and similar
Hydrology	- Alpha base flow and groundwater delay parameters - threshold depth of water in the shallow aquifer - daily flows - cumulative flows	- water retention curves - hydraulic conductivity function - diffusion/dispersion-coefficient - curve number

3.1.3 How can I run such models?

The first step before effectiveness modelling consists of precisely understanding the hydrological pathways. The model type is highly depending on the processes simulated and therefore strongly related to the quality of input data required for calibration, validation and simulation.

For the tested models, no change in model structure was required to introduce the BMP's. They can simply be implemented by changing different input parameters. However, some points must be treated with particular attention:

- when BMPs deal with groundwater pollution, calibration must focus on the parameters which influence percolation and the consequent nitrate leaching;
- when data were not specifically designed to spatialised modelling, they need to be interpreted before use. For example, the textural properties classically monitored at point scale are assigned to non point grid size required for modelling use;
- crop rotations must be considered due to the fact that simulations have to be run over a long period of time. In such case, it is possible to automatically allocate rotations to each land-use unit with an expert decision system. Fertilisation practices and yields for each type of rotation can be defined as the average of all similar rotations on the watershed;
- while some data should be measured on the field, others should be considered as calibration parameters, especially when dealing with lumped modelling systems.

Simulations can be performed by implementing each BMP in an iterative way on increasing surfaces corresponding to different sensibility areas of the watershed (critical areas).

3.1.4 How can I interpret the effectiveness?

The interpretation of effectiveness results depends obviously on the way the effects of BMPs have been characterized (fluxes, concentration, decrease in pollution pressure). The effect of a BMP implementation can be assessed through one of the following 3 criteria: concentration of the water, flux at the outlet or modification of the global fertilisation spread on the whole watershed.

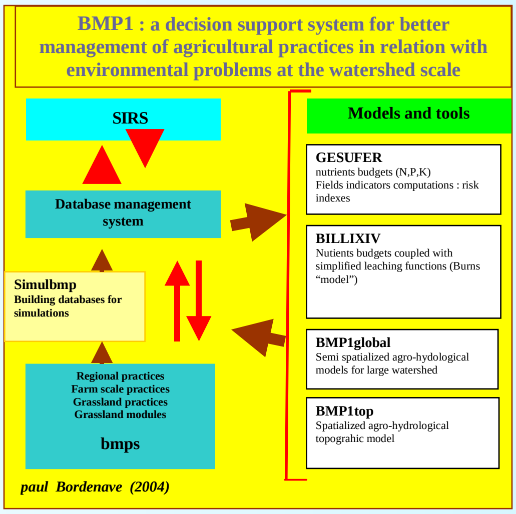
One possible representation of effectiveness is the percentage of remaining pollution with respect to the initial pollution level before the BMP was implemented. This type of representation was favoured within the AgriBMPWater project. The grade « 100 » is set for step 0 (no implementation); it decreases along as soon as the BMP is iteratively implemented on increasing sensitive surfaces (critical areas).

The process is repeated for each environmental issue according to the BMP that needs to be simulated. All results are sketched on a graph that allows a first comparative glance of the effectiveness and its evolution according to the treated surface with respect to the policy target-value. The graph allows to check whether the BMP allows to reach the target-value and what surface needs to be treated.

Bassin versant de la Fontaine du Theil

Case study : The Saint Léger watershed

At the beginning of the project, first simulations carried out over a period of 5 years showed that this interval was too short to obtain the full effectiveness, because of the inertia of the watershed response.



For this reason, we decided to run the model over 28 years including 7 years for model initialisation and 21 years for simulation. 13 simulations were performed. Seven BMPs are defined: four built with the DSS BMP1, three designed by Technical Institutes. The BMP0 (conventional practice) was built from survey data collected during seven years provided by the ARVALIS Institute. These BMPs are combined in order to take into account critical areas and economic calculations. The results showed below concern the three most significant BMPs. BMP5 is based on single optimisation of inorganic nitrogen fertilisation; BMP6 is based on optimisation of livestock feed combined with optimisation of inorganic and organic (manure) nitrogen fertilisation; BMP7 is based on increasing grassland area and decreasing corn area. The effectiveness is calculated using BMP1top.

Optimisation of inorganic nitrogen fertilisation (BMP5) and organic and inorganic nitrogen fertilisation (BMP6) have an effectiveness of about 30 % when applied on the total area. The most acceptable BMPs for farmers have an effectiveness of about 20 %, which is sufficient to obtain a concentration lower than 50 mg/l. The period necessary to reach this target-value is longer than five years for the Saint-Léger watershed. However, these BMPs don't make it possible to reach 25 mg/l. To approach this concentration, it is necessary to modify the crop system, like with BMP7.

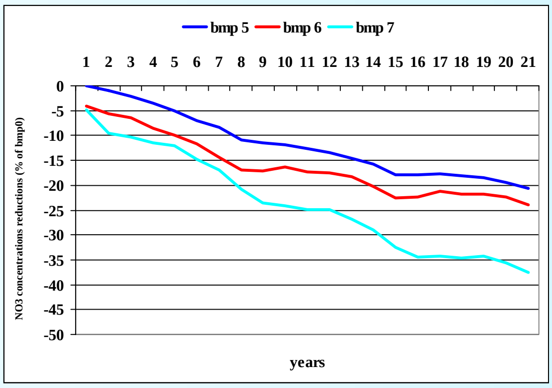


Figure1: relations between the effectiveness and the percent of area where the BMP is applied

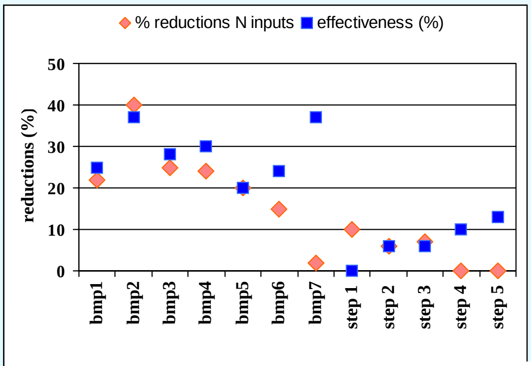
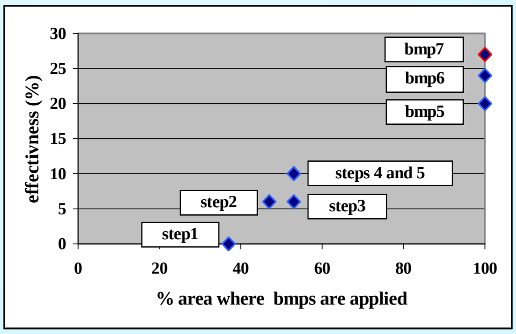


Figure2: relations between the effectiveness and the amount of N inputs for all BMPs tested

The N2 losses calculated by BMP1top in the atmosphere coming from denitrification decrease when a BMP is implemented. Consequently the reduction of flows and concentrations in water is not proportional to the reduction of the surplus of the nitrogen budget.

The BMPs effectiveness is not systematically explained by the area where they are applied. On this watershed, it is necessary to apply the BMPs simultaneously on a large part of the watershed in order to obtain a rapid decrease in the water nitrogen concentration.



The problem encountered to apply these BMPs on a large area is related to the difficulty for farmers to calculate with enough precision the proper amount of fertilisation. For cereals and corn, several methods are available but they require a local adaptation which is particularly difficult to compute in the case of grassland.

3.2 Soil erosion and related phosphorus problem

As soil erosion is highly variable in the spatial as well as temporal domain, processes governing soil and related phosphorus losses are different, too. Estimating amounts and processes requires the use of different methods and models depending on the scale and temporal resolution of interest. At the spatial extension of a research plot, detailed knowledge about factors which control soil loss is commonly available. At the small watershed scale, availability of data decreases rapidly and input information is often obtained from maps. At this scale, a convenient way of obtaining information about spatial distribution and extent of soil loss is by mapping visible linear erosion features after rainfall events. For large watersheds, no direct measurement of the spatial distribution of soil erosion can be obtained and sediment or related phosphorus production are usually measured at defined outlets. Quality of available data decreases and the application of erosion models is highly dependent on expertise.

3.2.1 Models used

EUROSEM
The EUROpean Soil Erosion Model is a distributed, event based model. EUROSEM simulates soil erosion by raindrop impact and infiltration-excess overland flow at small catchment scale with high temporal resolution (e.g. minutes within events).
The model deals with:
- interception of rainfall by the plant cover
- leaf drainage and direct throughfall (volume and kinetic energy)
- stemflow (volume)
- surface depression storage
- detachment of soil particles by raindrop impact and by runoff
- transport capacity of runoff

GLEAMS (see page 14).

