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Jean-Marc Douguet, Patrick Schembri

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Sustainable Agriculture and Water Quality Control – A Structural Approach

Jean-Marc Douguet and Patrick Schembri



C3ED : Centre d'Economie et d'Ethique pour l'Environnement et le Développement



UMR n°063 (IRD-UVSQ)



Université de Versailles Saint-Quentin-en-Yvelines
47 bd Vauban, 78047 GUYANCOURT Cedex France
Tél : +33 1 39 25 53 75 Fax : +33 1 39 25 53 00
Email : Publications.c3ed@c3ed.uvsq.fr
Internet : <http://www.c3ed.uvsq.fr>

Sustainable Agriculture and Water Quality Control
A structural approach to the evaluation of public environmental policies
applied to the Brittany region in France

by Jean-Marc Douguet and Patrick Schembri
C3ED, 47, Boulevard Vauban, 78047 Guyancourt cedex, France.

This study is part of the research project called 'CRITINC', *Making sustainability operational : Critical Natural Capital and the implication of a strong sustainability criterion* (n°PL9702076) and funded by the European Union. CRITINC was co-ordinated by P. Ekins (Keele University, UK), and was worked on in collaboration with the Fondazione Eni Enrico Mattei (scientific responsibility D. Pettenella, Agripolis, Italy), the University of Stockholm (scientific responsibility C. Folke, Sweden), the University of Wageningen (scientific responsibility R. de Groot, The Netherlands), the Wuppertal Institute (scientific responsibility C. Beuermann, Germany) and the C3ED - University of Versailles – Saint-Quentin en Yvelines (scientific responsibility M. O'Connor, France).

The research was carried out in parallel with that undertaken in the project *Quantification et modélisation du Capital Naturel Critique pour la mise en œuvre d'une politique de développement durable en France* (n°97085), carried out under the scientific direction of Martin O'Connor (C3ED) for the *Ministère de l'Aménagement du Territoire et de l'Environnement*. CRITINC was also pursued in parallel with the research initiative called *Validation socio-économique des indicateurs agro-écologiques* (n°97/C/62) and carried out in the context of the Interdisciplinary Research Programme called "Environnement, Vie et Société" (1997 – 1999) of the CNRS, under the scientific direction of Martin O'Connor (C3ED) and Philippe Girardin (INRA).

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Introduction

There is no disputing the fact that water pollution by nitrates is, in large part, caused by agricultural activities. Concerns about soil and water pollution by modern agricultural practices are becoming too important to be ignored. Point pollution can consist of direct discharges of animal excrement or be caused by the use of pesticides close to streams. Diffuse pollution caused by agricultural practices is more difficult to pin down. It is generally linked to systematic use of fertilisers and to the use of pesticides. The abatement capacity of the natural environment, partly due to dilution, partly due to the ability of plants and soils to absorb or fixate pollution, seems now to be constantly exceeded. Pollutants reach surface waters by run-off, and groundwater by infiltration. These different types of pollutant derive from the same production processes, thus suggesting that these activities use certain inputs in an inefficient or excessive way.

In the research study reported here, we focus on the Brittany region in France, its agricultural sector and the impacts of agricultural activity on water quality in Brittany. Our research has mainly focused on the construction and application of analytical tools aimed at measuring environmental performances and economic costs of adaptation. These tools deal with the physical and technical characteristics of the agricultural product, leaving to one side the issues concerning markets and employment.

The goal is to generate indicators that illustrate the confrontation between environmental performance and economic cost criteria, in the context of a comparative scenario analysis focused on growth and technological change paths for agricultural production in the Brittany region.

Due to existing ecological interdependencies and social proximity, agricultural activities are now in contradiction with the concern to protect the quality of certain categories of natural patrimony such as rural spaces, forests, fish and game resources, as well as other resources related to leisure activities. This protection or husbandry goal can be related to the notion of natural capital, defined as « a stock which produces flows of natural resources (in the ocean environment, for instance, it corresponds to the fish population, which generates the fish sold on the market ; it can also be a forest, which provides timber ; or oil reserves, whose exploitation provides the flow of oil available from a petrol station » (Daly, 1994 :30).

In developing our analysis, we use the structure developed by Ekins and Simon (1999) to identify critical natural capital through the notion of *environmental functions*. The latter are defined as the capacity of natural characters and processes to provide goods and services that (directly or indirectly) meet human needs (de Groot, 1992).

Because it plays various roles and since its degradation has economic, social and ecological implications, water and more precisely its quality constitutes a type of critical natural capital for the Brittany region. The critical natural capital *gives rise to important environmental functions at a given geographic scale, and for which no human-made or even natural substitutes exist*" (Noel and O'Connor, 1998: 78). Our approach focuses on the various types of environmental functions: source, sink, life support and human health and welfare. For each of these four categories, we construct or define appropriate state and pressure indicators.

The criticality refers not only to the existence of environmental thresholds (or 'norms') that are attributable to the components of the natural capital from the point of view of ecosystem stability, resilience and 'healthy' functioning, but also to socio-economic contingencies and to social

acceptability, both of which need to be taken into consideration when implementing programmes for sustainable development.

Any attempt to measure the potential for achieving a decrease in pollution must take into account the costs that are generated when implementing the various technical measures. But it is essential to make clear the way in which one calculates these costs. Our method is based on a cost-effectiveness type of approach. The cost-effectiveness approach relies on a clear identification of the ecological problem at stake, in terms of indicators of ecological pressure. It also implies that we identify key economic activities of particular importance and characterise them in a way that is adapted to a cost-effectiveness type of analysis. In the context of the model framework that will be presented in this paper, we develop such an analysis through comparing the long-term tendencies of target sectoral aggregates and the ecological pressure indicators.

We stress that this approach is novel in that:

- Its application is at a macro-economic scale and projected through time, based on a scenario analysis of the Brittany area.
- The analysis is geared to take into account both the uncertainties concerning the variability of ecological pressure indicators and the economic potential for realising the ecologically adjusted economic growth paths.

The research is organised in three steps. First, we identify the main environmental functions of water in the Brittany area and emphasise the essential role of this resource both from an ecological and from an economic perspective. Then, we present the structure of the model used in our analysis. Finally, we show to what extent the methods support the cost-effectiveness analysis. Two dimensions are then considered, which are directly used in the measurement of the environmental performance of any environmental policy. The first one deals with the limited reliability on data related to water and soil pollution generated by agricultural practices. The second one aims at ranking the various formulated scenarios of agricultural policies, following a set of pre-defined priority order criteria. This way, the three steps followed lead to the identification of the problem and its (re)construction in view of formulating alternative solutions.

1. Critical Natural Capital in Brittany: from theory to practice

The objective of this first Section is to identify the roles played by water in the Brittany area. To do so, our analysis focuses around two themes: environmental functions and critical natural capital. The idea is, first, to present a theoretical framework of strong sustainability within which these two themes are developed (Section 1.1). Then, we will identify the environmental functions provided by water in the Brittany area (Section 1.2). Finally, so as to set the problem of maintaining good water quality directly in relation to the predominant influence of agricultural activities, the available information will be organised (Section 1.3).

1.1 Strong Sustainability and Critical Natural Capital

This sub-Section presents the analytical framework in which strong sustainability, critical natural capital and environmental functions are being examined. We will present the notion of strong sustainability, followed by that of critical natural capital.

Then, we will explain how critical natural capital can be identified, using the framework developed by Ekins and Simon (1999) within the CRITINC project.

1.1.1 The strong sustainability perspective

A 'strong sustainability' perspective which underlies the notion of critical natural capital as a focus for defining rules to maintain sustainability, can be summarised as follows (see Faucheux and O'Connor, 1999 ; Faucheux and O'Connor (eds), 1998) :

For an economic activity to be sustainable in the long run, the elasticity of substitution between the productive (economic) capital and the natural capital is close to zero, because the production processes have complementary production factors. Human-made capital is not independent from natural capital since its production most often requires the use of natural capital, not only as an input, but also as a type of structural support. Besides, natural capital fulfils some survival functions which cannot be provided by human-made capital (such as the ozone layer).

