Assessing the cost, effectiveness and acceptability of best management farming practices: a pluri-disciplinary approach

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Abstract: The AgriBMPWater project has been imagined and built in a pluri-disciplinary approach and framework, with the study of the object 'BMPs' using several disciplines at the same time (hydrology, economy, sociology, geography and agronomy). The knowledge of the object in each discipline is deepened by a fertile multi-field contribution: borders of disciplines have been broken down, allowing crossbreeding between different scientific fields. This crossbreeding becomes necessary as sustainability in agriculture and livestock production gathers together very different and evolving notions. Moreover, crossbreeding between scientific findings and on-farm application contributed to enrich the analysis.

Keywords: cost-effectiveness; nonpoint source pollution; acceptability; best management practice.

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1 Introduction

This paper focuses on alternative practices that are proposed on a voluntary basis to farmers to improve the water quality in rural watersheds. These alternative practices are known as 'best management practices' in the USA (US Clean Water Act, amended 2002), or 'agri-environmental measures' in Europe (N°2078/92/EEC; 1257/99/EC). The European Council considered, during the Gothenburg meeting (June 2001), that more than 20% of the utilised agricultural area is farmed under agri-environment contracts. But the first environmental assessments of these contracts conclude that they only have little impact, for two main reasons: they have a low adoption rate, and farmers' participation do not coincide with the areas of highest environmental value or need (European Environment Agency, 2003).

The environmental policy concerning water preservation is well established, with the EU Water Framework Directive (WFD) in place. Focus now needs to be put on its implementation procedures (Commission of the European Communities, 2005). The WFD mandates the achievement of 'good status' for all waters by a set deadline (2015). As a consequence, local managers have to design mitigation programmes for currently polluted water sectors. Nevertheless, there are hundreds of environmentally friendly practices for each Member State. The local managers need to select among them the most cost-effective ones and those that are liable to be the easiest to adopt for the farmers. Designing agri-environmental schemes without considering together the three dimensions – cost, effectiveness, acceptability – may result in measures, which are efficient but extremely expensive (Deffontaines *et al.*, 1993), cheap but with low environmental performances (OECD, 2003), or even worse, the instrument may be cost-effective but experience very low commitment (Harvey, 2004). In any case, even if the selected environmentally friendly practices improve the sustainability of the farms who adopt them (Webster, 1999), there may be no improvement at the watershed or regional scale when the commitment is too low (Prato, 1999).

In this context, the aim of the AgriBMPWater research project is to help decision-makers in selecting among existing BMPs the most cost-effective ones and those that may be more easily adopted by the farmers (Turpin *et al.*, 2005). The general framework developed during the project takes into consideration:

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

The AgriBMPWater project was built on a pluri-disciplinary approach and framework, with the study of the object, 'BMPs', using several disciplines (agronomy, hydrology, economy, and sociology). The knowledge of the object in each discipline is deepened by a fertile multi-field contribution: discipline borders have been broken down, allowing crossbreeding between different scientific fields. This crossbreeding becomes necessary as sustainability in agriculture and livestock production gathers together very different and evolving notions, like resource efficiency, profitability, productivity, environmental soundness and social viability (Gamborg and Sandoe, 2005).

This paper describes two elements: first, the cooperation between the different disciplines can improve the comparison of different BMPs; the way this cooperation can be organised is analysed in Section 2 (its application on a case study is described in Section 3). Second, the aim of the AgriBMPWater project was to support decision-makers selecting BMPs. Thus, we also focused on the implementation of the research results. Section 4 presents how these research results can be translated into farmers' advice. In conclusion, Section 5 highlights the key points that may improve the design of agri-environmental schemes.

2 Crossbreeding between scientific fields

2.1 A common study object: the best management practice

The literature dealing with environmentally friendly farming practices, in each of the disciplines involved in the analysis, is broad. Hydrology focuses on the design, location or combination of these BMPs to comply with water standards (Anderson and Flaig, 1995). In most models, a BMP is represented as a change in some coefficient, describing a conventional farming practice. Economists focus on the economic instruments that could improve BMPs adoption (not on the BMPs themselves), and more recently on the econometric assessment of the relationship between BMPs adoption and farm profitability (Valentin *et al.*, 2004). Sociological studies on BMPs adoption are a fertile area, especially in the micro-sociological studies of participation (Morris and Potter, 1995; Ward and Munton, 1993; Wilson and Hart, 2000). None of these discipline focuses on the design of BMPs themselves, but they rather focus on their consequences from a specific point of view.