REMM (Riparian Ecosystem Management Model) is a comprehensive model developed to simulate the physical, chemical, and biological processes in riparian ecosystems. It is intended for use as a research tool to better understand their water quality functions. It has also been developed as a tool for evaluating management options to provide effective control of non point source pollution.
Model calibration is not necessary, due to the use of the model: comparison of scenarios, with and without BMP. Validation was based on experimental evidence about surface runoff at the edge of each buffer zone and nutrient analyses from shallow groundwater and subsurface runoff. No model modification due to BMPs introduction is required.

3.2.2 - How can I run such a model ?

Basically, needed data concern: climate, topography, hydrology, soil, land use and agricultural practices. Models must be calibrated with data from experiments and measures at the outlets (runoff).
Validation can be based on experimental evidence about: surface runoff at field scale, nutrient content in shallow groundwater and subsurface runoff.
In general, no change in models structure is necessary to introduce BMPs which can be implemented by changing values of different input parameters.
Results can be expanded to basin scale by derived meta model and GIS.

3.2.3 Tested BMPs

- Mulching on maize fields
- Changing maize fields to grassland (Green fallow; permanent grassland without fertilization and harvest, mulching one to three times a year)
- herbs under hazelnut trees for soil conservation
-landscape structures to control runoff, sediment and related phosphorus; main landscape structures against diffuse pollution sources are vegetative filter strips (VFS).

3.2.4 How can I interpret the effectiveness?

Soil erosion is a local process. Identifying risk areas and implementation of BMPs on these areas leads to reductions in soil loss. The modelling strategy should be applied to each BMP. The effectiveness should be calculated using the formula introduced in section 2.3.2. Simulations should be implemented by iterative process, i.e. step by step for decreasing risk area of erosion. Results can be presented by items such as: flux change amounts, concentration changes.

Topography	- Slope steepness and length - Land cover and land management - Orthophoto DEM 15 m - Cadastral maps (field survey)	- Slope, length, surface roughness, route of overland flow - Canopy cover
Climate	- Daily rainfalls (50 years) - Temperature (minimum and maximum), solar radiation (monthly) - Rain simulator experiments	- Automatic rain gauge (balance type) - Rainfall intensity at high temporal resolution
Soil	- Soil thickness, texture, pH, organic and nutrient content - Soil survey - Saturated hydraulic conductivity - Effective net capillary drive	- Porosity, initial moisture content, maximum moisture content, percentage of rock fragments - Interception storage - soil detachability, cohesion
Practices	- Nutrient and pesticides inputs, tillage system, dates	
Hydrology	- Runoff pattern (field survey) - Runoff (ultrasonic measurements, rain simulator experiments)	- Automatic sediment concentration sampling

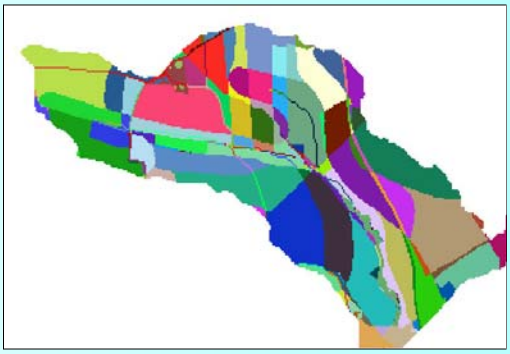
Case study : Petzenkirchen watershed

The EUROSEM model was calibrated on rain simulator experiments. In these experiments 2x5 meter plots were used and runoff and soil erosion were measured. The rainfall simulator experiments were carried out with three different rain patterns, each run was done with one replicate. A simple profiling method was used to fit EUROSEM hydrograph to the rain simulator experiment hydrographs. In a second step, EUROSEM was finally calibrated on watershed runoff measured in spring 2002.

In order to use EUROSEM in a grid-based catchment area it was necessary to use the SPIES-Application as linkage between ArcView GIS (ESRI, 2000) and EUROSEM. The SPIES-Application derives EUROSEM parameter from the digital elevation model (i.e. slope, hydrologic connectivity), stores EUROSEM input data in a database to provide EUROSEM parameter files and makes simulation results available to the GIS-application.

No change in model structure itself was necessary to introduce BMP's, which were implemented by changing values for different input parameters.

For this watershed, an example of the REC calculation (POWER application) is shown in the Fig. 1. The combination of REW configuration, soil and land-use maps, superimposed together with road and farm network, permits the identification of 225 irregular prismatic REC entities where every REC is characterized by its own specific textural and structural soil properties, land-use pattern and management practices. This gives an average REC size of roughly 0.75 ha. As the maximum number of RECs with which the POWER code is able to deal with, lies in the order 10^6 RECs per REW, a REW size of 1000 km^2 is still acceptable. Obviously, such REW size will never be encountered for "real world" watersheds.



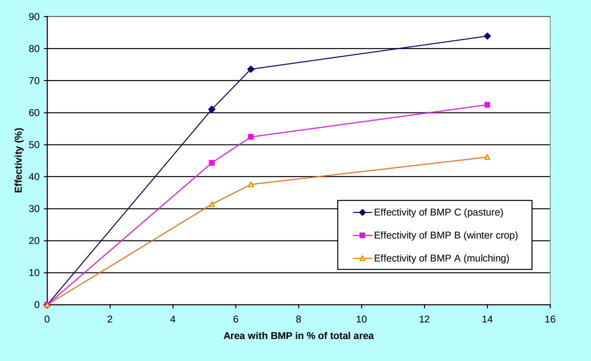


Fig 1: Ensemble of 225 RECs calculated for the Petzenkirchen watershed using a series of three superimposed GIS maps of soil texture land-use and road and infrastructure network.

Fig 2: Effectiveness of the different BMPs to reduce soil erosion in the experimental Petzenkirchen watershed

Model application

Tested BMPs were A=mulching, B=use of winter crops and C=pasture.

The effects were compared to conventional management practices.

Sediment pollution has been assessed in the experimental watershed taken in consideration the identified delineation of critical areas. The Fig. 2 depicts the change in effectiveness with increasing area of implementation for the three tested BMPs. Areas have been ranked according to their risk status beforehand (see Table).

Risk order		Area with BMP	mean erosion rate BMP C	BMP B	BMP A	Effectivity BMP C	BMP B	BMP A
	0	0.0	0.13	0.13	0.13	0	0	0
2	34.6	5.2	0.05	0.07	0.09	61	44	31
3	42.8	6.5	0.03	0.06	0.08	74	52	38
4	92.0	14.0	0.02	0.05	0.07	84	62	46

3.3 Pesticides problem

Pesticides can reach soil in different ways either by direct chemical application, incorporation in soil or wash off from plants after rain or irrigation. When the pesticide hits the soil, it is distributed in three different phases: gas in the soil atmosphere, dissolved in the soil water or adsorbed to soil. Distribution between the soil and water phase is controlled by sorption/desorption, while distribution between water and gas phase is described by Henry's law. Loss of pesticides in soil is due to degradation from all three phases mentioned above. Loss of pesticides can also be due to leaching dissolved in water, evaporation on the surface or transportation on soil surface (dissolved in run-off or sorbed to particles and removed together with sediments).

Prevention and reduction of pesticide transfer to groundwater and surface water are based on the understanding of the relationships among chemical properties, soil system properties and climatic and agronomical variables that combine to induce runoff and leaching. Pesticide transfer in soil has two major components (dissolved and sorbed transportation). Different soil management practices have different effects on the development of weeds and the needs for pesticides use.

3.3.1 Possible model

Within the AgriBMPWater project, only one approach deals with pesticides concern. The model of plant protection practice is an extension of PVNOR, which was developed within the modelling network of MIL-DRI (Environmental Management in Agriculture). While PVNOR was limited to weeds and diseases in cereals, the present model covers weeds and diseases in potatoes, and weeds and insects in cabbage as well. In addition the AgriBMPWater model allows to select any plant protection method (mechanical or chemical) in the current crop, provided it is approved for the crop at the specific developmental stage. The programme used to create the model is Powersim Constructor 2.51.
In the BMP strategies pesticides with lowest risk for the health of farmers, consumers and environment are selected based on the Environmental Indicator Quotient (EIQ) developed at Cornell University in USA. For each crop total score of pesticide load and environmental risks has been calculated. In the module the calculation of the environmental and n hydrological models to predict risks of pesticide leaching and runoff.
The AgriBMPWater model can deliver results of different kinds. The most important are: 1) number of treatments against the different pests by different crop rotations and tillage types, 2) development of the pests during the simulation period and 3) yield reduction by different combinations of crop rotation and tillage.