Technical change can have negative or only minor impacts on natural capital productivity. On the one hand, thermodynamic laws limit the possibility of matter and energy recycling. On the other hand, new technologies are not necessarily less polluting or beneficial to natural capital as a whole.

Sustainable development can then be defined as a permanent economic activity that can maintain the active properties of natural capital in the region or the country in which it takes place.

Sustainable development can be defined as a permanent economic activity that can maintain the active properties of natural capital in the region or the country in which it takes place. The approach adopted here is expressed in terms of joint production of economic goods and services concomitant to the reproduction and renewal of natural services and supports. So, if we observe figure 1, we can see that the management of economic resources must simultaneously fulfil two complementary functions (Faucheux and O'Connor (eds), 1998 ; O'Connor and Radermacher, 1999) :

It provides the basis for ecological welfare, while maintaining environmental functions and amenities (lower part of figure 1)

It ensures the basis for economic welfare with regards to the production of goods and services (higher part of figure 1)

In the figure, these functions are located in three parts (quadrants). The first quadrant (at the top of the figure) corresponds to the economic system (production system, etc.). The second quadrant (lower part of the figure) corresponds to the ecological system(s) through the interactions that exist between the components of natural capital. The last quadrant (on the right) is related to individual and social welfare. Various sorts of links exist between each of these quadrants. As the feedback arrows suggest, economic activities can have an impact on ecological systems. This impact can correspond to a degradation of the environment, related to the sink function for polluting substances emitted into the environment or to the physical disruption of features that are important for visual, scenic, or scientific reasons, or as the 'natural infrastructure' that supports economic activities, or to the quantitative exploitation of natural resources that will be used in the production process. Economic activity may also, in part, repair, restore or enhance environmental functions.

Goods and services, whether they are ecological or economic, all may contribute to human welfare. For analytical purposes, they can be considered as complementary, but in an asymmetric relation. Natural capital is perceived in terms of dynamic systems whose properties of interdependency are in perpetual evolution. When interpreted in this systemic way, natural capital constitutes the direct basic prerequisite both for human welfare and for the pursuit of any sustainable economic activity.

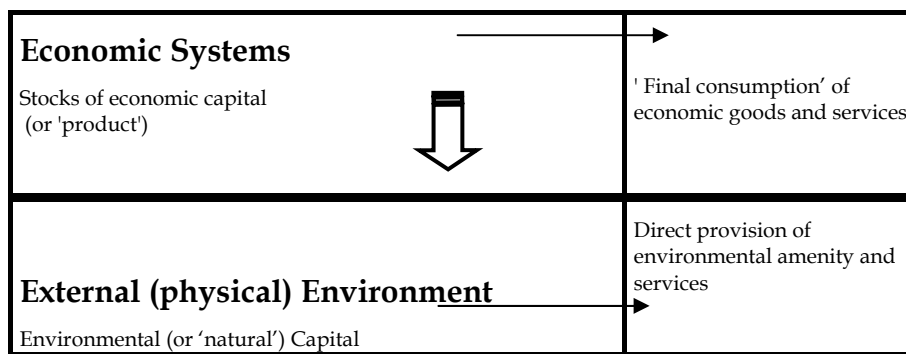


Figure 1 : Joint (re)production of economic and ecological goods and services
 (adapted from O'Connor 2000)

1.1.2 From Strong Sustainability to the notion of Critical Natural Capital

Once the basic notion of strong sustainability has been introduced, one needs to investigate the possibilities of 'translation' of its meaning, in terms of environmental policies. Two perspectives can be distinguished. One, rather substantive, can be considered as a 'conservative approach'. The other one, more procedural, will be called the 'institutional ecological economic' approach.

The simplest sustainability rule derives from the irreducible character of natural capital and can be described as 'conservative'. It states that:

$$\frac{dK_n(t)}{dt} \geq 0$$

this rule focuses on maintaining nature as it is, intact, which does rather imply that economic development should respect ecological constraints throughout time. Following this approach, the scale at which economic activities take place can be appreciated with regard to the natural capacities of ecosystems and environmental processes to generate energy, material and living resources, on the one hand, and the capacity of ecosystems to assimilate waste flows generated by economic activities, on the other hand.

The shortcomings of this approach appear when one attempts to derive and define from it, policies aimed at operationalising sustainable development. Unless there is a strong hypothesis (assumption) made concerning technical change, the conservative sustainability rule would imply some negative if not nil economic and demographic growth rates. If these rates were positive, we would observe, sooner or later, an increase in the energy and mineral consumption, responsible for both the exhaustion of the resource and environmental problems, in other words for the degradation and/or decrease of natural capital.

The second approach, also developed from an ecological economics perspective, advocates the respect of ecological constraints and the maintenance of the capacities of natural systems, but insists on an irreducibly *social* dimension of the analysis. The system analysis of natural capital seems more nuanced.

Natural capital is interpreted as a multi-dimensional matrix with a dynamic and complex way of functioning that must be analysed at different levels, taking account of its heterogeneous living and physico-chemical components. Also, the institutional ecological economics paradigm does not completely reject the possibility of substitutability between certain components of natural capital and technical capital, nor does it deny the possibility that technical change might have a beneficial role to play concerning the pressure on natural capital.

So, as in the work of Costanza and Daly (1992) or with the model developed by Barbier and Markandya (1990), the objectives of sustainability can be expressed through three main categories of ecological constraints, imposed on economic development:

- ❑ The use of renewable resources must not exceed their renewal rate
- ❑ Non-renewable resources must be exploited at a rate which permits their replacements by renewable resources
- ❑ The emission of wastes must be lower than the capacity of assimilation of the environment.

We can see here the emergence of the concept of Critical Natural Capital (CNC), underlying the rule of respect of the assimilation capacity of the environment and of the renewal of renewable resources. A CNC can be described as any component of nature *giving rise to important environmental functions at a given geographic scale, and for which no human-made or even natural substitutes exist*" (Noel and O'Connor, 1998: p.??).

A policy of sustainable development then necessitates that critical natural capital is submitted to Safe Minimum Standards (following the concept developed by Ciriacy-Wantrup, 1952; see also Bishop, 1978). These rules determine some exploitation thresholds that ensure the maintenance of critical natural capital. This perspective leads to the following sustainability rule :

$$\hat{K}_n^c \geq \Omega ,$$

where \hat{K}_n^c indicates a category of critical natural capital and Ω represents the safe minimum standard.

In order to generate some policy oriented empirical applications, three sets of questions should be solved concerning the safe minimum standards:

- ❑ *The definition and the measure of the categories of critical natural capital (At which geographical scale? What valuation units should be used? What are the perspectives concerning potential aggregations? etc...)*

- ❑ *The adequacy (or inadequacy) of a scientific determination of the norms that relate to the components of critical natural capital;*
- ❑ *How to choose between norms, if it is impossible to simultaneously respect all the critical thresholds at once.*

This is the reason why we introduce here the term ‘institutional’, as a way of emphasising the socio-political character of the problems of choices that one faces when confronted with the challenges presented by the sustainability or non sustainability characters of development patterns.

In this report, we provide some examples of responses to these questions and in this way illustrate ways of putting the concept of critical natural capital into practice.

1.1.3 The theoretical structure used to identify critical natural capital

In order to provide a framework for the operational the identification of critical natural capital, we employ systematically the notion of environmental functions of the natural capital. This approach is based on two main points : the identification of environmental functions of natural capital and the characterisation of the critical dimension of the environmental functions of the natural capital.