In the European Union, the contractual and volunteer agri-environmental measures mainly rely on agronomic recommendations and landscape management. Their designers consider their feasibility in terms of farming techniques and agricultural systems management. The AgriBMPWater framework considers that BMPs consist of *any kind of cropping method, agronomic technique or landscape fixture that potentially reduces water pollution and is proposed to the farmers on a contractual basis.*

The framework proposes to analyse the cost-effectiveness and acceptability of the BMPs within existing models rather than develop new ones. This framework iterates six main steps:

1. The BMPs are introduced into hydrologic models (Step 1) as land use practice.
2. These models provide both BMP efficiency (Step 2), and BMP combination scenarios.
3. The BMP scenarios are introduced into economic models (Step 3).
4. The economic models provide costs for the first set of scenarios (Step 4).
5. Because the BMPs are proposed on a voluntary basis, crossbreeding, between hydrology and economics, designs critical areas (Step 5).
6. If the sociological study (Step 6) suggests that the BMPs are liable to be accepted on the critical areas and Step 5 estimates that they may lead to comply with water quality standards at reasonable cost, the study stops. If not, a new set of BMP scenarios is designed, from the economic or sociologic results, and introduced into hydrological models (Step 1), and so on.

The results of this iterative framework are presented as a grid, which 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.

2.2 *Effectiveness assessment*

The environmental effectiveness of a given BMP is defined within the AgriBMPWater project as the evolution of water quality due to 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 effects 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.

Analysis provides the possible uncertainty existing in the estimation of effectiveness. We neglected in our analysis the effects of climate variability that can be important for short term estimations (Lacroix *et al.*, 2005): we estimated only long term trends on water quality.

Effectiveness is estimated through the introduction of pre-designed BMPs as alternative practices in previously validated models. 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 (Holmes, 1996). Effectiveness is calculated as:

$$effectiveness = \frac{VAR_{BMP} - VAR_{ref}}{VAR_{ref}} \times 100$$

where VAR_{BMP} is any variable simulated with a specific BMP implemented and VARref is measured or simulated with the ordinary practice in the baseline scenario (Laplana *et al.*, 2004). The assessment takes place at the outlet of the watershed.

2.3 Cost assessment

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 a wider economic analysis.

We consider an economy, which includes consumers (of agricultural products), tax-payers and producers, split into farmers and other producers; we neglected transaction and administrative costs, though they are of importance on the choice of mitigating instruments (Kampas and White, 2004). Farmers undergo a profit gap when adopting BMPs, which are less profitable than conventional practices. We only modelled medium term profit losses, that is we assumed that production means such as land or machinery are fixed (labour can be hired from outside the farm). The BMPs are proposed to the farmers on a voluntary basis: the regulator must compensate the farmers for their profit gap if she wants them to participate. On the one side, this compensation increases the participating farmers' profit, but on the other side it has a cost for the society: either the money is not yet available for other policies, or there is a need to raise the taxes paid by the tax-payers.

The total variation of farmers' profit (considering both losses from the BMP adoption and gain from the compensation) is included into the 'direct costs' of the BMP implementation.

The surplus variation borne by the 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. When the farmers try to compensate for direct costs induced by implementation of BMPs, they can raise their output prices so that agricultural goods would be more expensive for intermediate and final consumers or, if they cannot do so, they can switch to more profitable products, which has an impact on transformation industries and final consumers.

2.4 Acceptability

The problem of low implementation rates of BMPs is still too often explained by the resistance of farmers. Experience has shown that problems also occur in the various phases of the policy implementation and in the dissemination of information. In order to mitigate non-point source pollution, one voluntary BMP contract applied in an individual farm is not necessarily enough. In fact, they should be targeted on 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.