3.3.2 Requested data to run a model

For data used for EIQ calculation, see specific case study. Data concerning climate, hydrological pathways, runoff, soil characteristics and agricultural practices are also combined.

3.3.3 Running the model

A total of three years of practical experience has been gained from using EIQ index to choose the least harmful pesticides on cabbage and potatoes. To reduce the frequency and doses of pesticides even more, principles for Integrated Pest Management (IPM) have been used. The effectiveness of BMPs or reduction of possible impacts on health and environment has been evaluated as the reduction of the EIQ value.

Photo NCRI - Planteforsk

3.3.4 Model application

Tested BMPs:

1. Autumn ploughing every year with cereals, potatoes and cabbage all in a 22 years cycle.
2. Autumn ploughing before potatoes and cabbage, direct seeding before cereals.
3. Autumn ploughing before potatoes and cabbage, direct seeding before cereals.

The difference between strategy 2 and 3 is the selection of pesticide against late blight in potatoes.

Case study : the Heiabekken watershed

In the experimental strategy, the herbicide, fungicide and insecticide are chosen after EIQ calculation. To reduce the total dose, early warning forecasts and best knowledge about economic thresholds and pest and pathogen control are applied. The farmers are supposed to be specially followed up the local extension service and the specialists from NCRI.

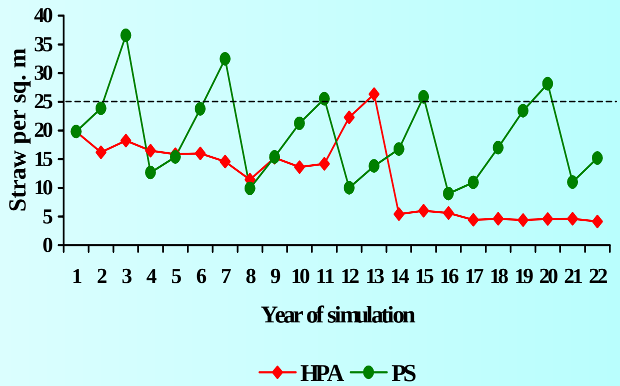


Figure: Effects on coachgrass comparing harrowing and ploughing in autumn (HPA) with ploughing in spring (PS). The line marks the threshold for pesticide application.

Ø.Grimstad	Potatoes					
Conventional practice						
Pesticides	**EIQ**	**ai**	**dose**	**EIQ-area**	**Number appl**	**Total**
metribuzin-Sencor	35	0.7	15	3.73	1	3.73
linuron-Afalon	40	0.5	50	10.08	1	10.08
mankozeb-Tattoo	62	0.3	350	65.75	1	65.75
propamokarb-Tattoo	16	0.2	350	14.24	1	14.24
esfenvalerat-Sumi Alpha	50	0.1	25	0.62	1	0.62
fluazinam-Shirlan	13	0.5	30	1.89	6	11.34
dikvat-Reglone	43	0.2	150	12.99	1	12.99
Total environmental load						118.74
Best management practice						
Pesticides	**EIQ**	**ai**	**dose**	**EIQ-area**	**Number appl**	**Total**
rimsulfuron	26	0.3	3	0.20	1	0.20
metribuzin-Sencor	35	0.7	10	2.49	1	2.49
fluazinam-shirlan	13	0.5	30	1.89	4	7.56
dikvat-reglone	43	0.2	100	8.66	1	8.66
Total environmental load						18.91

Results show an important decrease of total environmental loads of pesticides when implementing two different strategies (see Table 1).

Table 1: Summary of pesticide strategy

Table 2: Environmental load calculated with EIQ-risk indicator model after 22 years of different management practice growing cereals in combination with potatoes and cabbage.

Strategy	EIQ	Yield Tons/ ha	Weed No/ sq.m	Weed, % Ground-cover	No. of tubers with potato-blight
The farmers best conventional strategy	117	31.3	16	4	0
Experimental strategy	50	33.3	19	5	0
Statistical analyses		NS	NS	NS	NS

Crop	EIQ		
Cereals	342	470	470
Potatoes	236	302	1054
Cabbage	550	532	532
Total	1128	1304	2056

Table 3: Effectiveness of an experimental strategy on potatoes

Without consequences on yield production, it is possible to obtain an effectiveness of experimental strategy of 57 %.

3.4 Acidity problem

The following routine applies in case of water quality issues. Since this is a local issue, it has only been treated in one of our case studies.

In the Finnish case study area, Rintala polder in the Kyrönjoki watershed, one of the main environmental problems caused by the agriculture is acidification of surface waters caused by intensive drainage of acid sulphate soils. Acid sulphate soils are old sea sediments accumulated during the Littorina period of the Baltic Sea. As a consequence of intensive sub-surface drainage, the sulphides in the soil are oxidized into sulphuric acid at a rate exceeding the soil buffering and neutralizing capacity. High acidity levels, low water pH and high concentrations of toxic metal cations, especially during the spring and autumn floods, might cause fish deaths and serious damage to the fish reproduction.

3.4.1 The HAPSU model

The HAPSU model is an ionic flow model and especially developed for acid sulphate soils. It simulates SO_4-S, H^+, total Fe and total Al leaching in runoff. The model calculates the passage of heat, water, oxygen and liquids in a soil column. Acid sulphate soils and other non-acid soils are considered separately in the model.

3.4.2 Requested data to run the HAPSU model

Driving data to run the model is climate data, i.e. daily precipitation and air temperature measurements. Data needed to parametrize the model are mainly related to soil properties. It can be derived from measurements, earlier simulation work or literature. Data needed to calibrate and test the model is monitoring data, either on the depth of the groundwater table or drainage and runoff water pH and SO_4-S, Fe and Al concentrations.

3.4.3 Running the model

Calibration and validation
In this special case, the HAPSU model was calibrated for an experimental field for the

part which describes acid sulphate soils. This field consisted of four 2 ha plots, with the three BMPs and a reference field with ordinary sub-surface drainage. For the non-acidic soils previous parameterization from nearby catchments was used. The model was validated with drainage water quality data and the effectiveness of the BMPs on field scale.

Introduction of BMPs
BMPs are included in the process description of the HAPSU model. The tested BMPs either prevent low groundwater level (control drainage, CD) or neutralize acidity of water passing through the drainage system (lime filter drainage, LFD). These methods can also be combined together. Some additional parameters have to be defined, e.g., to describe the ground water level targeted by application of control drainage or the amount of lime needed for the lime filter drains.

3.4.4 Interpreting the effectiveness

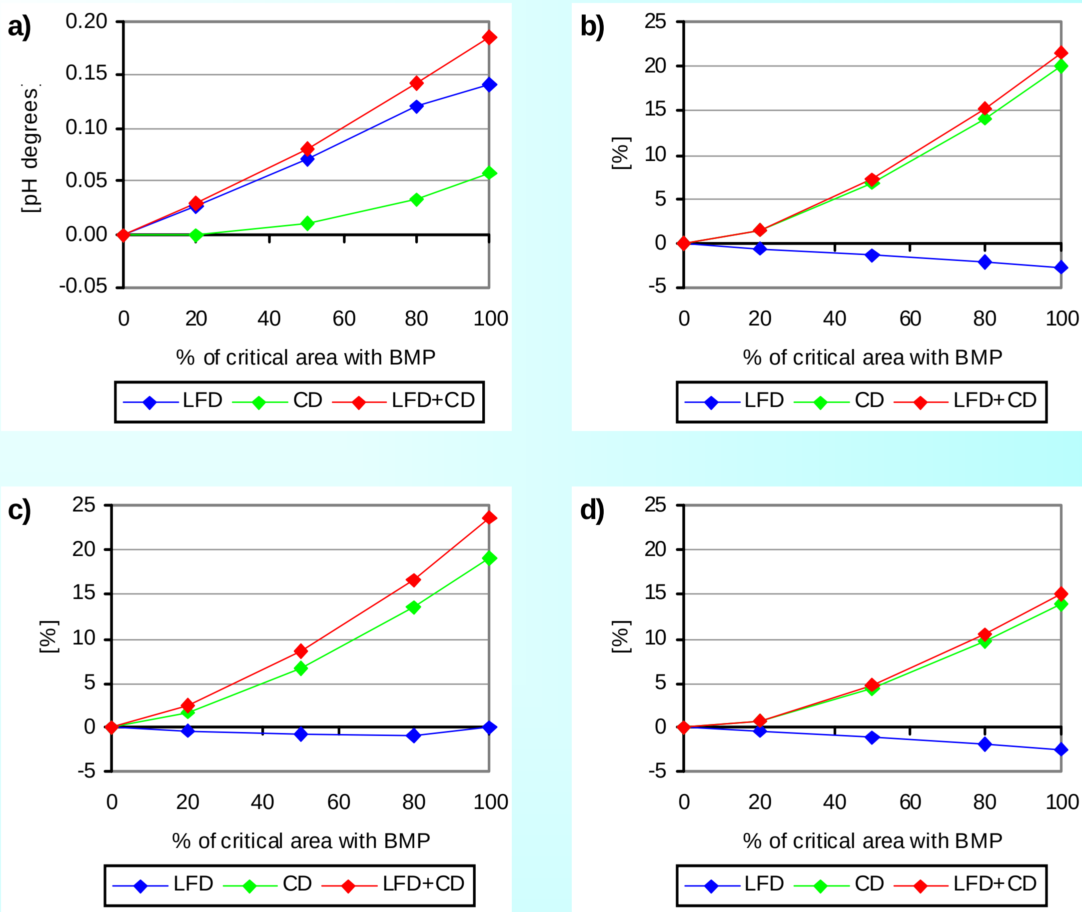
The effectiveness was calculated using the formula introduced in chapter 2.3.2, except for pH where effectiveness is given as pH units, not as a percentage. The reference situation was gained using HAPSU without BMPs. The simulation targets were an increase in water pH and a concentration reduction at the outlet of the polder. The Rintala polder was divided into acidic sulphate soil area (= critical area) and non-acidic area. The modelling strategy was to apply each BMP on 0%, 20%, 50%, 80% and 100% of the critical area.