For Huetting (1980), and other researches following Huetting's approach in ecological economics (e.g. de Groot, 1992), a reasoning based on the notion of environmental functions is what allows a meaningful quantification of changes in quantity and quality of natural capital. The concept of environmental functions, related to that of sustainability allows us, on the one hand, to structure the information on environmental data (focused on components and processes of natural capital that can be classified as being ‘critical’) and, on the other hand, to understand better how important – and why - the various components and processes of natural capital are for human beings. It is then useful to distinguish between two fundamental dimensions (Fauheux and O’Connor, 1999; Ekins and Simon, 1999):

- ❑ The *internal functioning* of the natural capital systems, term which confirms the dynamism and structure that are intrinsic to ecosystems and physical processes (as life support and component of the biosphere); and
- ❑ The *functions provided* by the natural capital systems for (or, more exactly, evaluated from the point of view of) economic activities and human welfare.

The ‘regulation functions’, which ensure the stability and the permanence of the biosphere as a habitat for the whole of living beings and processes, are part of the first category of internal functions. In the second big category of functions, one can find the various ‘roles’ played by the biophysical environment for the benefit of human beings : source of energy and raw materials, sites for productive activities, transport, consumption and recreation, object of scientific and aesthetic enjoyment, place where wastes are unloaded and pollutants are, consequently, transported or deposited or assimilated.

This distinction between environmental functions can be done in the context of four categories of natural capital (water, air/atmosphere, soil and land, and habitats). For any given category of natural capital, four types of environmental functions are then distinguished :

- ❑ The *source* functions (for instance the rate of aquifer recharge)
- ❑ The *sink* functions (spreading and dilution of atmospheric emissions, in the case of air)
- ❑ The *life support* functions (maintenance of biological and genetic diversity for habitats), and
- ❑ The *human health and welfare* functions (for instance, the provision of a recreational and cultural area).

This classification thus offers a set of information that is related to the role played by natural capital in relation to ecosystems or human activities. Ekins and Simon (1999) suggest a presentation of this as follows:

I – Source functions

Renewable resources

1. Soil fertility
2. Forestry resources
3. Fish resources
4. Water resources
5. Renewable energy resources

Non renewable resources

6. Minerals
7. Fossil fuels
8. Land use

II – Sink functions

9. Stable Climate
10. Ozone layer protection
11. Air quality
12. Fresh water quality
13. Sea water quality
14. Soils quality

III – Life support functions

15. Biodiversity
16. Landscapes of exceptional beauty
17. Recreation, landscape, aesthetic

IV – Human health and welfare

18. Health (air, water and soil quality)
19. Risks

The identification of the environmental functions that need protecting, and of the way in which rules, strategies and protection policies are being defined, constitute important steps. The question we then need to address is how we can qualify some characters of the environmental functions of natural capital as ‘critical’, and this to be provided for under sustainability policy.

1.1.4 The operationalisation of critical natural capital and the formulation of a policy for strong sustainability

In our research, the critical aspect of natural capital is linked to the role of environmental functions in the process of sustainability. The goal of maintenance of functions is what underlies the setting of the norms or thresholds that can be related to specific components of natural capital. The notion of ‘criticality’ is used to signal the risk of a loss of certain environmental functions, the socio-economic contingency – which must be economically viable – and the social non-acceptation of this loss. This implies that the definition of the critical character of the environmental functions of natural capital is dynamic since it can evolve with time, depending on the expectations of the local population.

In view of identifying critical natural capital, we use the theoretical structure developed by Ekins and Simon (1999) in the CRITINC project. It is presented as follows:

| | | | | |
|----------------|---|---|---|--|
| Level 1 | Characteristics of Natural Capital | | | |
| | Components and processes of ecosystems thanks to which natural capital can provide environmental functions | | | |
| Level 2 | Four types of environmental functions | | | |
| | <i>The environment as a provider of raw resources</i> | <i>Capacity of the environment to abate pollution</i> | <i>The environment as a life support</i> | <i>The contribution of the environment to human health and welfare</i> |
| | Indicators: stocks of resources (e.g. fish stocks) | Indicators: quality of the environment (e.g. air quality) | Indicators: state of habitats and species | Indicators : effects on human health related to the environment, aesthetic benefits, recreational benefits |
| | Link between national accounts and environmental functions: the idea is to show which economic activities affect which environmental functions. | | | |
| | Pressure Indicators e.g. water consumption by the agricultural sector | Pressure Indicators e.g. CO ₂ emissions by transport | Pressure Indicators e.g. on habitat and species | Pressure Indicators e.g. health problems related to pollution |
| Level 3 | Sustainability: thresholds, safe minimum standards.... Related to pressure and state indicators | | | |
| | Sustainability norms | Sustainability norms | Sustainability norms | Sustainability norms |
| | Comparison between pressure and state indicators and identification of the sustainability gaps used when identifying environmental policies. | | | |
| Level 4 | Socio-economic analysis (multicriteria analysis) to contribute to the decision-making process | | | |

Table 1 : Structure of identification of Critical Natural Capital

This analytical structure comprises different levels. The first level consists in classifying the characteristics of each type of natural capital. It is by virtue of several characteristics that environmental functions can be provided. Our typology is adapted from de Groot's classification, 1992. In level 2, environmental functions are divided into four categories: the source functions, the sink functions, the life support functions (for the ecosystems) and the human health and welfare functions. This classification does not, however, illustrate the *links* that exist between the environmental functions of different categories. What it does, is allow us to distinguish between two direct effects on the environment, generated by human activities:

- ❑ Through the use of resources, we tackle the issue of the exhaustion of the resource;
- ❑ From the issue of waste management, we can highlight the pollution problem.

Thus, the depreciation or exhaustion of the resource not only reduces the stock of resource but it also threatens the capacity of the environment to abate pollution. These impacts concern the life support functions and the health and welfare functions.

Level 3 introduces the concept of sustainability, defined as the maintenance of important environmental functions. Sustainability standards (norms) that would provide for maintenance, are established and are compared to the pressure and state indicators of the situation focused on. This allows the identification of a sustainability gap that can be expressed in physical terms (Ekins and Simon, 1999). Expressed differently, this gap corresponds to the 'distance' - indicated in some sort of physical units or system parameters- between the current situation we are dealing with and environmental sustainability. The reduction of this gap can be considered as an objective of public policy.

The fourth level relates to the decision-making processes and policy tools that may be put to work for diagnosing and promoting sustainability.

This identification framework allows us not only to operationalise the notion of critical natural capital, but also to oriente environmental policies that are necessary for its maintenance. This is the theoretical structure that has been implemented in the case of the water quality degradation due to agricultural activities in the Brittany area, in France. The case study situation is characterised by a definite conflict of uses of resources. Huetting (1980) has developed the notion of competition between environmental functions in cases where the use of one environmental function occurs at the expense of another function – as it is the case when productive uses of environmental functions compete with the recreational enjoyment of the site. This point for the Brittany case is examined in more depth in Section 1.3.

Before focusing on it, we first need to identify the environmental functions of water in the Brittany area.

1.2 The identification of environmental functions

Using the distinctions made by Ekins and Simon (1999), we present the role of water in the Brittany area by using a typology that stresses four types of environmental functions: source (sub-Section 1.2.1), sink (sub-Section 1.2.2), life support of ecosystems (sub-Section 1.2.3), the contribution of the environment to human health and welfare (Section 1.2.4).

1.2.1 The Production (or 'Source') function

Brittany is generally described as a rainy area. The rainfall in this area can reach an average of 850 mm per annum due to the climatic disturbances coming from the Atlantic ocean. However, the general abundance of water does not preclude great geographic disparities. Low water levels can often be observed in rivers, at certain times of the year.

The variability of river flows is partly due to the weak permeability of the subsoil, which is mainly made of granitic and schistose rocks. Most of the rainy waters flows on the surface of the ground, creating a very dense hydrographical set of brooks, streams and rivers (from 6000 to 7000 km per department/region within the Brittany area). The proximity of the sea and the uneven relief of the granitic areas do not allow these flows to organise themselves into a hydrographical network per se. Thus, apart from the sedimentary basins that are drained by the Vilaine, one can observe hundreds of coastal water catchments that are isolated from each other (DIREN and Brittany Area 1998).