In order to increase our understanding of the social factors contributing to the acceptability of the BMPs, more attention has to be paid to the policy implementation practices at the local and farm level. This means due consideration of the role of farmers in the policy implementation. In the analysis of social acceptability, the evaluation of the institutional setting is of utmost importance.

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:

- Several 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.
- One extensive case study, which examined the implementation practices of the agri-environmental policy at the local and farm level. The study 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 (Kaljonen, 2006) and arising intermediary mechanisms (Kaljonen, 2003). The empirical material was gathered with thematic interviews, observations and surveys.

2.5 Critical areas delineation

The Water Framework Directive requires 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 non-point source 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 targeting the measures to specific areas where they may be more effective, or cheaper to implement (Wu and Babcock, 2001).

The delineation of critical area emphasises the role of crossbreeding between disciplines. The intuition is simple: usually, the BMPs are proposed to the farmers on a voluntary basis, often with a premium to compensate the associated costs. The farmers who have the lower costs of adoption will adopt the BMPs first. As the farmers are not uniformly scattered within a watershed, which in general is not physically uniform either, the costs and acceptability of the BMPs have also consequences on their environmental effectiveness: for a given watershed, if the farmers located in the more sensitive areas have higher costs of adoption, they will not implement the BMP unless the associated premium is very high, and the BMP effectiveness on this watershed may dramatically drop.

When the watershed can be split into smaller homogenous areas, a two-stage allocation of agri-environmental funds can be proposed: the first stage consists in delineating eligible sites and the second stage in allocating the funds in these sites on a criterion of environmental effectiveness (Wu, 2004). Within AgriBMPWater, we defined 'critical areas' to meet this target.

At this point in the analysis, it is really important that physicists, economists, sociologists and stakeholders agree on a common definition for these priority zones, named 'critical areas'. 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 definition strongly depends on the aim of the study (Turpin *et al.*, 2005). 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)'. The use of a spatially distributed hydrologic model is of importance in selecting, among all the watershed areas, some areas where the implementation of BMPs is expected to be more efficient. These models need to be calibrated first on a baseline scenario. This baseline scenario is usually designed from traditional agricultural practices. 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 the watersheds 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.

When many stakeholders participate in the diagnosis, an *operational aim* can be adopted and the critical areas are defined as 'the sets of areas where feasible measures can be applied and are needed to reach the desired quality standard of the considered pollutant at the receptor'. 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. Then, the different areas have to be ranked according to both effectiveness and acceptability, before delineating the 'critical areas' according to the operational aim.

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' (*welfare economic aim*). This approach leads to rank the candidate areas according to a cost-effectiveness ratio, with their potential acceptability also being considered.

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

2.6 A grid to improve comparisons of BMPs

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. When choosing between BMPs, there is a trade-off between cost and environmental effects. Generally, high cost policies 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 as those that make it the dominant strategy for 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 in identifying 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.

3 Comparison of BMPs on a watershed

3.1 Watershed description

The Don watershed (71 706 ha) is located in the western part of France, in the 'Pays de la Loire' region. Farm production is mainly cattle breeding (dairy and meat productions), where cereals are grown for both grain and forage. Indoor breeding is still of low importance, but the number of pig and poultry farms is increasing. Grasslands, associated with dairy production, account for around 50% of the total agricultural area. Cereals represent 18% and corn, 15% of the total area. The average size of farms was 74 ha in 1999. The weather is typically oceanic, with cool wet winters and warm drier summers. The Don watershed is covered by brown soils, resulting from the alteration of the underlying schist rock. The watershed being quite flat and soil hydraulic conductivities rather low, these thin soils (60 to 90 cm deep) are frequently hydromorphic. The water coming from the Don watershed is connected to two pumping stations for drinking water, supplying around 150 000 people. The 'Departmental Council of Loire Atlantique' monitors water flows and nitrate concentrations at the 'Conquereuil' station (draining 59 306 ha of the whole Don watershed).

In the Don watershed, the nitrate concentration regularly reached or exceeded the EU guidelines of 50 mg/l at the 'Conquereuil' pumping station in the mid-1990's when a recovery programme was elaborated by local extension services. Cropping, fertilising and manuring advice have been proposed to the farmers who could voluntarily choose to adopt them or not, but receive no compensation if they adopt them. For several years, no change in water quality has been noticed, so attention was focused to the rate of adoption of the 'best practices' that had been promoted on this watershed.