3.4.5 BMP effectiveness

The water quality variables considered in the HAPSU simulations in the Rintala polder for the BMPs lime filter drainage (LFD), control drainage (CD) and combined method (LFD+CD) were:

a) water pH
b) sulphate sulphur concentration (SO_4-S)
c) total aluminium concentration (Al)
d) total iron concentration (Fe)

Case study : Kyrönjoki and Lappajärvi watersheds



BMP effectiveness due to lime filter drainage, control drainage and combined methods modeling on 0%, 20%, 50%, 80% and 100% of the critical area for drainage water pH (**a**), SO_4-S concentration (**b**), total Al concentration (**c**) and total Fe concentration (**d**).

Discussion: The simulated pH increase is largest for the combined drainage technique, 0.2 pH units. The difference between LFD and the combined method is small but the simulated effectiveness of CD method is clearly weaker (0.05 pH units). The combined method is most successful in reducing SO_4-S, Al and Fe concentrations: the effectiveness varies between 15 % and 25 %. The CD method alone reaches nearly the same level of effectiveness. In contradiction to this, the LFD method does not influence the chemical concentrations, or as for SO_4-S and Fe, it even seems to increase the concentrations.

In conclusion, lime filter drainage (LFD) is especially effective in increasing pH, whereas control drainage (CD) seems to be more appropriate for reducing concentrations of SO_4-S, total Al and total Fe. The combined method seems to perform slightly better than just one method alone.

4 Assessing the costs

The cost of a set of measures is the difference of the total surplus between the baseline scenario and the modified situation. The total surplus is the producers', plus the consumers', plus the tax payers' surplus. The producers can belong to the regulated sector (here the agricultural sector) or to other sectors of the economy.

4.1 The BMP affects the farmers only

When implementing BMPs in a small watershed (less than 100 km^2), the indirect effects on the other sectors of the economy can be neglected. If the BMP is associated with a subsidy that compensates the producers' profit losses, the cost of the BMP is related to the tax-payers' profit variation only.

4.1.1 Costs at the farm level

For small watersheds, accurate calculation of BMP implementation costs can be carried out just by upscaling from the farm level to watershed level. To assess costs at the farm level, the methodology of economic optimisation is relevant because of its availability to allow decision makers to substitute alternative strategies into the decision making framework.

The linear programming (LP) paradigm used in farm modelling is a method to determine a profit combination of farm enterprises that is feasible with respect to a set of fixed farm constraints.

Alternative farming practices on the whole-farm basis include BMPs considered as alternative practices with different coefficients than the current practices. The maximisation of the Gross Margin as the objective function implies that each individual farmer is considered as a profit maximiser, that is he maximises the total revenue plus any net appreciation in livestock capital less labour and capital costs. On critical areas, management practices that should be banned could appear as new constraints.

BMPs generally imply reduced profits in comparison with more polluting standard practices. Incentives need then to be proposed to farmers for their adoption. In order to make them appear in optimal solutions, increasing incentives linked with BMPs are proposed until non optimal environment friendly activities enter optimal solutions. These levels of incentives are considered to represent direct costs for BMPs implementation, that is the loss in the objective function that the farmer would have suffered when adopting them

4.1.2 Costs at the watershed level

One solution to assess costs at the watershed level is to model farms in some aggregative manner (representative farms and typical farms) and then to multiply results according to the frequency of each farm type within the watershed.

An alternative form for assessing costs at the watershed level can be to model farms together as if they were a single large farm. Doing so may overstate flexibility and coordination of agricultural production.

It is however a widely accepted mean of modelling a large area and may be appropriate for small catchments, in particular when farms are straddling different watersheds, and often relevant to be tested in comparison with the first aggregation approach especially for very small watersheds including only a few farms.

4.1.3 Running the models

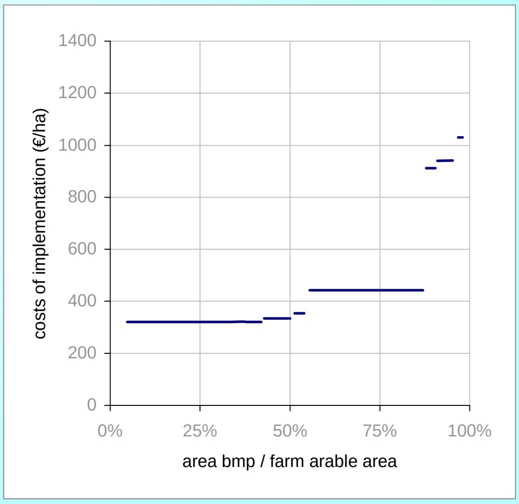
During the project, depending on the application cases, the models have been developed for either a representative dairy farm or for all the farms on the watershed. Other types of models have been devised for arable, dairy and hog farms for the specific

Specific case of investments

When the BMPs refer to investments, multi-period linear programming needs to be used so that to cover the costs of investment. It should incorporate investment schemes and therefore specify the set of investment projects that optimises the objective function which is, if no constraints exists on borrowing opportunities, the optimisation of the compounded sum of achieved objectives in each period.
The multi-period nature of such models allows to capture the dynamics of farmers' adjustment investment processes. Investment in the optimal setting can be planned on different years depending on the level of incentive. As for the case of single period model, the level of incentive that makes the investment be implemented (that is kept in optimal solution) is considered to represent the direct costs of the BMP.

Case Study : cost at the farm level
(Austrian watershed, changes from arable land to permanent grassland)

When BMPs refer to activities changes (e. g. from arable land to permanent grassland like depicted in the Figure), then direct costs per hectare of implementation are not linear and can be presented in a step wise function showing that non-marginal changes cost much more than marginal ones
When BMPs refer to changes of practices *stricto sensu* (e.g. catch crops, mulching, reduction of fertilization), outcomes of the models show that there is a threshold value for incentive and thus for cost so as to make BMP profitable for farmers.



case of BMPs relating to drainage schemes investment. These models can be used for similar farms only. But the literature provides a wide range of LP models that could be used elsewhere.

4.1.4 Requested data

Data can be obtained either from regional data for modelling representative farms (average of a group of farms) or by developing sets of typical farms that may be thought of as case farms (can be real or synthetic). Production technology information is necessary too: technical data consist of inputs and outputs coefficients needed for the construction of the technical coefficients matrix. For BMPs related to investment, in addition to previous information, data related to installation and maintenance are needed.

4.1.5 BMPs modelling

Usually, the model are developed for specific BMPs. Within the project, the modelled BMPs concern practices or activity changes (mainly crops and forage strategies) or drainage investment. For new BMPs technical data on new practices are necessary and need first to be converted into model specifications.

4.1.6 Comparing BMPs

On farm models compute direct costs for BMPs implementation, that is the loss the farmer would have suffered from adopting such practices. BMPs can be compared on their respective costs per area unit of implementation.