Due to its granitic and schistose platform, Brittany is not a very aquiferous area. The underground water that can be abstracted is located in little tertiary basins, in alluvium, or in deep cracks located in impermeable rocks such as sandstone. The watercourses are therefore fed, to a large extent, by surface flows. For an average year, average annual flows of water are maximum in the Monts d'Aree and reach 25 litres/second/km². They decrease towards the East of the area and become very low in the Rennes basin with only 5 litres/second/km².

An important feature is the construction of numerous dams aimed at supplying the mills, creating pisciculture ponds, developing canals for navigation and making sure they are supplied with enough water (e.g. the pond of Bosmeleac), producing electricity (e.g. the dam of Guerledan), ensuring the provision of drinking water or maintaining some minimum levels of flow.

The shortfall in groundwater has led to the use and abstraction of surface water for drinking purposes. Currently, more than a hundred abstraction points provide 80% of the adduction of water. In total, 268 million m³ of water are consumed per year. The withdrawals of surface water represent 82% of annual volumes of water and the consumption of drinking water amounts for 86.5% of these withdrawals (see Table 2).

| Consumption | | Industrial use | | Irrigation | |
|---------------|-------------|----------------|-------------|---------------|-------------|
| Surface water | groundwater | Surface water | groundwater | Surface water | groundwater |
| 190 217 | 39 486 | 25 526 | 8 166 100 | 4 056 200 | 485 800 |

Table 2 Water demand for drinking water in 1995 (DIREN and Region Brittany, 1998)

The industries use 80 million m³ of water (private consumption of surface and ground water and 'Drinking Water Supply'). This water enters the composition of the final product and can be used as a cooling and cleaning agent (cooling and cleaning of machinery...). Slaughterhouses, dairy industries and paper mills are amongst the biggest consumers of water and require good quality water.

But, in recent years, chemical pollution has degraded the quality of this vital resource, to the extent that some of the local populations and the restaurants of public institutions (such as schools, for instance) choose to consume bottled water, since the nitrate content of tap water has been reaching unacceptably high levels. This has become a major issue of regional governance. With the exception of a few tributaries of the Vilaine River, most of the water courses in the area have their sources within Brittany. This region can therefore be in control of the management of its water resources, both from a quantitative and a qualitative point of view.

1.2.2 The sink function

The degradation of water quality is linked to the presence of human activities that damage the water being used, or that emit polluting substances which then get carried away by rain water. The most important types of pollution are generated by households, and industrial and agricultural activities.

Household pollutions are characterised by the presence of pathogenic bacteria, suspended matter, organic matters, nitrates and phosphates. The higher the density of population is and the closer houses are to each other, the higher the pressure on the natural environment becomes.

Concerning industrial wastes, the farm-produce industries (189 such industries exist in the Brittany area) constitute a major source of pollutants in the water environment. More than 65% of the volume of pollutants are produced by three main sources of polluters: the slaughterhouses, the dairy industry and the vegetable canning industry. A high contribution also comes from chemical substances than can be oxidised, notably nitrates and phosphates. Chemical industries and / or surface treatment industries also generate some sub-products. Their pollution is calibrated as a function of their toxicity. The potential risk for the milieu is very localised in the region. Out of the thirty industries taken into consideration, six generate 80% of the pollution and five sites are at the source of 83% of the effluents: Fougères, Lannion, Saint Briec, Redon and Rennes.

Scientific studies carried out during the last years, show that the evolution of the concentration of nitrates in rivers could not be explained by the occurrence of organic pollutions that originate from urban environment or industrial activities. The emission of nitrates (generated by agricultural activities) in water has become the main cause for this degradation. This is why we focus on this activity in the rest of the study. The situation, which had strongly degenerated from 1987 to 1992,

seems to have been stabilised since then. Globally, in the Brittany region, 24% of water samples collected in 1997 have exceeded the threshold of 50 mg/l at least once and, in the case of 28% of water samples, maximum concentrations of between 40 and 50 mg/l have been observed during the same year (Region Brittany, 1999). It is in the Department of the Cotes d'Armor that the situation is the most worrying since, for one sample out of three, average concentrations of nitrates have exceeded the threshold of 50 mg/l. The same can be observed in the vegetable growing area of the Finistere.

The phytosanitary products (or pesticides) also constitute a source of water pollution. The main contamination of surface water results from the spreading of herbicides on sweetcorn crops and also their use in non-agricultural activities. In the case of agricultural usage, the % losses that are measured at the outlet are low (below 1%), compared with the quantities that are globally spread at the scale of the catchment. For non-agricultural uses, the spreading of herbicides on waterproof areas leads to them being directly transported to surface waters by run-offs, during rainy periods. The losses, in these cases, are very high, compared with the quantities that are being spread.

1.2.3 The function 'Equilibrium of ecosystems'

The environmental function 'life support of ecosystems' could be the object of very extensive ecosystem studies. It is approached here by looking at three indicators that we chose because of the consistency of their measure: the otter, the piscicultural population and the spread of algae.

- The first indicator we consider is the distribution of the European otter. The durability of this semi-aquatic mammal implies (i) a certain density of potential shelters (rivers and streams with banksides that are sufficiently rich in vegetation) linked to places that are very rarely visited by humans and (ii) a territory where water quality and availability are not seriously disrupted (*Eaux et Rivières Brittany*, no. 103). Although legally protected by the ministerial decree of the 17th of April 1981, the otter population is, in reality, exposed to the pressures of physical alterations of the landscape and chemical pollution of water, both of which constitute prime causes for the decline of this species. Following a national initiative, the setting up of the network SOS otter (based at la Maison de la Rivière a Sizun) has generated a pro-active attitude seeking to identify and prevent the causes of this decline. A toxicological programme initiated in Brittany has encouraged the examination of 24 European otters from 1987 to 1995. This work has highlighted trends in the contamination of aquatic biocenoses, in particular by heavy metals and pesticides.
- The second indicator that we focus on is the fish population. Fish constitute a good biological indicator of the state of the health of aquatic environments because of their position in the food chain. Factors such as steep slopes in the river, low depth, a moderate temperature in summer, and the quick current in running water favour the development of salmonid species, trout and salmon in particular. Brittany is the leading area for salmon fishery in France, with 70% of capture of Atlantic salmon by line fishing. Following the Conseil Supérieur de la Pêche, who compared the populations observed throughout 32 RHP stations (1990-1995 inventory), only 22% of the sample areas show a satisfactory population. In the case of half of the monitoring stations, the population stock shows some signs of disturbance (disruption signs) and 31% show some signs of obvious degradation. In the East of Brittany, this indicator is even more accentuated since all the monitoring stations show some disturbance in the fish populations.
- The third indicator focuses on the proliferation of green algae (like ulva) which happens in summer on certain beaches of Brittany. Studies carried out by IFREMER show that the cause of this proliferation is the increase in fluxes of nitrates. These phenomena have existed since the

beginning of the 1950s in certain sites (Baie de Saint-Brieuc, Baie de Lannion...) but have grown in importance and spread since then. In 1997, 50 sites were affected and the total quantity observed amounts to 200 000 tonnes (DIREN and Region Brittany 1998:39). The decomposition of these algae disturbs swimming/recreational activities and obliges local communities to restore the beaches. This cost greatly exceeds the million francs suggested by local authorities. SOURCE??

These three indicators are examples of the overall perspective necessary for an integrated management of water and aquatic environments (Eaux et Rivières de Brittany, no. 103:2). Due to the diversity of their determinants, they reflect numerous species and habitats. Their sensitivity to water quality degradation and their preservation corresponds to our desire for a framework that is focused on a large regional scale.

1.2.4 The contribution of water to human health and welfare.

So far, we have presented the key characteristics of water resources and the pressures exerted on them in Brittany. In this Section, we focus on the role of water and the impact of its degradation for the local population. Water can be used in different ways and aquatic environments support a variety of activities. It therefore seems difficult to inventory all the uses of water and aquatic milieux. We will therefore focus only on some of them, selected on the basis of their importance in the area.