3.2 Building the comparison grid

3.2.1 Data collection

On this watershed, the analysis focused on the diversity of the farms, of their practices, and of the relationship between the supply of commodity outputs and N emissions. Data describing on-farm practices have been collected on a sample of 10% of the farms after stratification of the whole population on production system criteria (see Turpin *et al.*, 2005 for details). Special attention has been paid to the evolution, during the last five years, of the stages of decision-making by the farmers faced with environmental questions. A precise description of the fertilisation practices for each crop in each rotation has been collected for the last ten years. For the farmers who accepted it, gross and net output, and production costs for the last three years have been collected.

Working with the farmers and the extension services along the analysis lead to the emerging idea that the reasons why BMPs are adopted differ a lot from one farm to another, and often go beyond strict monetary considerations. The simplest way to characterise these reasons was to simply ask the farmers to describe what they changed in their own farms during the survey, and to add open-ended questions to enable them to describe why they changed something. From the farmers' answers, the extension services grouped the farms into eight types according to a multiple correspondence analysis (Leparoux *et al.*, 2001). Figure 1 depicts the proportion of farms in each type and their share of the agricultural area:

1 T1 farms are characterised by small production means (land, labour and capital), practices are very stable, all the crops are over-fertilised; the farmers do not consider the environmental consequences of their practices.

2 T2 farmers are rather old. They have low dairy quotas but the farm area is larger than that of T1. The grassland area is rather extensive and the cropland area highly over-fertilised. These farmers consider that they are not concerned by environmental questions because they have small farms compared to the others in the watershed.

3 T3 farm are beef growers. Their soils are heavy, wet and cold. The main concern for these farmers is to reduce production costs and simplify the production system; they are open to changes and very sensitive to how consumers perceive farming since the beef crisis in France.

4 T4 farms are dairy producers with very specific systems: the forage production relies on extensive grassland, the corn area is as small as possible. These farms largely changed over the past ten years, with improved labour organisation and increased gross margins; they now consider the environmental consequences of their farming practices.

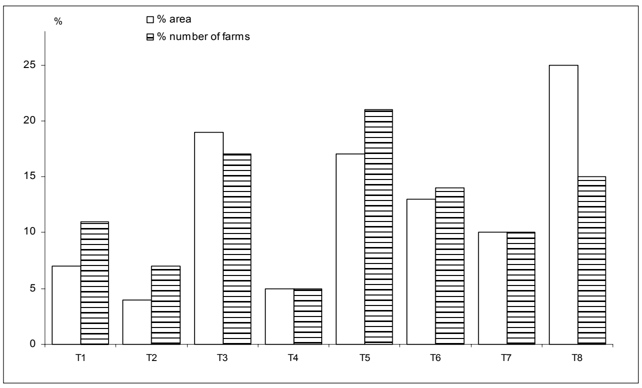
5 T5 farms are dairy farms. The farmers seek an increase of their income through an increase of the production outputs. Dairy cows are mostly fed with corn, the area devoted to cereals is large and the grassland area is intensively cropped. These farmers did not enter the farming networks existing on the watershed, and usually do not consider the environmental consequences of what they do.

6 T6 farms are also mostly dairy farms, but the farmers try to improve their income through a decrease in their production costs. The forage systems in evolving, with an increase of the grassland area. These farmers are open to the environmental considerations, but there is still large room for improvements on these farms.

7 T7 farmers are mostly interested in crop growing and they continuously improve their cropping techniques, and the equipment they use.

8 T8 farms are associations for which the improvement of the income was more performed through the increase of the product output than a decrease of the costs. The cattle is mostly fed with corn; the herds are large; the farm trajectory is based on productivity; half of the farmers are concerned with environmental considerations, while the other half do not bother about them.