Specific case of pest management practices

The choice of pest management practices entails particular problems as pest outbreaks have to impacts: (i) losses in yields, and (ii) reduced quality on the produce. For contract crops both items are challenging as the failure of growers to meet crop contract terms (a given quantity that exceeds a quality standard) may trigger substantial declines in the prices paid to growers, and in some cases a loss of the crop contract for the future. Pest management BMPs must therefore be designed to avoid these kinds of variability if they are to be accepted by growers without excessive compensations. One possibility to high compensatory payments is insurance. Such schemes are hard to design if one is to avoid severe moral hazard problems.

Specific case of partial budget approaches

When at watershed scale, the different types of farms are known, Partial Budget Method can be an appropriate approach to investigate the implementation effects of well known BMPs on net income. Partial budget is a balance tool based on the analysis and valuation of farm input and output which will change as a result of BMPs implementation. In the procedure, costs and benefits are usually organised in four categories: additional income, reduced costs, additional costs and reduced income. Loss of income due to alternative farming practices could be considered as the incentive amount necessary for farmers adhesion. The major disadvantage is that budgets may not reflect efficient decisions from an economic perspective and consideration of only a limited number of budgets may unrealistically restrict substitution possibilities.

4.2 The BMP affects both the producers and the tax-payers

One key issue for the design of mitigating policies is the heterogeneity of farms. It is obvious that farms have a wide range of production factors (such as soils, climatic situation, management skills, genetic value of the herds) and that the farmers' objectives are very diverse. This results in a wide range of technical choices, such as the degree of production intensification, the amount of inputs used, the techniques implemented. The heterogeneity of the farms have consequences on their behaviour when facing a regulation, and on the amounts of pollutants they emit, i.e. the same technical choice in two different farms may result in different emission rates. When designing a mitigation policy, a regulator will also have to make choices on how he will distribute the de-polluting effort among the heterogeneous producers. For a regulator, designing a policy to mitigate NPS pollution from farms, means choosing two different things. First the regulator has to determine which instrument is to be regulated. Many studies conclude that the choice of the instrument base can significantly influence the cost-effectiveness of agri-environmental policy. This instrument can be an estimation of the individual emissions, or some input related with these emissions, or some specific production technique which is supposed to be polluting, or the production level. Second the regulator has to define the method of applying the policy: will he content himself with a uniform regulation or does he need an optimally differentiated one ?

4.2.1 What is a Principal-Agent (PA) model ?

The economic model represents the farmers as price-takers (the prices of input and output are not affected by on-farm decisions) and profit maximizers (the farmers wish to maximize their profit, given some constraints on land, capital and labour, on their own farms). The Principal-Agent model represents the farms with continuous cost and yield functions, including heterogeneity among the producers. The model focuses on asymmetric information problems between a regulator (the Principal) and the farmers (the Agents). The Agents are supposed to have more precise information on their own farm than the Principal, who has information on the density functions for each parameter only. Basically, each farm information set is captured into a mono-dimensional parameter, named the type of the farm and denoted θ.

4.2.2 Requested data

The only data requested for a Principal-Agent model are the description of the type dependant cost, emission and damage functions. The parameters of these functions can be estimated from surveyed farms. In a near future, functions libraries should be available.

4.2.3 Running a PA model

Once the cost, emission and damage functions have been described and their parameters estimated, the regulation design is an optimisation problem: the regulator's objective is to maximize a welfare function, written as the sum of taxpayers' surplus, the farmers' total surplus, minus the environmental damage. Feasible allocations are constrained by the information set of the regulator. We also introduce acceptability constraints as part of the constraints the regulator has to take into account. Basically, the regulator has to satisfy a given proportion of farmers through his intervention and a farmer is satisfied if he does not loose from regulation compared to the baseline scenario.

This representation allows the assessment of both the introduction of "technical" Best Management practices (BMPs), defined as a modification of the cost or the yield functions (or both), and the application of various policies: the modelled farms react to a given policy by moving along their profit function.

4.2.4 - What kind of results should I get ?

Three types of mitigating policies have been tested within this framework:

1. Firstly we considered policies which are optimally differentiated and take into consideration the heterogeneity of farms concerning their cost and emission func-

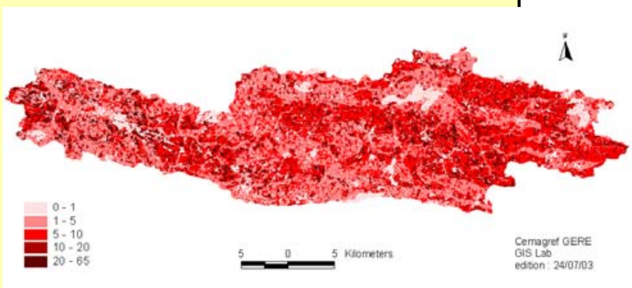
tions. The regulator proposes a contract to the farmers and designs this contract by maximizing his own welfare function.

2. Secondly, we compared these differentiated policies with the mandatory application of new, less polluting techniques (BMPs). The associated costs are mostly borne by the farmers. The costs are associated with an increased use of machinery or labour, or related to a risk of yield decrease when lower amounts of polluting inputs are used. Some benefits can be associated with the lower use of polluting inputs, if they are not replaced by more expensive ones.

3. And finally we compared the differentiated policies with standard economic instruments, such as taxes or quotas applied on inputs or outputs. These linear standard instruments can also be associated with subsidies that increase on-farm profit, such that more farmers benefit from the policy.

For each policy, the level of the instrument (the tax, the subsidy) is determined by the model while maximizing the welfare function of the regulator. Thus, the polluting level is not fixed by the regulator as an objective but is a result of the maximization process.

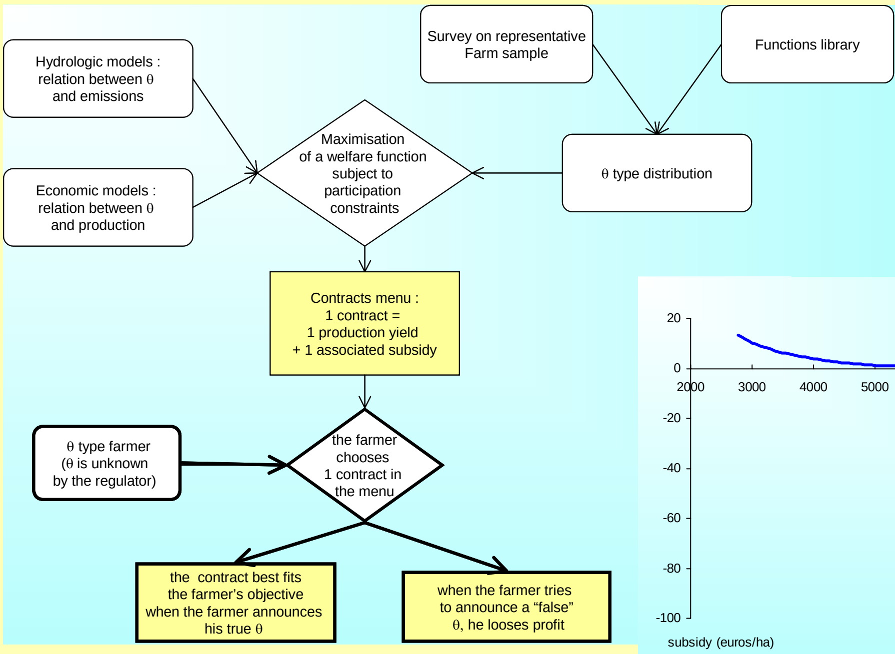
We should notice that optimally differentiated policies have a high level of acceptability, perform with an increase of social welfare, and allow the EU standard for water quality to be reached with most of half of the farmers benefiting from the regulation on the watersheds where they have been tested.

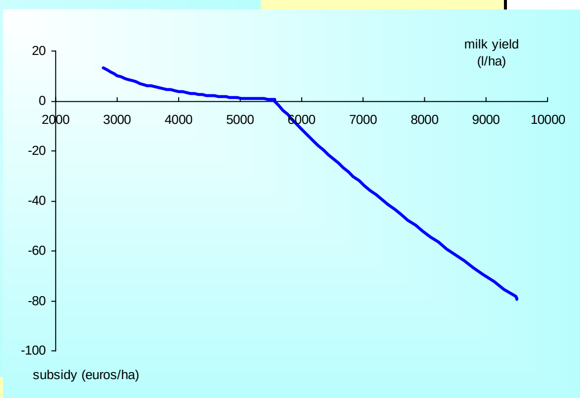


SWAT estimation of leaching under the root zone per HRU on the Don watershed (year 2000)

Case study: contract menus for differentiated strategies

On the Don watershed, because the farms variability was so large, the mitigating policy took this variability into consideration. It has been designed using the following framework:





The optimisation procedure provides the contract menu, each contract being here a milk yield the farmer engages himself to produce and an associated tax or subsidy he is going to receive in return.

