Workshop 5

Combined micro-economic and ecological assessment tools for sustainable rural development

Decision support for cost-efficient environmental management of small watersheds: How to deal with the costs of agricultural Best Management Practices

Jean- Marie Lescot[1]

Abstract

This paper focuses on the methodology used for costs/effectiveness analysis of changes from conventional to environmental friendly practices at the farm and watershed level. Environmental friendly practices are proposed for their environmental potential efficiency assessed by modeling the transfers between soil and groundwater. Direct cost assessment of these changes attempt to provide the necessary elements for calculating the support that may allow a sufficient involvement rate and then a sufficient environmental effectiveness at acceptable social costs. Costs are analyzed by modeling (Linear Programming) and estimated at the farm level either from representative (average farms) or typical farms (modal farms). The aggregation issue to shift up from farm to watershed level is discussed and different ways of targeting Best Management Practices (BMP) are compared. Results show that direct costs are of a very different nature depending on the practice changes. Thus a mechanism with constant incentives per hectare may present the risk of achieving limited adherence by farmers leading only to marginal changes that will not address finally the expected effects on the environment.

---

[1] Cemagref - Agriculture and Rural Areas Dynamics Research Unit - 50, avenue de Verdun, Gazinet, 33612 Cestas cedex, France, Phone: +33 (0)5.57.89.08.45, Fax: +33 (0)5.57.89.08.01

Keywords: Best management practices, decision making, farm modeling, cost-efficiency analysis, small watershed

1 Introduction

Many studies have been carried out on environmental effectiveness of Best Management Practices (BMPs) to reduce water pollution by means of modelling or the use of indicators. Others have focused on economic issues and the costs associated with the implementation of BMP's (Yuan et al. 2002, Wossink et al. 2002, Forster et al. 2002). Studies have also been carried out on the implementation of the BMPs at the farm-level showing the complexity of farmers' environmental decision-making (Wilson & Hart 2001). Nevertheless, to encourage farmers to implement the appropriate farm practices for sustained profitability and to assist decision-makers in assessing the cost of these changes, there is a need for information on the financial impact to farms of environmental friendly practices and the introduction of BMPs. Techniques combining microeconomic and hydrological models incorporating GIS, were developed too, to improve water quality, e.g. for targeting land retirement (Khanna and al. 2003). The work presented here started within the framework of the interdisciplinary integrated E.U. funded research program AgriBMPWater, under the 5th Framework Programme, developed to propose decision support for cost-efficient environmental management of small watersheds (from 0.66 km^2 to 30 km^2).

Proposals for BMPs are given at the farm level from their potential effectiveness to reach environmental objectives (reduction of nutrient leaching, pesticide contamination, erosion etc.). As the effectiveness of BMPs is currently assessed at the watershed level, then, for a cost/effectiveness analysis, direct costs have been appraised first at the farm level then at the watershed level too. Nevertheless, the involvement of farmers (the level of adherence or acceptability of the changes) will define in the end the produced amenity. Furthermore, questions on targeting changes either on particular types of farms or only on part of the watersheds (critical areas[2]) arise: targeting BMPs may indeed be found to be more efficient. This paper aims to discuss the methodology which has been proposed to calculate direct extra costs of environmental friendly practices (and additionally to assess the level of incentives that might be needed to encourage farmers to modify their practices). As direct costs of BMP implementation at the farm level are only roughly known (or even inknown) by farmers, the level of support proposed to them is in fact compared with its level of acceptability which depends on many factors, that are not just financial. Acceptability of the changes has therefore been part of this project but will not be developed here (see Feichtinger F.and al, 2003).

2 Methodology for cost assessment on small watersheds

2.1 Budget analysis and economic optimisation

While recognizing the value of enterprise budget analysis and partial budget analysis for sustainable agriculture research, there is a need for whole-farm analysis because many practices that appears

---

[2] Critical area: a critical area is defined as the most sensitive (vulnerable) area within the watershed that gives the largest contribution to the water pollution. Soil types identified as high risks of leaching and/or runoff of nutrient, pesticides or soil will be classified as critical areas.

profitable from a single analysis may prove less attractive when analysed as part of the whole-farm system (Dillon M. Feuz, and Melvin D. Skold 1991). The economic budgeting approach admittedly may reflect real word behaviour playing an important part for the farmer in the decision making process by analysing a range of both current and more environmental friendly management practices. Nevertheless, the major disadvantage is that budgets may not reflect efficient decisions from an economic perspective. To derive a meaningful trade-off curve, all economic methodologies need to allow farmers the ability to interchange a variety of optional strategies into the decision making framework. (Lee, L. K. 1998). Consideration of only a limited number of budgets may unrealistically restrict substitution possibilities. Thus a methodology of economic optimisation may be expected to reveal more favourable trade-offs between farm income and environment quality, relative to econometric[3] and budgeting techniques.