Figure 1 Types of farms on the Don watershed, number of farms and cropped area



3.2.2 Step 1: Hydrological modelling

The N emissions from the agricultural activity have been estimated with the SWAT model (see Turpin *et al.*, 2005 for details). The SWAT model (Arnold *et al.*, 2001) is a semi-distributed watershed model with a GIS interface (DiLuzio *et al.*, 2002) that outlines the sub-basins and stream networks from a digital elevation model and calculates daily water balances from meteorological, soil and land-use data. SWAT simulates each sub-basin separately according to the soil water budget equation, taking into account daily amounts of precipitation, runoff, riverbed transmission losses, percolation from the soil profile, and evapo-transpiration. The modelling confirms what has already been observed on other watersheds in the Western part of France: there is not ONE production system that causes more emissions than the others, but there is a multitude of practices with a large range of risks (Bontems *et al.*, 2004).

3.2.3 Step 2: Environmental effectiveness

The BMPs that have been described to the farmers concern fertilisation (organic and non-organic): decrease of mineral fertilisers (BMP1), better use of manure (BMP2) or both (BMP3). These BMPs are modelled as being able to lower the N losses at the outlet of the watershed below the EU threshold of 25 mg NO3/l when applied widely.

3.2.4 Steps 3 and 4: Economic modelling and cost assessment

The consequences of these BMPs for the farmers may affect their income with possible yield losses, increase of labour and machinery requirements (to spread the manure on fields far from the stable), learning costs for the new techniques. Thus, adopting a BMP affects the production cost of the farm, c, and its emission function, g.

The Don watershed encounters a large heterogeneity of the farms. Bontems *et al.* (2005) reduced the heterogeneity of the farms along two dimensions, their ability to transform inputs into final production and the available area they own. Productive ability is private information to the farmers while available area and final production are observable characteristics. The economic model considers that the profit function depends on the farms' heterogeneity parameter, θ:

$$\pi(s, y, \theta) = (py - c(y, \theta))s$$

with y as the production of the farm, p its price, s the area of the farm and $c(y, \theta)$ the production cost. We considered a non-linear relation between the production cost and the N emissions, captured from the Step 2 modelling with an emission function $g(y, \theta)$. Before any regulation, the welfare function of the regulator (W°) is the sum of the farmers' profit (∏°) less the cost of the damage due to the emissions (D(E°)).

Adopting a BMP moves the cost function from c to c^{BMP} and the emission function form g to g^{BMP}. The regulator's welfare function becomes:

$$W^{BMP} = \Pi^{BMP} - D(E^{BMP}) - (1+\lambda)T$$

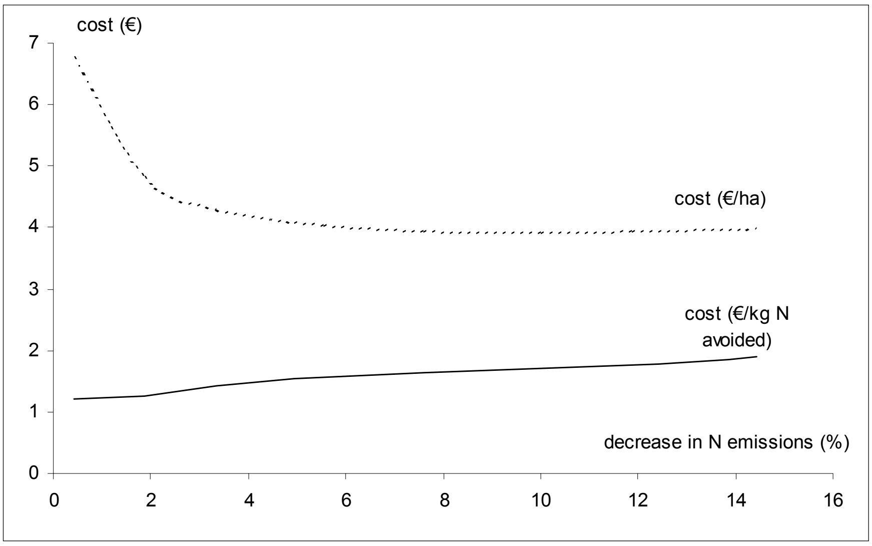
with T as the total transfer associated with the BMP (usually paid by the tax-payers) and λ the marginal cost of public funds. The total cost of the BMP adoption is $W° - W^{BMP}$. This analysis was the basis for the assessment of the cost-effectiveness ratio for the modelled BMPs.