4.3 – Indirect costs associated with agricultural BMPs

4.3.1 What are indirect costs ?

As has been presented in the previous sections, farmers who implement BMPs shall suffer a *direct* impact on the economic output of their farm: for example, the substitution from one cropping method to another may result in a reduced yield, thus reduced income, or an increased input use, thus increased costs, or both. But, as described in section 2.4.1, these direct costs may in turn induce *indirect costs*, that is costs supported by other agents in the economy, if a sufficiently large number of farmers do implement BMPs. Therefore, we shall try to estimate the potential indirect costs associated with BMPs when implemented at the scale of a sufficiently large watershed, that is when indirect impacts might reveal noticeable.

4.3.2 Which model should I use ?

Because they aim at representing the functioning of an economy in a comprehensive way, that is in all its components and processes (among which production, intermediate and final consumption, imports and exports, investment and savings, tax/subsidy system, etc.), Computable General Equilibrium (CGE) models provide a suitable framework for assessing such indirect costs.

Basically, general equilibrium models consist of a generalization to every market of an economy of the simple economic law of supply and demand; in their applied or computable versions, these models provide the user with operational figures which may help decision making on the basis of quantified estimates.

Still these models are most often designed at a national or international scale. We therefore developed a procedure to adapt the CGE modelling framework to the sub-national scale that fits the study of locally defined BMPs. For this purpose, we also introduced the spatial, geographical, dimension into the model thanks to a multi-regional approach, so that insights concerning critical areas could be pursued.

4.3.3 How can I run this kind of model ?

Technically, the multi-regional CGE model we developed here is a comparative static one with the assumption of perfect competition in all sectors. It was designed under the GAMS environment (General Algebraic Modelling System) in a Mixed Complementarity Programming (MCP) format using the PATH solver.

Building a CGEM typically comprises 6 main steps which are slightly adapted in our particular case due to the sub-national and multi-regional specification of the model:

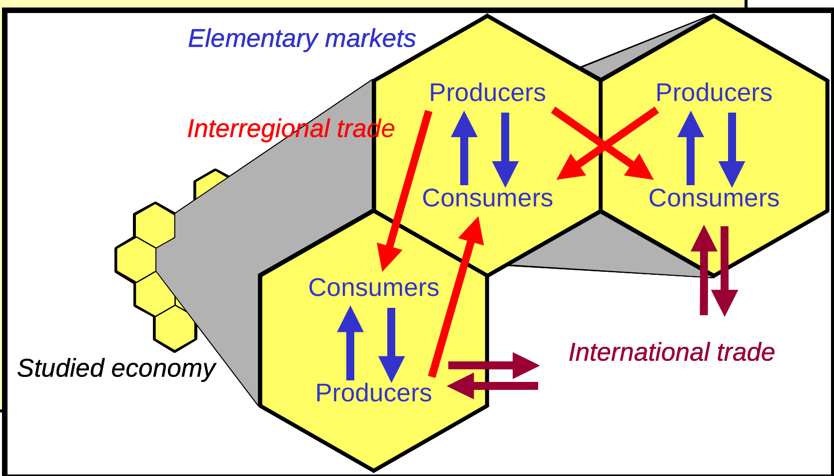
1. Specify dimensions of the model: number and list of internal and external regions, production factors, activities, commodities and consumers types,
2. Specify assumptions, functional forms of economic processes and macroeconomic closure rules,
3. Construct the database for a benchmark year at the *national* scale,
4. Calibrate the model in its *national non-spatial* version,

5'. Verify that the national non-spatial model replicates the national benchmark,

5''. Calibrate parameters for every sub-national explicitly modelled sub-region by modifying national averages calculated during step 4' to account for spatial heterogeneousness at the local scale,

5'''. Run the full (*i.e.* spatial) model to compute the multi-regional benchmark equilibrium,

6. Carry out counterfactual studies.



4.3.4 Which data do I need ?

Steps 3 and 3' of the overall method state that implementing a CGE model requires that its parameters be calibrated with respect to a benchmark equilibrium. For this purpose, data corresponding to this reference year are usually organised into a Social Accounting Matrix (SAM).

A SAM is a square matrix which rows correspond to resource accounts and columns to expenditure accounts of all the economic agents in the economy it represents. Such matrices are particularly suited for calibrating CGE models: when row totals equal corresponding column totals (*i.e.* resources equal uses for any account), the resulting balanced SAM represents a general equilibrium point for the studied economy which can be used for calibration.

In this project, a 3-stage methodology for constructing such national SAMs was set up from Eurostat European System of Accounts data (SEC 95) and other data such as National Accounts, Input-Output tables and Farm Accounting Data Network (FADN) in which the agricultural sector is quite disaggregated.

Still regionalizing data are further needed to run the model at the sub-national scale and in its multi-regional approach. There are three types of such data:

1. first, one needs statistical evidence which permits to account for the geographical heterogeneousness of production functions and consumers preferences at the scale of each studied sub-region (see step 5'' above);
2. second, one needs transport costs estimates for every tradable commodities and any pair of sub-regions, that is, for any possible interregional trade route;
3. third, one finally needs data that characterize each sub-region, mainly local labour force, capital endowments, available agricultural land and production quotas (*e.g.* milk quotas); further, if a public administration is modelled, the share of production factors that it owns in each sub-region must be specified.

4.3.5 How can I model BMPs ?

In this CGE modelling framework, BMPs are dealt with as additional agricultural activities which act as substitutes for traditional activities. Moreover, it is first made certain that BMPs do not show up in the replicated benchmark equilibrium, or in other words, that they are not *a priori* optimal with respect to the traditional technologies (otherwise they should appear in the reference data as farmers would gain profit by already implementing them).

Simulations then consist in finding the market conditions at which such BMPs become optimal so that agricultural producers switch from traditional activities to alternative ones. Several mechanisms leading to such a switch can be studied: subsidising BMP activities, taxing traditional activities on the use of some key inputs (*e.g.* fertilizers), fixing a minimum level for BMP production (*i.e.* a production quota), or a combination of these.

4.3.6 What kind of results should I get ?

Basically, total indirect costs are then assessed as the welfare variation of final consumers induced by the adoption of a BMP by local farmers. In our CGE modelling framework, this variation can be measured by the "compensating variation" (or similarly by the "equivalent variation") which represents the amount of money that final consumers should receive in order to maintain the same utility (or income) as before, given the price system prevailing in the new equilibrium.

This welfare impact may be decomposed to evaluate the share which is borne by each agent. Thus, costs supported solely by agricultural producers can be inferred and may be compared to the direct costs described in the previous sections.

Interesting enough, one can finally express these indirect costs through a multiplier effect by relating the total compensating variation to the total amount of subsidy that must be granted to farmers for them to adopt a particular BMP.

5 Assessing the acceptability

The acceptability analysis can give a valuable input to the integrative analysis of the BMPs allowing to estimate what kind of policy objectives would be realistic to achieve. It also allows comparisons between the economic cost calculations and farmers' own estimations of the costs. In an iterative approach these two would proceed side by side, allowing both parties to learn from each other.

The analysis of social acceptability can also help to highlight the main barriers for contracting, which may include e.g. the bureaucracy and complicated contract conditions, the level of compensation or management requirements (see Austrian case study). The analysis may also show that the contracting for a BMP may not depend solely on money, but also on the more general aspects of the policy implementation.

The extensive case study on the acceptability carried out in Finland has revealed that farmers tend to interpret the agri-environmental management practices in rather different terms proposed by the agri-environmental schemes and resist the standardised terms of enrolment.

They criticise the agri-environmental schemes as being dismissive of the social context of farming and the local environmental conditions. Same kind of contests over the valid knowledge have been frequent within the natural resource management. Local and universal knowledge should, however, not be regarded as different *a priori*. Farming relies on both knowledge categories and in practice they get blurred. The ways in which the boundaries between these universal and local knowledge categories are defined and maintained depend upon a specific context.