2.2 Average farms and typical farms

Ultimately each individual farm in a small watershed should be modelled separately: to a certain extent, all farms and farmers operate under unique circumstances and personal references. Should modelling every individual farm be possible on very small watersheds, information is nevertheless, not always available either through statistics (only aggregate data available) nor surveys (willingness of farmers to participate).

Other data sources could include average statistics or existing surveys: the advantage of these sources is that data are representative of the farms but technologies used and economic results cannot be linked. Averages from new surveys give a good overview on farm situations but with similar disadvantages and moreover time input is very high. For typical farms, the important characteristic is that the resource base and the technological constraints are typical and are not the average of a group of farms, as is the case for representative farms.

Developing a model with typical farms gives a realistic picture of farming and could represent a significant number of farms within a watershed. The main disadvantage is that this is not representative in a statistical sense. Thus, for modelling farms within watersheds, using representative (in an average concept) or typical farms (in a modal concept) is still the most relevant way, even if not fully satisfactory. The types of data required and the analysis performed as well as the interpretation of the results are nevertheless considerably different for a typical farm compared to a representative farm. Usually, not only one but different types of farms are located within watersheds, even small ones. It may be necessary therefore, to classify the universe of the farms in homogeneous groups within production lines and to define representative or typical farms for each of these groups. For each relevant farm type to set up one moderate sized farm and one large farm will allow a significant number of farms to be represented, a large amount of production within the watershed and economies of scale to be captured and therefore, differences in BMP implementation costs. Size, which expresses the main important issue characterising typical farms is measured in average dairy cow or beef cattle number or sows or in acreage (ha) depending on the production line. Technical data consist of input and output flows needed for construction of the technical coefficients matrix. Additional information allow checks to be made on how

---

[3] This method may be less capable of assessing the impact of new untried practices that are reduced to modification of parameters and variables already in models for simulation.

representative the farm structures used in the models are. However, the main issue when calculating costs at a watershed level is the potential bias from aggregating farm level data or using average or aggregate data at the farm level.

2.3 Direct cost calculation at the farm scale

Classical linear programming framework (LP) is used in farm modelling. On the whole-farm basis, alternative farming practices, including Best Management Practices, are considered as alternative ones. The maximisation of Gross Margin as an objective function implies that each individual farmer is considered as a profit maximiser. In order to take into account all the aspects of the production process that could be modified by BMP implementation (feeding programme, crop rotation, crop management sequence...), the models developed are detailed enough to include every step of the cropping processes. As introducing seasonality will further restrict the model solutions and could lead to lower values of the objective function, any options the farmer has for reducing seasonal bottlenecks in resource use has therefore been included (e.g. labour constraints can be released by additional labour activities). If critical areas[4] are defined within the watershed, management practices that should be banned could appear as new constraints for all or part of the farm area. Ratios between outputs and inputs for standard and alternative production processes have been assumed to be constant too (deterministic farm models). Mean values of input and output prices for the current year have been used. New specifications for traditional linear programming like Positive Mathematical Programming (Hovitt R.E. 1995; Arriaza, 2003) could help overcome the problems of calibration of models and incorporate non linear parameters in the objective function (yield and costs per crops). Further development of this methodology for cost/efficiency analysis on small watersheds will probably need a change to a more relevant model.

2.3.1 Linear Programming Model

The general Linear programming model that is used to specify the decision making problem of a profit maximising agricultural farm is frequently specified as in the following form:

$$\text{Max. } Z = f(X) = C\,X$$

$$\text{subject to } A\,X \leq B$$

$$\text{and } X \geq 0$$

Z is the scalar product of C and X and represents the objective function , X is the vector of decision variables in conventional and environmental friendly practices, C is the vector giving corresponding contributions of these variables to the objective function, B represents the physical, institutional and personal restraints that define the environment within which choices are made, A defines the technical relationships between variables and the restraints per unit for the decision variables.