- Recreational activities require good quality water. Beside fishing, one can also mention swimming in fresh water, water sports, not to forget the amenity value of the landscape. Freshwater fishing remains a very popular recreational activity in Brittany. In 1997, there were around 50 000 fishermen. Water sports are also well developed and constitute an important attraction for tourists, whose number was estimated at 1 310 000 ('tourist beds') in 1997, making Brittany one of the most popular tourist areas in France. Thus, any degradation of the image of this area, which owes its reputation to the naturalness of its landscape and to the protection of its environment, is likely to be extremely damaging for the whole set of the area's activities.
- Piscicultural activities have also been widely developed on salmonid watercourses. More than a hundred establishments produce around 14000 tonnes of salmonids (which corresponds to a quarter of the French production). The impacts of these activities as well as the existence of low flows disturb the natural environment. Their sensitivity to pollution makes it essential that upstream polluters take adequate precautions.
- Finally, the estuaries and certain portions of the coastal wetlands of Brittany are conchylicoles or fishing sites where shellfish are of high value. Brittany is one of the leading areas for the production of mussels and oysters (25% of the national production).

As we have shown, water is fundamental in Brittany. More particularly, there is a tension between extractive and in situ uses. Groundwaters are not abundant enough to meet the extractive needs of local populations and, as a consequence, surface freshwaters have started being abstracted for such purpose. Currently, more than a hundred water abstraction points provide 80% of water conveyance.

1.3 The importance of the role of water in the Brittany area

The previous step allowed us to highlight the multifunctionality of water and, more precisely, of its quality, within the Brittany area. The objective of this Section is to provide a picture of how water gets degraded, in a rigorous and systematic way. To do so, it is first important to identify the reasons why

the situation can be described as ‘critical’ (sub-Section 1.3.1). We will then highlight the existence of social conflicts concerning the themes of water management and orientation of agricultural activities (sub-Section 1.3.2). Finally, we will provide the analytical framework that allows us to integrate such information and to envisage various alternative options (sub-Section 1.3.3).

1.3.1 The sustainable quality of water

Water, as presented so far, plays various roles (source, sink, life support, contribution to human health and welfare). In other words, water plays an extremely important role in the environmental functioning internal to the natural capital systems and in providing services or functions that meet human needs in a more direct way.

Water quality can thus be considered as ‘critical natural capital’. Its maintenance is at the heart of sustainable economic processes. We note that activities such as aquaculture, farm produce industries, tourism, can be directly affected by the degradation of water quality (increase in treatment costs to obtain clean water, degradation of the image of the area). But more particularly, the agricultural sector, which constitutes one of the main sources of pollution, as well as being dependent on water, has to be scrutinised. This leads us to conclude that the notion of ‘criticality’ is not only related to

- *ecological dimensions* – which manifest themselves by, for instance, the spreading of green tides
- but also *economic levels* – because of the impacts that the degradation of water quality has on the regional economy (increase of production costs related to water treatment or to the attempt to improve the image of the area) –
- and, finally, to a *social level*, since water pollution plays a crucial role in the conflicts concerning the choices of orientation of development measures taken in the Brittany area.

On the basis of empirical studies, we identify three main themes of disagreement within the Brittany community:

- ❑ *The orientations of policies of restoration of the quality of water and, more generally, of the environment (for instance, a rejection of the project to construct a treatment plant),*
- ❑ *The denunciation of certain actions or non actions undertaken by some governmental institutions (for instance, officially permitting the illegal extension of pigsties, construction of pigsties in excedentary zones, non-transposition by the French government of the Nitrate Directive as a whole),*
- ❑ *The existence of claims related to the role played by the agricultural sector in the area (for instance, the idea of ‘terroir’, agricultural products of high quality...)*

These three themes are strongly linked to the question of the mode of production. The intensive system that is actually being developed in Brittany, is based on a concept of mass production with low costs and high returns. This has led to the regrouping of lands, the modification of landscapes, the decrease in levels of employment and the increase in the size of the farms, hence a strong dependency on the market and on the commercial bank system. All of this has contributed, on the one hand, to an increase in pollution due to increased concentration of polluting matters, an over-production crisis, and the ‘freeing up’ of markets. The problems generated by the management of surpluses reveal a certain laxism on the part of from national and local authorities.

This can be illustrated as follows. The Association ‘Eau et Rivières de Bretagne’ appealed to the European Commission in 1992 by lodging a complaint against the French Government for its defective/ faulty transposition of the EEC Directive n. 80 on the quality of water, aimed at direct

human consumption¹. The advice of the European Commission, in the last step in the legal procedure before submission of the case to the European Court of Justice, stipulates that 'by not ensuring the restoration of the quality of surface water aimed at human consumption, the French government did not fulfil its obligations'. One can recognise in this a key role of pressure groups on the state authorities, which is to make visible the failure to assure legal duties and the postponing of real implementation of policies. At the Brittany region level, this manifested itself in the formulation of new authorisations of farm developments in some areas that are already high in nitrates.

Whether motivated by political influence or by objectives of jobs protection, this legal action has put into question both results of and hopes put in the regulatory system. Thus, it is made clear that, although regulations do exist, the lack of motivation to implement them and the maintenance of contradictory political views decrease dramatically the overall performance. This applies concretely to the whole programme of actions called 'Brittany pure water' which was precisely aimed at respecting the European regulations².

The problem is two sided since it requires a refereeing between the exploitation of natural resources and of the rural space, and its protection in terms of life support environment. The divergence of views on this matter highlights the duality of the production system in Brittany : one side is productivist, while the other seeks to put less pressure on the environment. The management of water quality and the development of agricultural activities in the Brittany area are directly linked because of the interdependencies that exist at an ecological level; economy and ecosystems are in close co-evolution. In this context, one can list numerous actors (policy-makers, farmers, consumers, citizens), interests (protection of the environment, rural development) and of impacts (on the environment, human health, and land-use).

In summary, this situation can be characterised by the existence of a conflict between value systems that view the evolution of the economy in the region in radically different ways. Two themes are at the heart of the debate: (i) a conflict between the uses that can be made of resources extracted from ecosystems, and (ii) a conflict in terms of choices concerning the production methods.

1.3.2 Conflicts concerning the objectives to pursue

Although economic tools were orientated towards the development of technically oriented solutions (subsidies in the context of PMPOA, etc.), the implementation of water treatment systems, and ensuring that farmers and fertilisers users are better informed, the selected measures did not result in what was originally expected. The problem is not related to the *choice* between various incentive schemes but, rather, to the *structural orientations* of agricultural activities. Thus, the confrontation between two general options, concerning the future of this area, constitutes a real problem that opposes the citizens' lobby to the farm-produce industry lobby.

The conflicts between these two social groups come from the way in which they identify the final objectives to be reached, the methods to be implemented (questioning of agricultural systems of production, opposition to the instalment of water treatment plant...), and the political influence

¹ This Directive has been transposed in the internal legal system by a series of decrees (3rd of January 1989, hence 9 years after the European Directive) and of circulars (1th of April 1990) which allowed nitrate (and other products) contents that exceed the maximum acceptable amounts.

² The Government, the regional authorities, the local authorities and the Water Agency in Loire-Brittany committed themselves to the implementation of a programme of restoration of water quality. The strategy of this pro-active policy lies on a strong mobilisation of all the actors. The actions took place in 20 water catchments.

(predominance of elected politicians or people working in administrations with an agricultural background).

1.3.2.1 The agricultural lobby

The legitimacy of the agricultural lobby, whose claims are more or less strongly expressed, lies on the development of the agricultural sector since the end of the second World War. The type of development adopted generated a certain cohesion around the objective of *progress* within the Brittany society, progress which consequently became directly related to the development of the agricultural sector. The agricultural lobby therefore focuses on a strong mobilisation and structuration of the agricultural sector.