In the implementation of the agri-environmental policy in Finland, the boundaries between so called universal and local

Case study: Intermediaries between different scales of action
Riparian zone planning at the Lake Lappajärvi watershed, Finland

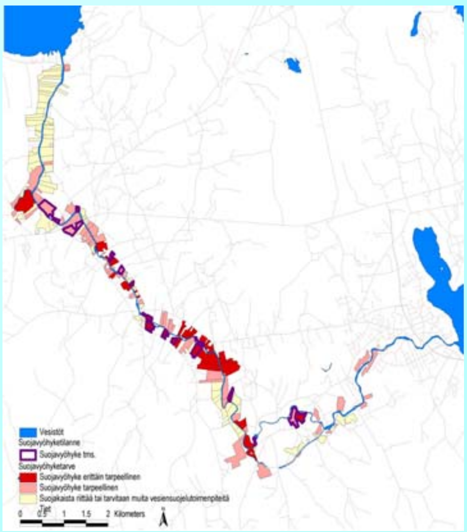
The Finnish case study of the implementation practices at the local level has revealed the importance of the role as *intermediators* and intermediaries in the implementation of agri-environmental policy. In the Finnish case especially, the role of rural advisors and municipal agricultural officials has developed into a significant one. Farmers are dependent on the policy information they possess, but at the same time, the relationship between farmers and municipal agricultural officials, seems to have developed flexible enough to accommodate farmers own account of identity and the problems of rural areas. The skills of these expert groups are needed to interpret the policy into practice and combine the two cultures of farming and environmental protection.

Riparian zone on a river bank (photo by Liisa Maris Rautio)

Another illustrating example on the need of *intermediaries* between the different actors and their interpretations of agri-environmental management, are the many different local environmental projects, which have emerged bottom-up. These local projects, provide an illustrative example of how the friction between universal and localised accounts of agri-environmental management can be mitigated during the implementation of policy.

For example in Finland, several riparian zone plans have been carried out for various river and lake watersheds. The planning is based on the identification of environmentally critical areas and materialising them on a map format, which allows extending the scale of environmental management from separate technical solutions to watershed level actions. It allows also the extension of one-year budget frames into a more durable time frame, making also the planning of future actions possible.

The gained experiences indicate that riparian zone planning has also offered conditions for social learning at the local level. Watershed level planning has, at the same time, helped to take into account the locally varying environmental conditions as well as farmers‘ experience-based knowledge on farming and local environment. Furthermore, it has brought environmental authorities to the fields offering, also, for farmers a channel to participate. The planning practices have developed flexible enough to accommodate farmers' own account of identity and helped to mitigate the friction between universality and locality in the implementation of agri-environmental policy. Watershed-level planning has strengthened the local dimension in the agri-environmental policy and in so doing supported the social conditions for agri-environmental management.



Riparian zone plan of the Kurejoki river in the watershed of lake Lappajärvi (map production by Juha-Matti Markkula).

Austrian case study: Willingness to contract

We carried out a farmer survey in the Austrian case study watersheds and asked farmers about their willingness to contract for a BMPs of N-reduction, catch crop, permanent grassland or mulching. The BMP for catch crop has been the most popular among the farmers (62% of the respondents have a contract), and c. 30% of the respondents have a contract for N-reduction.

According to the survey results we can conclude, that farmers have rather high expectations for the compensation of the costs. For example, as we asked farmers to estimate what would be the most important aspects that should be taken into account when developing the agri-environmental policy, the issues of voluntariness and compensation of costs ranked as of uttermost importance (Fig.). No one really argued for revoking all environmental norms (however 30% see it "quite important"). Farmers also call for better monitoring and control of the agri-environmental subsidies.

Voluntariness of agri-environmental schemes is not, however, always all voluntary. The Austrian ÖPUL schemes are partly income support. There is an element of control in the voluntary agri-environmental policy based on economic incentives as well. On the one hand it means, that a farmer is dependent on the subsidies distributed through the agri-environmental schemes. This means that one also has to report and make ones farming activities visible for the purposes of the subsidy control. This means also investing a significant amount of working hours to the paper work. These elements of control and bureaucracy are of course crucial social factors contributing to the acceptability of the BMPs and agri-environmental policy in general. According to the survey results farmers see that agri-environmental regulation will increase in the future, however nearly 70% of the answers stated it should not.

There are differences in the willingness to contract BMPs depending upon the management requirements and effects e.g. on the yield. The results also reveal that the ones who do not have a BMP contract know very little about the possibilities offered by the agri-environmental policies, or do not want to comment on them. In the survey results, there are also some indications that larger full-time farms were more interested and capable of making the contract compared to the smaller part-time farms.

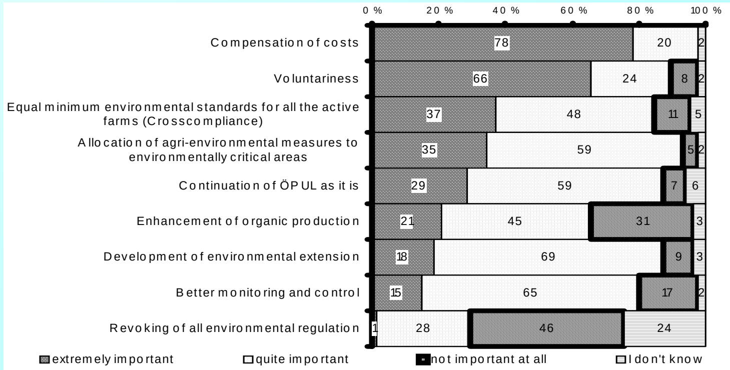


Fig.: the most important aspects that should be taken into account when developing the agri-environmental policy according to the Austrian farmer survey

knowledge have sharpened and become relevant stakes in the politics of agri-environmental management.

Appealing on the experienced based knowledge on farming and local environmental conditions is social action that defines farmers' position in the implementation of agri-environmental policy and, respectively, their agency as an environmental manager. The farmers' response can be interpreted as a cultural response to a cultural form of intervention - that is, one embodying particular normative models about human activities relationship to nature. The other is neither right nor wrong, but the scale of action is different.

The tensions between the local and universal knowledge have been examined largely in the context of developing countries; however, as this study shows the issue is central also in the debates of sustainable agriculture and environmental policies in Europe.

Agriculture's environmental impacts are caused by non-point source pollution, visible only in the long run and dependent on the local natural conditions. This means that the local variations in environment's quality are crucial to its social value and to the management practices best suited to it. Current model of agri-environmental policy in Finland has not been very successful of recognising this, as our results point out. We could talk about the "naïvi sociology" of the agri-environmental schemes, which relies on the assumption that environmental management practices can be carried out the same way at each farm and in each field. There is a risk of creating an intensifying cycle of dependency, where language, and knowledge, is reserved to a certain group of experts, excluding the other ways of knowing. At the same time the policy overlooks the local natural and farming conditions, which are relevant for diminishing the environmental impacts of agriculture.

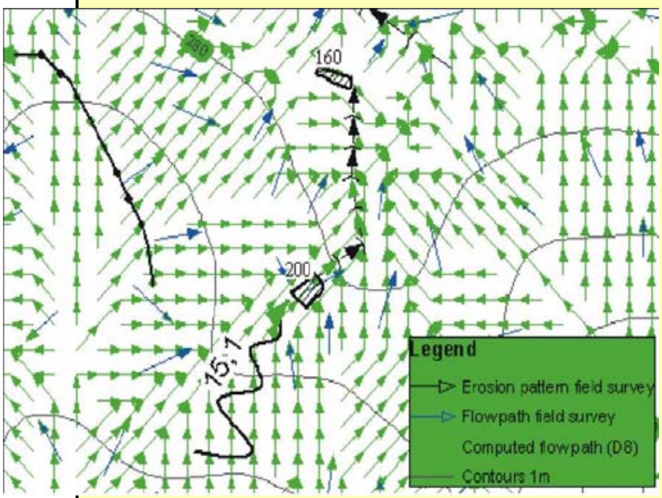
In order to ensure better and more lasting results of agri-environmental policies, implementation practices need to be further developed. The emphasis in the implementation of the agri-environmental policy should be directed to the management of uncertainties. Policy implementation should be seen as a non-linear and contextual learning process, in which the system's capacity for self-governance, enabling social learning, becomes crucial.

Once all the previous steps have been completed, the integration of the different elements is a very useful decision tool.