3.2.5 Step 5: Critical areas

The Don watershed is physically heterogeneous, with heavy clay soils upstream and light lime soils downstream. The farmers are varied too, and the relationship between farming practices and N emission is largely non-linear (Bontems *et al.*, 2004). Thus we adopted the welfare economic aim definition of the critical areas for each BMP.

As an example, let us examine the BMP2 on the Don watershed. This BMP consists of spreading the on-farm manure on the grassland area rather than on corn fields and disseminating the amount of produced manure on a larger area than previously. This BMP is associated with technical constraints like delays between manure spreading and grazing periods, modification of the grass growth; it also causes additional costs for transporting to fields that are distant from the stable. This BMP improves the water quality while modifying the rate and chronology of fresh organic compound mineralisation along the crop rotations. A regulator willing that the farmers adopt this BMP can rank the different sub-watersheds in the area according to a cost-effectiveness ratio, define critical areas, and encourage the farmers to adopt the BMP on these critical areas first. Unfortunately, the farms which crop these areas do bear higher decrease of emissions per hectare than other farms. As a consequence, the cost of their adoption, expressed per hectare of implementation, is far higher than for the other farms (see Figure 2). Obviously, these farms would be the last to adopt the BMP if it had been proposed on the whole watershed: in this case, targeting the measures leads to an important decrease of the total cost of the measure.

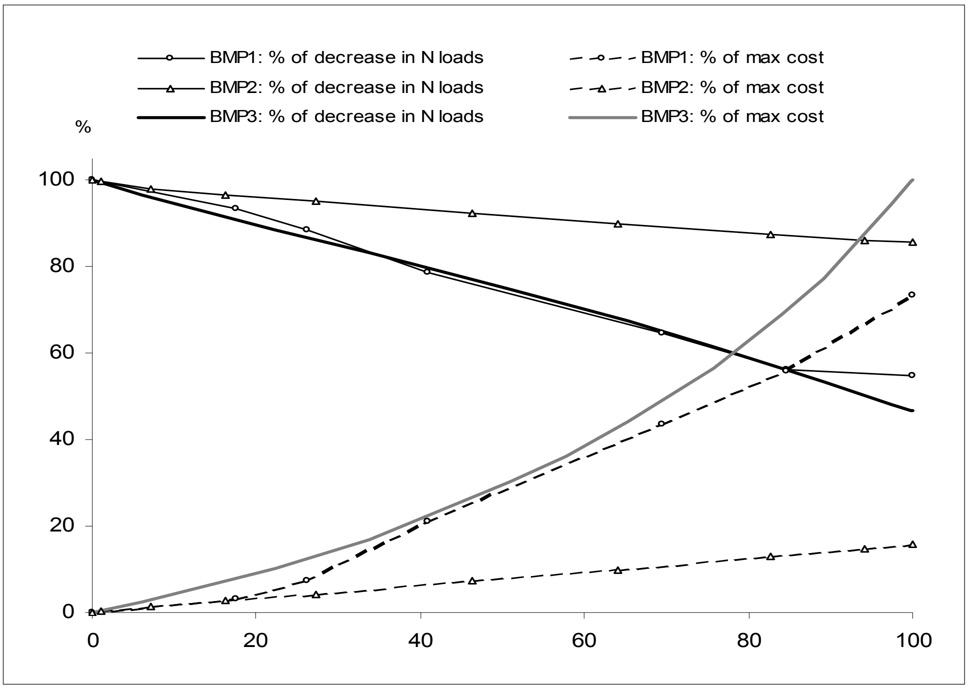
Figure 2 Costs associated with the implementation of the BMP2 on the Don watershed – costs assigned to the farmers (€/ha implemented) and cost-effectiveness for the regulator (€/kg of avoided N emission)



The definition of the critical areas is of utmost importance for the analysis of the BMPs' consequences: the way the different candidate areas are ranked may considerably modify the results of a cost-effectiveness analysis.