In farm models, activities with environmental friendly practices, don't appear in most cases in optimal solutions of activity combination (that squares with the real word where farmers usually

---

[4] Critical area: A critical area is defined as the most sensitive (vulnerable) area within the watershed that gives the largest contribution to the water pollution. Soil types identified as high risks of leaching and/or runoff of nutrient, pesticides or soil will be classified as critical areas.

don't apply such farming practices)[5]. As BMPs generally imply reduced profits in comparison with more polluting standard practices, incentives or compensation need to be proposed to farmers for their adoption. In order to make them appear in optimal solutions, incentives linked with BMPs are proposed. With an increasing level of incentives, non-optimal environment friendly activities enter optimal solutions gradually or entirely. These levels of incentives are considered to represent direct costs for Best Management Practice implementation, that is the loss in the objective function that the farmer would suffer in adopting such practices[6]. The models proposed have then the following form:

$$\text{Maximize } Z = \sum_{js} c_{js} X_{js} + \left(\sum_{jb} (c_{jb} + I) X_{jb} \right)$$

$$\text{subject to } \sum_{j} \sum_{p} a_{ijp} X_{jp} \leq b_i$$

$$\text{and } X_{jp} \geq 0$$

Z: total gross margin of the farm, X_{js} , X_{jb}: level ot the j^{th} activity with standard and best management practices, c_{js} , c_{jb} : forecasted gross margin of a unit of the j^{th} activity with standard and best management practices, a_{ijp}: technical coefficients describing the production processes (quantity of the i^{th} resource required to produce one unit of the j^{th} activity) and practices (standard and environment friendly), b_i: amount of the i^{th} resource available, I: incentive.

As changes of practices with incentives may lead to a higher objective than that reached with standard polluting practices, changes from incentives to direct costs are achieved as in the following:

$$C = I - \frac{\left(Z_I^* - Z_0^* \right)}{s}$$

C: direct costs per ha, I: incentive per hectare, Z_0^*: objective when incentive = 0 (with standard practices), $_I^*$ objective with incentive I (when BMP is implemented), s: number of hectares implemented with BMP).

2.4 Up scaling to watershed scale: cost assessment for the watershed

Aggregation can be achieved in two ways: either by modelling farms in some aggregate manner (representative farm and typical farms for each type) and then multiplying results according to their frequency in the watershed either by modelling farms together as if they were a single large-farm. In the first solution, available data on the joint size and type distribution of farms, are unfortunately not sufficient to ensure exact aggregation, nor to identify aggregation bias (Day, 1963). For the second solution modelling farms together may overstate flexibility and co-ordination of agricultural production. It is however a widely accepted means for modelling large areas (O'Callaghan, 1996) and may be expected to be appropriate for small catchments, in particular when farms are straddling different watersheds. In any case testing the two issues may be useful for

---

[5] If Best Management Practices enter the optimal solutions, the model may still not be relevant even if these practices are profitable for non-financial reasons

[6] Interpreting shadow prices for direct cost calculations doesn't appear to be relevant. Although the shadow costs give a reliable indication of how large an improvement is necessary for a BMP activity to enter the optimum solution, it does not indicate what the optimal level of the activity would be if the BMP activity did enter the solution, nor does it indicate how the optimal levels of other activities currently in the solution would be affected.

comparison of model outcomes. Furthermore, areas implemented with BMP may concern only a part of the farm acreage and this part as well may be different between farms (e.g. between farming systems or those located, or not, in critical areas).

2.4.1 Individual farms

If farms are classified in a smaller number of homogeneous groups, and models constructed for representative farms in each group, farm models are then aggregated for the watershed using the number of farms in each group as weights[7]. Costs of implementation are then calculated as in the following:

$$C_w = \sum_i \sum_j n_{ij} s_{ij} C_{ij}$$

where C_w denotes the cost of BMP implementation for the watershed, C_{ij} costs per ha of BMP implementation for representative farm i within type j, s_{ij} the area of BMP which is implemented on the farm i of type j, n_{ij} number of representative farms i of type j. If farms are classified into groups, aggregation bias could be avoided only if this classification is done according to requirements of homogeneity that Day denotes as technological homogeneity, pecunious and institutional proportionality (Day, 1963).