The agricultural lobby is made of various entities which reflect different modes of production - porcine, poultry, vegetables, dairy products,... It is integrated, to a large extent, within the agro-industrial system, and is close to unions such as the FNSEA (National Federation of the Farmer Unions) and the CDJA. It seeks to protect the interests of the farmer profession. This lobby is characterised by a strong mobilisation - for instance during the strike at the prefecture of Morlaix in 1961 and at the road bridge in Morlaix in 1998 -, as well as a strong influence on economic and political milieux.

Recent poultry, porcine and vegetable production crisis have, once again, showed how persuasive the agricultural lobby can be when opting for an agricultural model based on world competitiveness (see Canevet, 1992). This latter is characterised by a strong dependency on markets and competition - and hence by a certain fragility related to the way in which mass production is being preferred to production systems with high value added and to the high dependency of the agro-industrial system.

Another weakness of this system of production is that it generates negative impacts on the environment.

The Brittany area is strongly influenced by this phenomenon of modernisation of the society. Confronted to the successive crisis generated by this mode of production, the agricultural lobby is in the process of re-orientating itself, with the objective of taking into account certain social expectations (quality products, preservation of the environment, jobs protection) while not questioning the very foundations of the new modes of production it embraced. However, these claims remain largely sectoral, although their advocates highlight the links between the development of the agricultural sector and that of the region as a whole.

Certain social groups (association for environmental protection, of consumers, of farmers) are strongly opposed to this position.

1.3.2.2 Structuring a citizen counter power

The formulation of this counter-power was based on the establishment of a link between numerous movements with varying interests. Grouped in associations or 'communities' ('Collectif Coherence' was created in 1998, 'Collectif Pure Water' in 1992), some advocates of water protection, consumers associations, farmers, and more generally citizens who are keen to protect the environment, all highlight the inconsistency between the measures taken to fight against environmental degradation, the need to respect environmental regulations, and the necessary evolution of mentalities and of systems of production, in particular in the agricultural sector (see Network sustainable agriculture (1998, 1999)). All agree that environmental quality restoration programmes, and those aimed at improving

agricultural practices, are noticeably weak. Moreover, they denounce the legalisation of illegal extensions of pigsties and the inconsistency of the orientation taken by environmental policies (general lack of implementation of the Nitrate Directive, weakness in the application of the MAE, diversion from the logic of the PMPOA).

Originally concerned by local problems, some of these associations have broadened their range of actions and claims³. Nowadays, this protest movement constitutes a real counter-weight to the intensive agriculture lobby and intervenes in the decision-making process both concerning the definition of norms and the implementation of actions.

The reversal of situation observed during the Guingamp trial (1996), is perhaps the most visible effect that resulted from this rise in power. This issue had a media effect at a national scale, although it directly affected only 180 consumers. It constituted the first step towards the questioning of the current system of water management. It is important to highlight the important role of the media who, by providing information to local populations on a regular basis, gave rise to a real rise in environmental awareness. Various actions have been initiated from then, which focused on themes as varied as water management in the centre of the Brittany area (1998) and agricultural orientations (meeting in Pontivy, 1999). The impacts of these actors are varied since they both improve the environmental awareness of local populations and have an impact at the political and legal levels (see table 3).

The position defended by industries that are in charge of the distribution of water is also noticeable in that they have adapted their strategy as a response to problems caused by water degradation. Accused and condemned for having distributed water which did not comply with European norms, they and certain associations (Eaux et Rivières de Bretagne), took the French Government to court for having badly transposed European environmental regulations. The water companies highlighted the inconsistency of the position taken by the French Government who encourages actions that limit the impacts of agricultural activities on the environment, while still not questioning, nor forbidding, the development of certain cattle breeding, and not condemning either farmers who are in illegal situations.

Mid-way between the agricultural lobby and political power, the pressure groups find their legitimacy in the emphasis placed on the claims coming from different entities of the society. This approach is therefore not sectoral, as is the case of the agricultural lobby. Instead, it is citizens-centred.

This opposition between various social groups highlights the existence of different value systems which lead to different orientations concerning the development of agricultural activities in the region.

Table 3: Synthetic representation of protest actions against the degradation of water quality in the Brittany area.

| ACTORS | OBJECTIVES | MEANS OF ACTION | YEAR |
|---------------------------------------|---|---|------|
| 180 Consumers in the town of Guingamp | <u>1st objective:</u> legal action against the 'Lyonnaise des Eaux' (Water company) for not respecting drinking water norms. <u>2nd objective:</u> the water company denounces the French Government | <u>1st objective:</u> legal action at the national scale <u>2nd objective:</u> legal action at the European scale <u>3rd objective:</u> denounce the increase of the water bill. | 1996 |

³ For instance the association Eaux et Rivières in Brittany, previously called 'Association for the protection of salmon in Brittany', had been created to protect the stock of salmon, viewed as a real patrimony of the area. This association became a group for the protection of the environment and of the consumers in 1989.

| | | | |
|---|--|--|------|
| | for not respecting the nitrate Directive <u>3rd objective</u> : question current water treatment investments for their non sustainable character | Mediatization at the national level water price relation price-quality of water People realise that water is produced by rivers The protection of rivers if not only an environmental objective. | |
| 200 households in St Brieux | Denounce the attitude of public authorities concerning a real water policy. Inadequation between the price increase and the decrease in water quality. Weakness of financial aids targeted to environmentally friendly types of agriculture Use of charges to fund the PMPOA Refuse of pollution/ depollution cycle In favour of the precautionary principle with regards to the impacts of water degradation on human health | Non payment of amounts corresponding to the charge in the water bill | 1996 |
| Association of consumers for the protection of the environment (Eaux et rivières de Bretagne) | Environmental awareness amongst the population Drinking water and protection of the environmental milieu Techniques to treat the water Land use management (PMPOA) Increase in water bills | 1 st of January 1998: ERB can present: 45 definitive decisions, 67 running procedures, 71 debates of the administrative council concerning contentious actions. | 1996 |
| Group 'Pure water' - includes numerous associations of consumers and farmers in favour of env ^{al} protection. | Water as a common source of interest Drinking water and protection of the environment Water treatment techniques Land use management (PMPOA) Increase in water bills | Environmental awareness campaign Using media, demonstrations -as was the case for instance in St Brieux where thousands of bottles were left in front of the prefecture. | 1992 |
| Coherence group, including numerous associations of consumers and farmers in favour of environmental protection. | People realise the shift in agricultural practices and its effects on water policies | Demonstrations in Pontivy in June 1999 | 1999 |

1.3.3 Suggestion: analysis of the scenarios using a cost-effectiveness approach

As we just showed, the role of water is fundamental in the Brittany society. The degradation of its quality jeopardises the whole set of human activities and destabilises the natural environment. We have distinguished between the various environmental functions provided by water (the *source*, *sink*, and *life support* functions and the contribution to *human health and welfare*).

From a graph composed of three quadrants – economic system(s), ecological system(s) and a third quadrant that relates to human health and welfare - it is possible to represent the various links that highlight the various environmental functions (see Figure 2):

- (i) the impact of the economy on environmental resources as inputs in production processes or as sink in the case of economic wastes

- (ii) the links between the ecological systems and human health and welfare (impact of the degradation of water on health, ...)
- (iii) the links between the economic system and the individual and social welfare (incomes derived from the production, consumption of goods...).

By approaching the notion of environmental functions in the Brittany area, we have highlighted the multiplicity of uses of water (consumption, recreational activities, ...), of actors (policy-makers, farmers, consumers, citizens), of interests (protection of the environment, rural development) and of impacts (on the environment, human health and land use).

This graphical representation allows us to illustrate the degradation of water in the Brittany area, while integrating it in a context that is broader than ecological systems. In particular, we were keen to emphasise the impacts that exist at economic and social levels. Our approach aims at stressing the fact that bad water quality has a strong impact on human activities and at identifying polluting activities. This leads us to address the question concerning which modes of regulation are capable of ensuring a sustainable management of water resources.