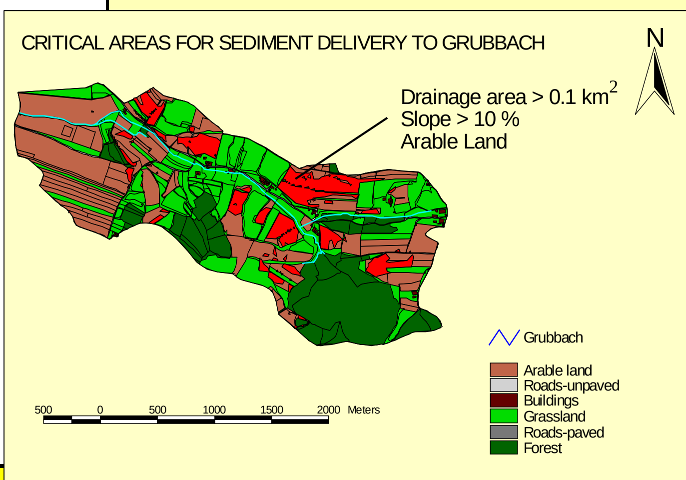
The integration is performed through a synthetic diagram that depicts on each watershed the contracted area, the effectiveness of the BMP, the associated costs and either the current participating area or the potential area where the BMP is acceptable.

Illustration of the integrated framework

Now let us summarise the whole framework and illustrate this by a case study. The Grub watershed faces an erosion problem with high discharge loads. To mitigate this erosion problem, three BMPs have been foreseen, A=mulching on maize fields, B=changing maize fields to non fertilised grassland, C=winter crops instead of spring crops.



On this watershed, the hydrological pathways and critical areas have been defined using several methods (field surveys for erosion patterns and flow paths, and Eurosem modelling).



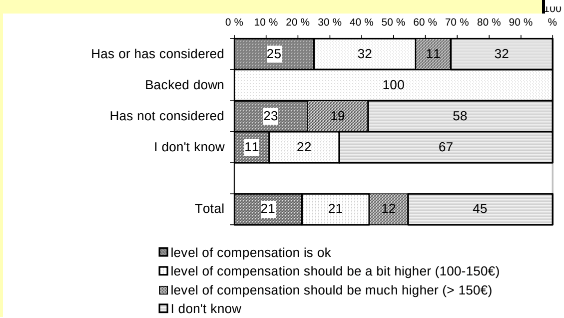
The use of the EUROSEM model, once calibrated and validated, lead to the assessment of the effectiveness for the three BMPs.

Risk order	Area with BMP		mean erosion rate			Effectiveness		
	ha	% of total area	BMP C t/ha	BMP B t/ha	BMP A t/ha	BMP C %	BMP B %	BMP A %
	0.0	0.0	0.25	0.25	0.25	0	0	0
2	78.5	2.9	0.09	0.12	0.18	66	51	29
3	195.1	7.1	0.04	0.08	0.15	82	67	40
4	319.9	11.7	0.01	0.05	0.13	96	81	50
5	361.1	13.2	0.01	0.04	0.12	98	82	52

The design of a linear programming model leads to the estimation of the costs associated with these BMPs.

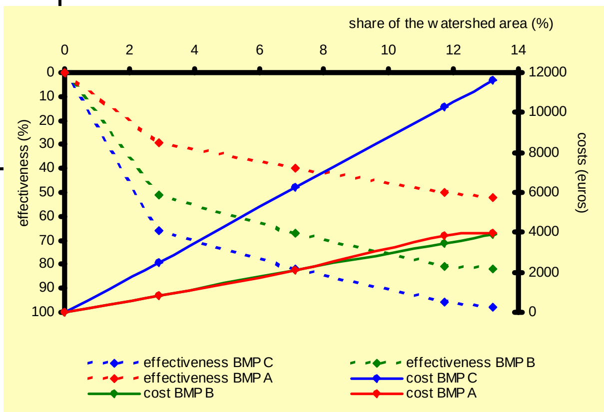
Risk order	Area with BMP		Direct Costs			Cost effectiveness ratio		
	ha	% of total area	BMP C	BMP B	BMP A	BMP C €/ton	BMP B €/ton	BMP A €/ton
	0	0	0	0	0	0	0	0
2	78.5	2.9	2521	848	856	55	24	43
3	195.1	7.1	6262	2107	2126	109	46	77
4	319.9	11.7	10270	3455	3487	154	62	100
5	361.1	13.2	11592	3900	3936	171	68	110

The integration of the two last steps provides a cost/effectiveness ratio for any BMP, depending on its area of application. Because BMPs A and B are already parts of national agri-environmental programs, the survey for acceptability included questions on the farmers' opinion about the proposed subsidies.



Farmers' perceptions of the level of the compensation – ÖPUL2000 contract for N reduction.

According to the survey results we can conclude, that farmers have rather high expectations for the compensation of the costs. There are also differences in the willingness to contract BMPs depending upon the management requirements and effects e.g. on the yield. The results also reveal that the ones who do not have a BMP contract know very little about the possibilities offered by the agri-environmental policies, or do not want to comment on them.



When choosing between BMPs there is a trade-off between costs and environmental effect, exemplified with BMP B and BMP C, where the environmental effectiveness of BMP C is the highest, but also entails larger costs. The question is which of these BMPs to choose. Although BMP B has the most preferable cost effectiveness ratio, BMP C may still be a candidate for implementation if BMP B falls short of the environmental objectives (sufficient improvement in water quality) or the receptor is particularly valuable in terms of recreational benefits etc. Summing up: one needs to remove dominated policies (like BMP A in this example), and then consider the relative importance of the environmental effects (where BMP C scores the best in this example) and cost effectiveness (where BMP B scores the best in this example).

Generally, high cost policies (like BMP C) are more difficult to implement. If warranted for environmental reasons, i.e., other BMPs fail to reach environmental targets, more care must be taken in terms of designing contract menus that ensure that in relative terms, low cost providers of high cost BMPs implement the BMP first. In practical terms this implies designing contract menus such that make it the dominant strategy of agents (farmers) to truthfully reveal their costs of implementing the BMP. If it is difficult to design policies that make low cost providers adopt the BMP, the concept of critical areas is a helpful tool to identify farmers or fields, where adoption of high cost BMPs are the least costly. The rationale for this is that such micro level cost and environmental effectiveness differences may occur even within a watershed or small regions.

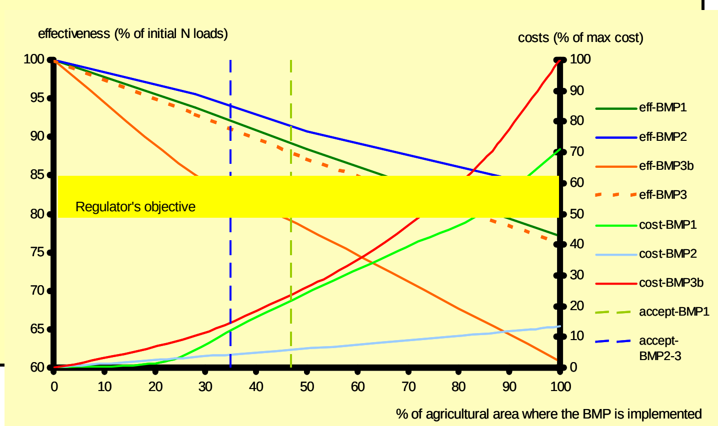
Interpretation of the grid

Let us take another example. On the Don watershed, the technical BMPs that have been compared are: BMP1= decrease of the inorganic nitrogen spread over all the crops, BMP2 = manure spreads on grasslands instead of corn, BMP3 combines both BMPs 1 and 2 and BMP3b is BMP3 with an adjusted inorganic fertilisation close to the crops requirements. When comparing the size of their implementation area and their simulated effect on water quality on the watershed, it is easy to notice that a regulator with the objective of reaching the EU threshold of 25 mg NO3-/l has to implement these BMPs on a large range on the watershed area (60 % of the agricultural area for BMP3 and 85 % for BMP1). It is now possible to compare this necessary implementation area with the area where the farmers declare themselves ready to implement each BMP: clearly, on the Don watershed, there is no way to conciliate the potential area of BMP implementation (37 % of the agricultural area for BMP3 and 45 % for BMP1) with the simulated necessary area.

Only BMP3b, which requires a high technology level and the capacity to adapt the fertilisation each year depending on the previous climatic conditions could conciliate the regulator's objective and a low level of implementation, but its acceptability (not depicted on the Figure) is too low.

A regulator who would rely on the volunteer adoption of the technical BMPs would never reach his objective of meeting the EU 25 mg/l threshold.

Thus there is a need to design other BMPs. This conclusion is strengthened by the difference noted within the acceptability analysis between the BMPs' acceptability and their feasibility.



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The AgriBMPWater
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