2.4.2 Watershed as a single farm

As expressed before, aggregating the resources of the whole watershed and modelling aggregated variables as a single large-farm is another way to calculate direct cost at the watershed level. Aggregation bias however is always in an upward direction[8]

If the linear programming model of the i farm is written in matrix notation:

$$\text{Max. } Z = f(X_i) = C_i X_i$$

$$\text{subject to} \quad A_i \quad X_i \le B_i$$

$$\text{and} \quad X_i \ge 0$$

and if the aggregate farm model is denoted in the same way but with w subscripts, we make the assumption that:

$$A_w = A_i$$

$$B_w = \sum_i B_i$$

$$\text{and } C_w = C_i$$

If no aggregation bias exists, the optimal solution for the watershed X* would then be equal to the sum of the X_i* (optimal solution of the i th farm within the watershed) and cost for the watershed C_w be equal to the sum of the costs C_i (cost for the i th farm).

---

[7] Using the number of farms in each group as weights is the correct aggregation procedure if the representative farms are defined as the arithmetic mean farms for their groups (Hazell, P. B., and R. D. Norton. 1986) Weighting procedure may have to be rather more complex with typical farms (modal farms)

[8] it overstates resource mobility by enabling farms to combine resources in proportions not available to them individually, it carries too the implicit assumption that all farms have the same technologies of production.

3 Integration for Cost efficiency analysis

A framework of environmental effectiveness, associated costs and social acceptability of environmental friendly practices was the main task of the AgriBMPwater[9] programme, which should finally lead to an operative grid for integrative assessment of BMPs. Farm models are not integrated with hydrological ones but run in parallel allowing research teams to continue working with existing hydrological models (GLEAMS, SWAT, EROSEM, USTL, STOTRASIM). Costs of BMP implementation calculated at the watershed level are then compared with their effectiveness assessed from hydrological modelling. In order to compare BMP and the model outcomes, an effectiveness rate[10] has been defined as follows:

$$E_a\,(\%) = \left| \frac{VAR_{BMP} - VAR_{std}}{VAR_{std}} \right| * 100$$

Where VAR *denotes concerned variable value, for which improvement is supposed by practice changes.* VAR_{std}*,* VAR_{bmp}*: variable values with standard practices and Best Management Practices*[11]*. Variables could be soil loss, phosphorus export, nitrogen*[12] *or pesticides leaching or water quality variables.*

For different levels of areas with BMPs, this effectiveness rate can be compared with the corresponding direct costs of implementation of these BMPs (Fig 1).

Grub watershed area with BMP			Effectivity			Costs			
			BMP 2	BMP 3	BMP 1	BMP 2a	BMP 2b	BMP 3	BMP 1
ha	% of total area	% of total arable area	%	%	%	€	€	€	€
0	0	0.0	0	0	0	0	0	0	0
7.9	2.9	5.7	66	51	29	2521	2521	848	856
19.5	7.1	13.8	82	67	40	6262	6314	2107	2126
32.0	11.7	22.8	96	81	50	10270	10810	3455	3487
36.1	13.2	25.7	98	82	52	11592	12632	3900	3936

Petzenkirchen watershed area with BMP			Effectivity			Costs			
			BMP 2	BMP 3	BMP 1	BMP 2a	BMP 2b	BMP 3	BMP 1
ha	% of total area	% of total arable area	%	%	%	€	€	€	€
0	0	0.0	0	0	0	0	0	0	0
3.46	5.2	6.1	61	44	31	1111	1111	374	377
4.28	6.5	7.7	74	52	38	1374	1374	462	467
9.25	14	16.5	84	62	46	2969	2989	999	1008

Source for effectivity: Federal Agency for Water Management, Institute for Land and water Management Research, Petzenkirchen, Austria

BMP 2a: pasture on every farm, **BMP 2 b**: pasture on two farms(Grub), one farm (Petzenkirchen), **BMP 3**: winter crop on every farm, **BMP 1**: mulching on every farm

Table 1. Costs and effectiveness of different BMPs for erosion control -Austria

---

[9] For programme presentation see Turpin and al. (2002)

[10] Effectiveness rate can be related to a target value (limit value, threshold value, value of/for political decision). Effectiveness is then calculated as following :

[11] Ea = actual effectiveness, Er: effectiveness related to a target value, VAR_t : target value of the variable.
For example for Nitrate concentration: Er [%] = [(NO3.standard - NO3.bmp) / (NO3.standard- NO3.tolerance)] * 100 where NO3. standard = nitrate concentration with standard practices, NO3.bmp = Nitrate concentration with BMP's applied, NO3.Tolerance = threshold value of nitrate concentration.