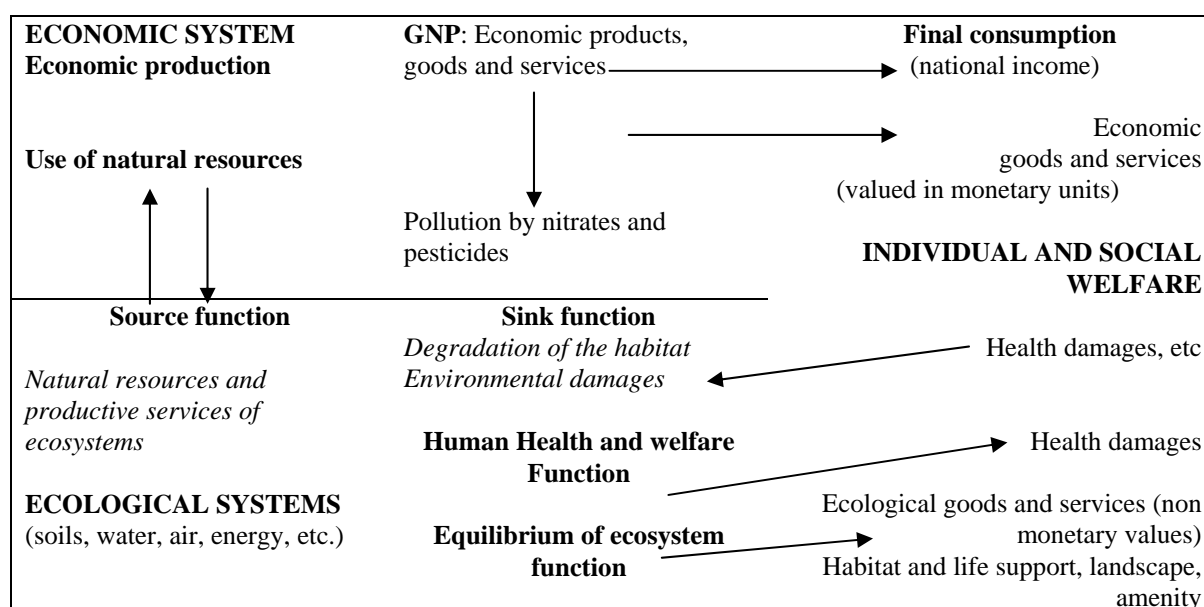


Figure 1. Joint (re) production of economic and ecological goods and services (adapted from Brouwer, O'Connor and Radermacher, 1991)

2. A structural approach for the analysis of regional scenarios

So far, we have presented an analytical framework that deals with the degradation of water in the Brittany area. The difficulty lies in evaluating the costs that are generated by the operationalisation of a sustainable development strategy. The methodology said 'of sustainability costs' will be presented in the Section 2.1. When looking for modes of adjustment focused on the regulation and governance of the economy, we will focus on the agricultural sector, which is one of the main water polluting group of activities (Section 2.3). Finally, in view of apprehending the environmental impacts related to the modes of agricultural production, we will look for environmental pressure indicators that seem to be the most relevant to illustrate the situation (Section 2.4).

2.1 The "sustainability costs" methodology

Once the problem of water quality degradation has been apprehended in a new way, we need to integrate, in the analytical framework, the 'sustainability cost' methodology that is focused on costs associated to the search for a sustainable development alternative.

To do so, we will proceed in three steps:

- ❑ identification of modes of adjustment (sub Section 2.1.1.)
- ❑ 'sustainability costs and strong sustainability approach (sub Section 2.1.2.), and
- ❑ presentation of the M3ED modelling example (sub-Section 2.1.3)

2.1.1 The identification of modes of adjustment

In our structural perspective (see Faucheux & O'Connor (eds.) 1998; Brouwer, O'Connor & Radermacher 1999), economic resource management for sustainability must fulfil (at least) two complementary functions:

- ❑ the delivery of an ecological welfare base, through ensuring the maintenance of critical environmental functions and amenity (lower portion of Figure1), and
- ❑ the delivery of an economic welfare base, through the production of economic goods and services (upper portion of Figure1).

In this perspective, environmental quality is considered to be a primary support for human welfare and for sustainable economic activity. Policies aimed at safeguarding this primary support function — that is, meaning to commit scarce resources in order to maintain or recover the desirable level of environmental quality — correspond to a kind of « social demand » for maintenance of environmental functions.

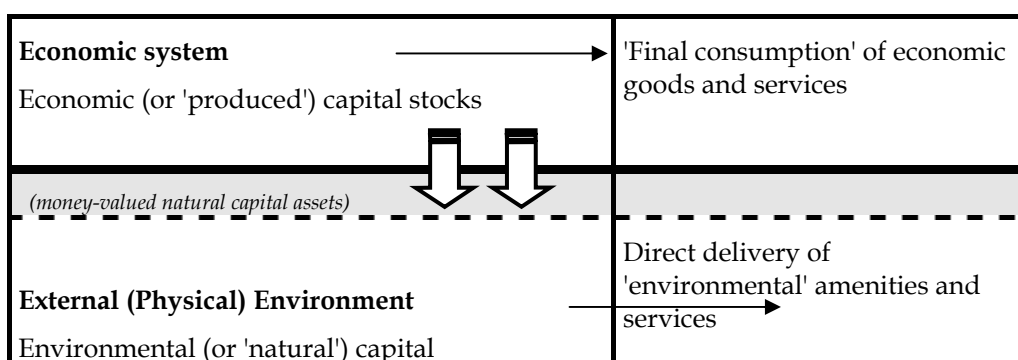


Figure1 — Framework for defining 'environmentally-adjusted' macro-economic aggregates

The term 'greened national accounts' refers to national accounting systems extended to include information on the state of the environment and on interactions (e.g., 'pressures') between economy and environment. The environmental and interface accounts will include some stock and flow information categories expressed in monetary value terms, and others in non-monetary units of measure. It is, however, crucial to define clearly the respective roles of monetary and non-monetary measures for the various categories of information. In economics, it is habitual to ask if the value of a benefit obtained, or of the loss avoided are worth the investment of economic goods and labour needed to obtain it? Yet the 'demand' for environmental quality, which may include provision for future generations and a demand for protection from environmental harms, cannot easily be expressed as a value in monetary terms. And, even when estimates can be made, the numbers obtained often have very large sensitivity to underlying parameter assumptions concerning possibilities and elasticities of substitution, endowment and income distribution, technological progress prospects, ecological system resilience, and so on. These are challenges to be confronted for quality and usefulness of indicators.

As a first step in typology of procedures for defining 'environmentally adjusted' macro-economic indicators, we refer to the above diagram (Figure 3) in order to define two types of adjustment, which are complementary rather than exclusive. There are distinct the types of macroeconomic aggregates associated with each adjustment type (and later Sections of the paper will discuss the policy uses, also complementary, of each indicator type).

- ❑ The first type of adjustment, relative to standard national accounting conventions, is a change in the system boundary, an enlargement of the scope of national accounting to include specified categories of environmental assets. In Figure 1, this can be thought of as a shifting of the frontier (the heavy horizontal line) dividing the economy from its external environment. This shift brings some environmental capital (such as minerals, oil and gas, forest or fisheries stocks) into the field of economic accounting, signalled by the fat arrows pointing downwards.
- ❑ The second is *adjustment of the economy itself*, that is, an 'adjusted economy' with a new pattern of production processes, levels of production and consumption activity, technologies employed, etc., which respects specified environmental performance standards. In Figure 1, the focus of attention is on the interface between the economic system and its environment, the heavy horizontal line, which is 'crossed' by environmental pressure indicators such as natural resource inputs and pollutant emissions. The volumes of these 'environmental pressures' are to be regulated through adjustments to the economy (technical and structural change).

We now consider how each of these adjustments can be the basis of a useful sort of 'environmentally adjusted national income' figure. Table 4 below outlines the four combinations of adjustment logically possible, and identifies each combination with established measures and concepts in the green accounting literature.