Moreover, when several BMPs are proposed to the farmers, the different critical areas for each BMP do not coincide and the cost of implementation for two complementary BMPs is often quite different from the sum of the unit costs. Let us illustrate this fact with the BMP3 on the Don watershed, which technically is BMP1 plus BMP2. The critical areas for BMP1 and BMP2 are different from each other and the cost associated with BMP3 is lower or greater than the sum of costs of BMP1 and BMP2, depending on the implementation area (see Figure 3).

Figure 3 Assessed costs and effectiveness on the Don watershed (BMP3 = BMP1+ BMP2)

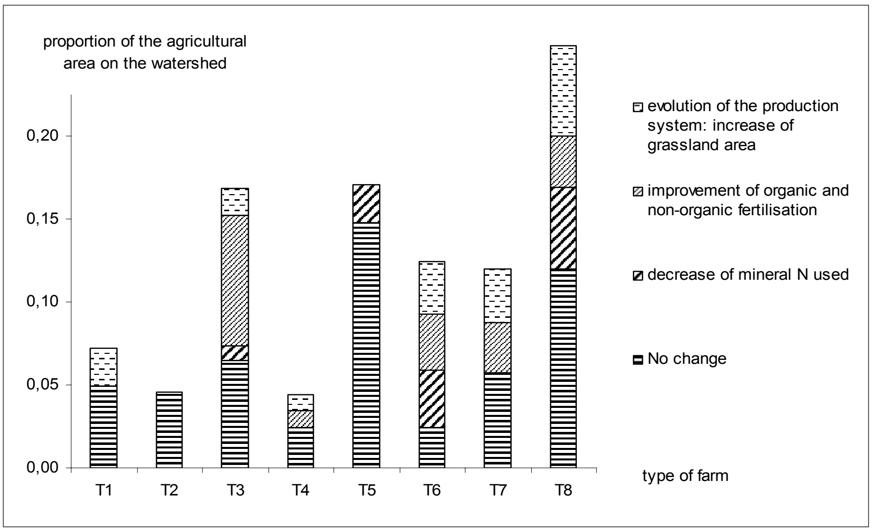


3.2.6 *Step 6: Acceptability*

Unexpectedly, some farmers declared themselves ready to implement these BMPs, even if they are rather expensive. The same willingness to pay for environmental improvements on their own farms has been detected in some recent analysis (Dupraz *et al.*, 2004).

Not all the farmers intend to consider the water quality. Indeed, farmers from types T1, T2, T5 and half of T8 do not intend to change their practices for environmental concerns in the next years. At the watershed scale, half of the agricultural area is cropped by farmers who do not foresee any modifications (see Figure 4). Farmers from T4 type do not intend to greatly modify their practices to improve the water quality, but they already have only low impact on it.

Figure 4 What do the farmers intend to modify within the next years on the Don watershed



Farmers from types T3, T6 and half of T8 do intend to modify their practices within the next years: improvement of the non-organic fertilisation, better management of the organic fertilisers at the farm scale, and for some of them extensification of the forage area.

These modifications take place into farm trajectories: some farmers progressively adjust the fertilisers to the plant requirements (they crop 30% of the whole agricultural area on the Don watershed), others are engaged in a more important change of their farms, including important modifications of the cropping pattern (17% of the whole agricultural area).

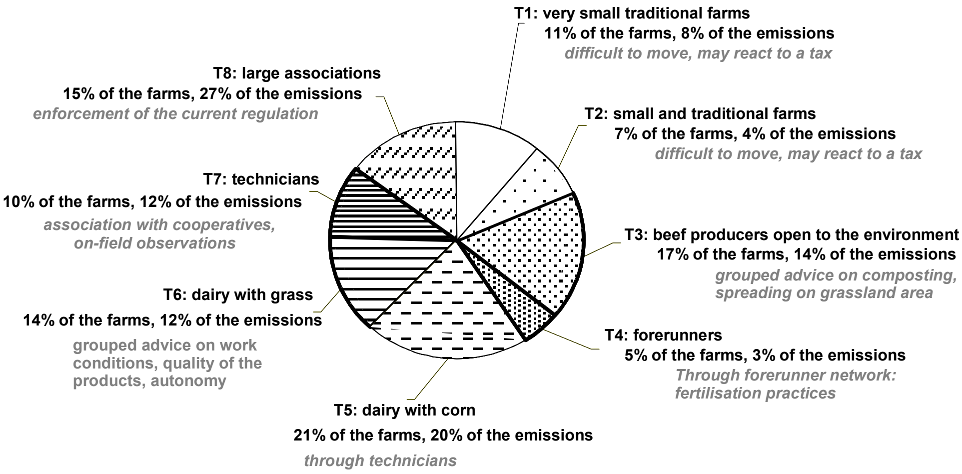
Diversity of the farms, willingness to pay for environmental improvements, and farm evolution trajectories are key elements deepening classical cost-effectiveness analysis.