[12] Er [%] = [(NO3.standard - NO3.bmp) / (NO3.standard - NO3.tolerance)] * 100 where NO3. standard = nitrate concentration with standard practices, NO3.bmp = Nitrate concentration with BMP's applied, NO3.Tolerance = threshold value of nitrate concentration.

Usually support associated with environmental friendly practices already exists (e.g. ÖPUL programme in Austria) but its support is frequently calculated using budgeting approaches and often undervalue the real direct costs for the farm, explaining for a part, the low level of participation. Thus, if they are not already included in models, direct costs calculated by farm modelling can be compared with existing support.

For cost effectiveness analysis, costs can be presented too per unit of effectiveness (Fig 2).

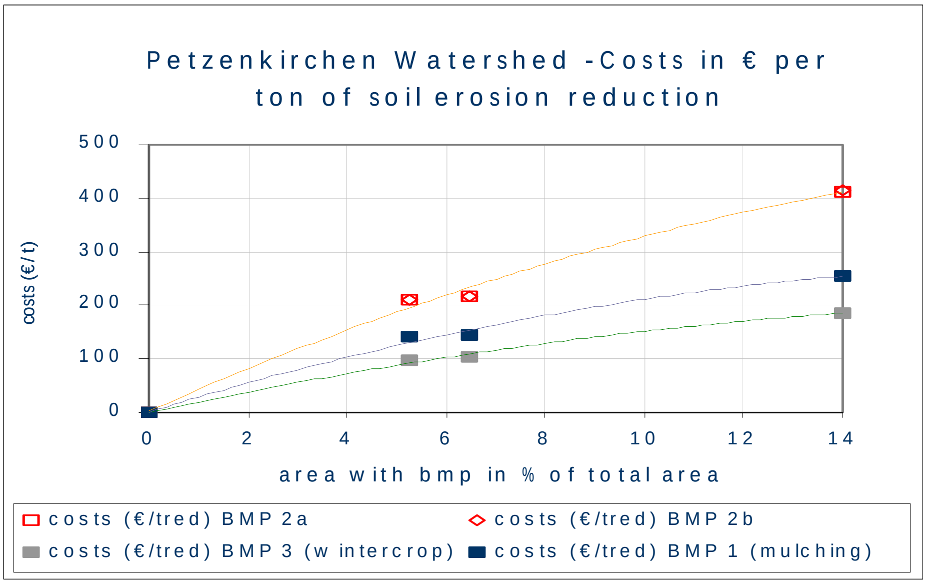


Fig 1 – Costs per ton of soil erosion reduction –Petzenkirchen watershed (Austria)

In the end, the area implemented with the BMP and therefore its effectiveness will depend on the farmers' participation rate. Different factors may explain farmer willingness to change practices and amongst them, the level of support is likely to be an important one.

Application to European watersheds

This framework for cost assessment has been developed for different environmental concerns and on different small watersheds in Europe (Fig 2) for the problem of nitrate loading (Feichtinger and al. 2003) and erosion in Austria (Grub and Petzenkirchen watersheds) with a dairy representative farm, for nitrate loading in France (St Leger watershed) with typical farms, for erosion and phosphorus export in Italy (Lake of Vico) with a representative hazelnut growing farm. In Finland, (Rintala Polder) multiperiod linear programming models have been developed[13] for representative dairy, hog and crop farms (average farms). Data sources used were either typical farm models or averages from regional statistics (FADN) and own surveys. Costs have been calculated for different Best Management Practices (mulching, cover intercrops, change from arable land to permanent grassland, reduction of fertilization, grass cover instead of tillage, different drainage investments). Linear programming models (mixed integer programming models) have been developed using GAMS software. Aggregation has been achieved in two different ways: adding farm direct costs, directly calculating the costs for the watershed considered as a single large-farm.

---

[13] Intertemporal linear programming models were developed due to the characteristics of the BMPs: different types of drainage to solve problems of acidification.

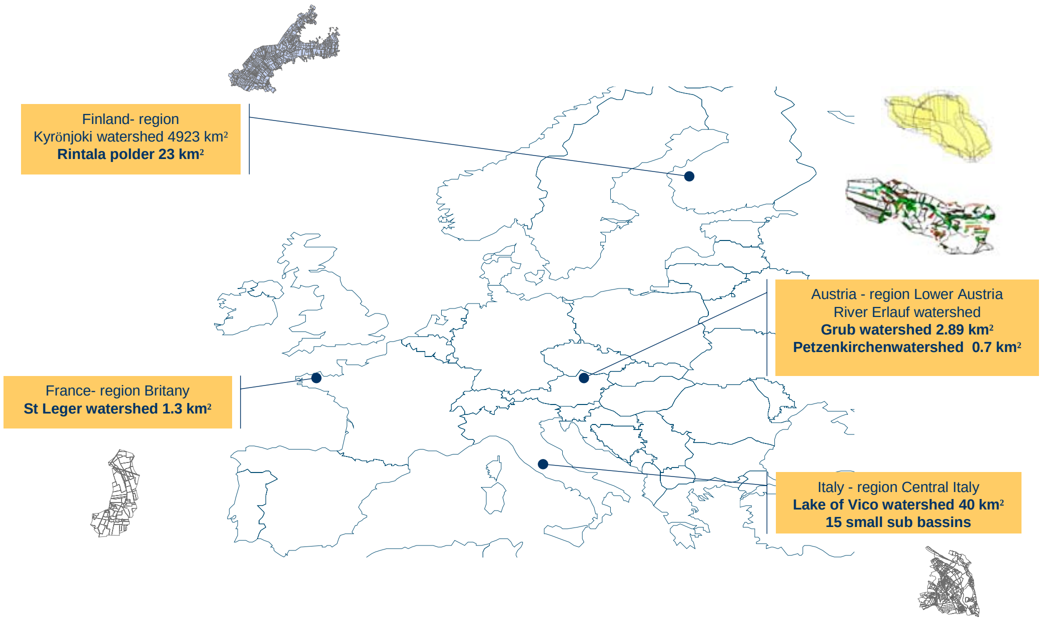


Fig 2. Location of the different small watersheds where the cost/effectiveness approach has been applied

3.1.1 Costs at the farm level

Analysis of model results shows that when environment friendly practices refer to changes of activities (BMP: arable crops to permanent green fallow), the level of compensation per hectare needed to make changes profitable are not linear (Fig 3). Slight implementation of the BMP results in marginal opportunity costs for the farm but with realization of a larger area, opportunity costs rise exponentially because of broad changes in crops and herd. Directs costs per hectare calculated from incentives can be presented in a step wise function showing that non-marginal changes cost much more than marginal ones. In the case of this BMP, choosing extensive practices on one part of the farm, may actually lead to shift up to more intensive practices on the other part so as to keep the farm economically viable. Model results indeed show that adoption of this Best Management Practice leads first to potentially more polluting farm management, because milk production becomes more intensive to make up for the reduction of heads following BMP implementation, and corn acreage increases so as to make up the reduction of fodder crops.