4 Crossbreeding between scientific results and on-farm implementation strategies

The different simulations on the Don watershed suggest that the BMPs may have the expected effect on the water quality improvement only if they are implemented on a large share of the watershed area. Reaching water quality near the EU requirements of 25 mg NO3/l would need a decrease of the average emissions from 15% to 20% on this watershed. This level can be reached while implementing BMP3 on more than 60% of the watershed.

Spontaneously, the farmers describe themselves as ready to implement modifications on 45% and 35% of the agricultural area for BMP1 and BMP3, respectively. No local administration was ready to design an incentive scheme to improve the adoption rate, and thus, there was a need for a modification of the communication to the farmers. To encourage the farmers to adopt the BMPs, a strategy of advice has been differentiated according to the previously built typology (see Figure 5). T3 farmers are open to practice modifications and assist easily to grouped advice sessions; they have been proposed specific advice sessions, dealing with spreading on grassland and composting techniques. As the T6 farmers have already improved their search for savings more than T5 ones, they now look for information on work conditions, product quality, precision practices, production autonomy, and reduction of the inputs. All these topics have been included in the advice and have been related to the possibilities of the environmental improvement they enable.

Figure 5 Advice strategy designed to encourage the different farmers to implement BMPs on the Don watershed



Specific on-field experiments and demonstration plots have been developed with the help of local cooperatives of farmers. These experiments focused on the improvement of techniques and on their impact on the water quality. Lots of farmers take part in these experiments for various reasons: farmers from groups T7 looked for improvements of their techniques, but most of T5, T6 and T8 farmers participated. The key for participation seems to be the location of the experiments, which were very close to the farm fields, and had the same pedo-climatic conditions.

5 Conclusion

Compensating farmers who adopt costly but pollution-decreasing practices is an idea that is supported by an increasing number of both farmers and environmentalists. This has already been tested in many areas in Europe. Stewardship compensation programmes must however overcome many difficulties, the most important being enforcement problems when the practices are not easily observed. In spite of these difficulties, EU Member States have to ensure a programme of measures to mitigate water pollution within the Water Framework Directive (2000/60/EC) and they need to select some among the set of potential measures: the most cost-effective ones.

The design of policies to mitigate non-point source pollution from farms with a differentiated framework induces a better allocation of the abatement effort between farms: the empirical application on the Don watershed suggests that this abatement effort is mostly borne by the farms having the lower ratio of profit/emissions, and, given this ratio, by the more efficient farmers. The cost investigation suggests that optimally differentiated regulations are the best way to conciliate effectiveness, implementation costs, and acceptability of mitigating instruments.

Diversity of the farms, willingness to pay for environmental improvements, and farm evolution paths are key elements to deepen classical cost-effectiveness analysis. Extending the consideration of farm diversity to advice design strategies in encouraging the farmers to adopt new practices is of utmost importance to improve the cooperation between different organisations (extension service, cooperatives, private sellers) and between the farmers.

The individual advice proposed to the farmers on the Don watershed gave satisfaction to the different consultants who intervened on the watershed. A similar approach is under development for the neighbouring watershed.

Many other improvements of this research can be foreseen: until now, we only have focused on the potential effects and costs of particular BMPs. Obviously, the implementation of a specific BMP generates effects on other practices at the farm level. Developing a joint approach that incorporates the economical, sociological and physical aspects of the modelling through the building of a Decision Support System is, in our opinion, the key for future research in the area of mitigating non-point source pollution from human activities. This would be the best way to help EU Member States to guarantee a programme of measures to mitigate water pollution within the Water Framework Directive.

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