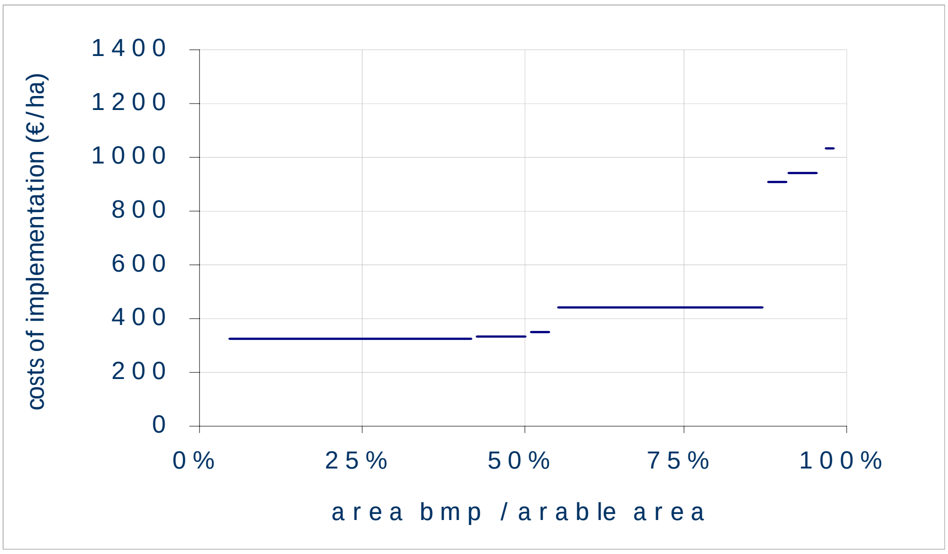


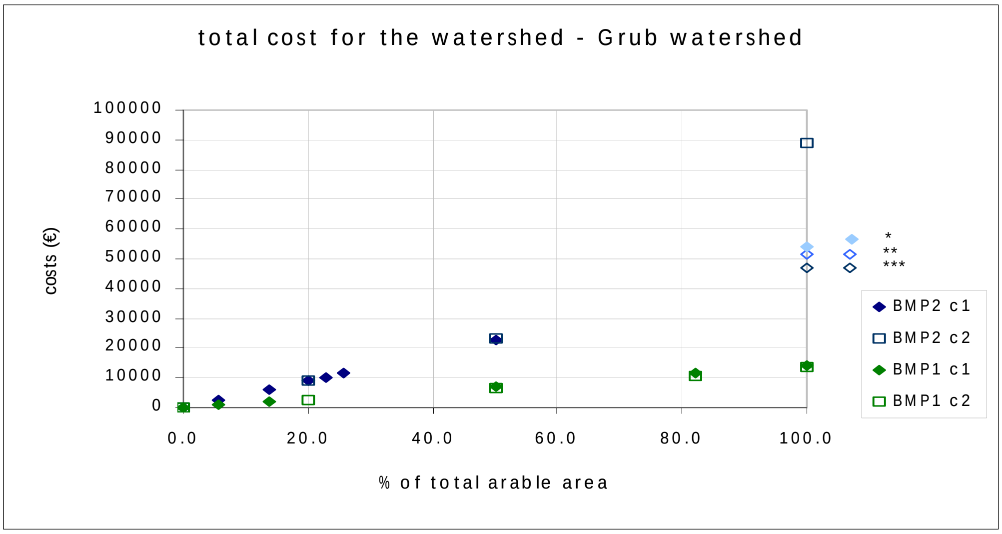
Fig 3: Costs of the BMP permanent green fallow - implementation at the farm level (Dairy average farm, Austria)

When Best Management Practices refer to changes of practices in the strict sense of the word (BMP: catch crops, reduction of fertilization by x%), 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. Increasing incentives beyond this threshold value may even lead to promoting the activities for which practices need to be changed (e.g. increase of corn and cereals for catch crops). There is in fact an optimum in incentive for least costs and largest area in BMP and beyond this optimum the area with BMP often decreases when incentives reach high levels.

For example with implementation of BMP catch crops on arable land, at a dairy representative farm level (Austria), the threshold value for compensation is e.g. 108 €/ha for 76 % of the arable land (cereals area before and after corn) and 111 €/ for the whole arable land. For BMP reduction of fertilization costs, assessments have been achieved considering that the reduction of fertilization will lead to a reduction of yield by 10% and 20 % and no reduction in yield. Outcomes show that, given the reduction of yield, direct costs per hectare of changes vary depending on the crops.

3.1.2 Costs at the watershed level

Results of Cost/efficiency analysis for each watershed will be presented in detail in different papers. From comparison of costs calculated with individual farms and with a single large-farm, it emerges that the two methods could be used indifferently when implementation of Best Management Practices concern only small share of the watershed. On the other hand, calculated costs differ considerably between the two methods when a large part of the arable area is implemented. Such differences may be explained either by the non-linearity of direct costs of BMP implementation or by the consequent bias to overstatement of the degree of resource flexibility in the aggregate-level LP model. Costs differ considerably too when Best Management Practices are implemented on every farm within the watershed or are targeted only on a few (Fig 4 and Table 2).



BMP 2 : pasture on every farm; **c1** individual farms, **c2** :watershed single farm
* 12 farms (11.5 ha); ** 3farms (21 ha)+9 farms (8 ha); *** 6 farms (21 ha) + 6 farms (2 ha)
BMP 1: mulching; **c1** individual farms, **c2** :watershed single farm

Fig 4 - Costs of BMP permanent green fallow - implementation watershed level (Austria)

BMP	**share of the arable land with bmp**	*20%*	*50%*	*82%*	*100%a*	**100%b**	**100%c**
Bmp 2	costs 1	8984	22727		47049	51513	54257
	costs 2	8997	23114		88656		
Bmp 3	costs 1	2878	7194	11690	14388		
	costs 2	2645	6614	10810	13595		

Table 2 – Costs for the watershed in euros
BMP2: permanent grassland – BMP3: wintercrops - costs 1 (individual farms) , costs 2 (watershed as a single large-farm) - a: 12 farms (11.5 ha) ; b: 3 farms (21 ha) +9 farms (8 ha) ; c : 6 farms (21 ha) +6 farms (2 ha)

3.2 Conclusion

Results from Painter and Young analysis (Painter, K.M. and Young, D.L., 1994) suggested that more flexible agriculture policies could increase both groundwater quality and farm returns. Future farm level research should then focus on groundwater quality strategies that can achieve non-marginal improvements in ground water quality. Implementations of Best Management Practices and other adjustment of current cropping practices usually result in marginal improvements in groundwater quality with little (or no) change in farm income. In some cases this may be sufficient to satisfy public demands for safety, in other cases it may not. Cost calculations have helped to identify reasonable incentives for realisation of sustainable agriculture but as high realisation of BMP could lead to large costs at the farm level, land retirement if appropriately targeted should generate enough surface water quality benefits to offset the social costs of such programmes.
The research questions aroused are then to define if large improvements in groundwater quality can be achieved through farm management strategies that are also economically viable for the farm.

References

Arriaza, M. and J. A. Gomez-Limon (2003). "Comparative performance of selected mathematical programming models." Agricultural Systems 77(2): 155-171.

Day, R. H. (1963). On aggregating linear programming models of production. Journal of Farm Economics 45: 797-813.

Dillon M. Feuz, and Melvin D. Skold (1991).Typical farm Theory in Agricultural Research. Journal of Sustainable Agriculture 2:43-58.

Feichtinger F., P. Strauß, J.-M. Lescot, G. Hofmacher, M. Kaljonen (2003): Groundwater protection by Agricultural Best Management Practices. Under preparation

GAMS user's guide by Brooke, Kendrick, Meeraus, and Raman, GAMS Development Corporation, 1217 Potomac Street, N.W., Washington, DC 20007, USA.

Hazell, P. B., and R. D. Norton (1986) Mathematical Programming for Economic Analysis in Agriculture, Mac Millan Publishing Compagny - New York..

Hovitt R.E. (1995) Positive mathematical programming, American Journal of Agricultural Economics 77, pp329-342

Lee Linda K. (1998) Groundwater Quality and farm Income: What Have we learned? Review of Agricultural Economics, Volume 20, Number 1:168-185.

M. Khanna, W. Yang, R. Farnsworth, H. Önal, Cost-effective targeting of land retirement to improve water quality with endogenous sediment deposition coefficients, American Journal of Agricultural Economics 85 (3), pp538-553

Moxey, A., and J.R. Tiffin. (1994). Estimating linear production coefficients from farm business survey data: a note. Journal of Agricultural Economics 45:381-5.

O'Callaghan, J.R. (1996) Land Use, the interaction of economics, ecology and hydrology, Chapman and Hall, London.

Painter, K.M. and Young, D.L., (1994) Environmental and Economic Impacts of Agricultural Policy Reform: An Interregional Comparison J. Agr. and Appl. Econ. 26 (December 1994):451-462.

Turpin N. and al. (2002) AgriBMPWater: Systems approach to environmentally acceptable farming. MULINO workshop on Policies and tools for the sustainable water management in the EU, Venice, November 21-23, 2002.

Wilson, Geoff and Kaley Hart (2001). Farmer participation in agri-environmental schemes: towards conservation-orientated thinking? Sociologia Ruralis Vol. 41, No. 2, pp 254-274

Wossink, G.A.A. and D.L. Osmond (2002). Farm economics to support the design of cost-effective Best Managament Practice (BMP) programs to improve water quality: Nitrogen control in the Neuse River Basin, North Carolina. Journal of Soil and Water Conservation 57: 213-220.

Yuan, Y., S.M. Dabney and R.L. Binger (2002). Cost effectiveness of agricultural BMPs for sediment reduction in the Mississippi Delta. Journal of Soil and Water Conservation 57: 257-