- ❑ The **TOP LEFT** box refers to the 'traditional' macro-economic indicators based on the 'standard' national accounting conventions for estimating GNP and NNP.
- ❑ In the **TOP RIGHT** box, there are 'environmentally adjusted net national income' figures for an existing economy. These are based on using an enlarged asset boundary when assessing net asset change for the national economy during the current accounting period. The 'environmentally adjusted national income' or 'green NNP' is then defined as this net asset change (net savings) minus national consumption. Both consumption and asset changes are valued using current prices (or, in the case of some environmental assets for which real prices don't exist, using shadow prices obtained by reference to other goods or costs for the current

period). We refer to this as *the 'environmentally adjusted' or 'green' NNP for an unadjusted economy*.

- In the **BOTTOM LEFT** box, there are *the 'unadjusted' GNP and NNP for an 'environmentally adjusted economy'*. These are figures obtained for a hypothetical economic structure, using suitable statistical and analytical techniques, responding to the question: *What would be a feasible macro-economic performance, is the existing economy were modified so as to respect specified environmental performance standards?* We refer to such figures as *'greened economy GNP'* (or greened economy NNP, as the case may be). Such figures may be obtained in several ways, the most obvious being comparative static and dynamic scenario modelling analyses. (This is the approach developed in the European Commission's *GREENSTAMP* project in 1994-96, which in turn built on experience with 'greened economy' scenarios since the 1970s.)

| | | System boundary (capital stocks included in the measure of asset value change) | |
|---|---|---|--|
| | | <i>Usual set of produced economic assets</i> | <i>Enlarged to include all produced assets plus specified environmental assets</i> |
| Reference economy for estimation | <i>Statistics for the current really existing economy</i> | The traditional or 'unadjusted' GNP and NNP (NNP = net savings – consumption) | World Bank 'genuine savings' indicator: An 'environmentally adjusted' indicator for an enlarged portfolio of national assets |
| | <i>'Shadow aggregates' for a model economy respecting environmental performance standards</i> | The GREENSTAMP approach: GDP and NNP 'volume' measures for an <u>'environmentally adjusted economy'</u> | — |

Table 4 — Typology of 'environmentally adjusted' aggregates

The top right and bottom left boxes each involve only one of the two forms of 'adjustment' to estimation procedures. The bottom right box provides, logically, for indicator measures that combine both types of adjustment together, but this option is not needed for present purposes.

Our "strong sustainability" approach is based on the proposition that the maintenance in the long-term of economic welfare levels requires the sustaining, in a functional symbiosis, of economic and natural capital. The physical environment is considered as a complex system, and one may speak of (1) the 'functioning of' natural systems — the internal regulation, cycles of renewal, evolution and transformation by which biosphere activity is maintained; and (2) the specific roles or services provided by natural systems that support economic activity and human welfare — that is, the environment's 'functions for' the human economy.

2.1.2. Sustainability costs and the strong sustainability approach

In the "strong sustainability" perspective it is postulated that, in general, it may not be possible to find full substitutes for this ensemble of functions fulfilled by a given environmental asset. Nor can technological progress be considered to apply in any uniform way to these functions. This leads to the following framework for developing sustainability criteria and rules:

- The identification of categories of 'critical natural capital' whose stocks ought to be maintained at or above some specified minimum levels.

- ❑ The problem of resource management for maintenance of essential and desired environmental functions is approached in terms of cost-effectiveness. The requirements are, first, to determine environmental standards or norms, for example, for pollution emissions or natural resource consumption, in physical terms, independently of any notion of economic optimisation; and second, to find the least-economic–cost way of achieving the defined norm.
- ❑ A separation is thus maintained between ecological sustainability objectives as such, and the question of economic requirements for attaining them.

In order to give an operational specification to this general framework, supplementary information and analytical propositions must be introduced. These include:

- ❑ Explanation of the spatial and temporal scales at which the sustainability criteria will be applied;
- ❑ The scientific or other justifications for the threshold levels or 'norms' that are proposed;
- ❑ Explanation of the analytical framework that will be applied to quantify the economic opportunity costs associated with the respect of the specified standards, including whether or not full respect is required immediately or via a transition path over a number of years;

This approach explores the question, what might a 'greened' or 'environmentally adjusted economy' look like that respects the specified sustainability standards? It is thus a scenario-type approach. This distinguishes the approach from the ex post definition of an environmentally-adjusted GNP for the existing economy. The policy-relevance of this sort of analysis is also different. Since the question is how to adjust the economy, attention can be given to the likely difficulty (in terms of short-term economic costs and social adjustment processes) of satisfying simultaneously a large number of sustainability standards on the basis of available science. This helps to frame policy debates.

In this approach, indicators are developed that measure the *cost of achieving sustainability*. In effect, a monetary figure may be sought for the minimum cost that would have to be borne in order, through preservation, prevention, protection or restoration measures, to respect the designated sustainability norms. This would be a quantification of the opportunity cost of achieving sustainability. Since scarce economic resources will have to be engaged to achieve environmental goals (such as restoration activities, pollution abatement or natural–capital augmenting but higher-cost alternatives for production), this opportunity cost can, in principle, be expressed in money terms as an amount of consumption that would have to be forgone by the society to achieve or maintain the specified levels of environmental functions. In effect, the analysis aims at quantifying the policy trade-off between: (i) depleting/degrading environmental functions (critical natural capitals) by not making the adjustments required to satisfy the norms; and (ii) forgoing consumption and/or using up economic capital if it makes the resource commitments required for achieving the norms.

Recent reports and papers by members of the C3ED have presented examples of empirical work carried out in this norm-based cost-effectiveness perspective, using a dynamic multi-sector scenario simulation model for a national economy (see O'Connor & Ryan 1999; Schembri 1999a, 1999b).

2.1.3. The example of the M3ED

These analyses are close in spirit to methodological perspectives developed in the research project "Methodological Problems In The Calculation Of Environmentally Adjusted National Income Figures" carried out during 1994–1996 for the European Commission Directorate General XII under Contract No. EV5V-CT94-0363. Now known as *The GREENSTAMP Project (GREENed National*

Statistical and Modelling Procedures), this work focussed on the development of empirically and theoretically robust methods for quantifying economic opportunity costs associated with meeting specified sustainability standards at the sectorial and macroeconomic levels of analysis (see Brouwer & O'Connor 1997a, 1997b; Brouwer, O'Connor & Radermacher 1999). In particular, *GREENSTAMP* investigated prospects for statistical estimation and modelling procedures for quantifying the long-term economic performance potential based on cost-effectiveness relative to “satisfying” criteria in a scenario perspective. The concept of “greened GDP” recommended was that of a performance potential, viz.:

an estimate of the level of output (or of consumption, or of national income, etc., depending on the exact measure proposed) that a national economy would have been able or might in the future be able to achieve while simultaneously respecting specified environmental quality and resource husbandry requirements.

The value of environmental assets and services is not estimated in monetary terms directly. Rather there is a modular approach. First, information is organised in so-called satellite environmental accounts which describe the state of the environment according to chosen categories and measures (largely non-monetary) and which establish links between economic activity sectors and environmental change in terms of the pressures acting on each environmental category. Second, cost information is obtained through various levels of analysis (firms and households, sectors and macro-economic aggregates) about the economic resource requirements — such as investments or consumption foregone — that would be necessary in order to reduce a specified environmental pressure. In this way estimates of the costs of specified improvements in environmental performance can be considered in relation to scientific, political and economic judgements about the importance of the environmental functions, services and assets in question.

For the present analysis, we consider the French national economy as a backdrop, and develop more disaggregated scenarios for the agricultural sector at the Brittany region level. The national economy is portrayed with the simulation tool *M3ED (Modèle Economie Energie Environnement Développement)* as it has been developed at the C3ED (Schembri, 1999a, 1999b gives a full mathematical specification). The modular *M3ED* structure is as follows:

- ❑ A *population module* (or sub-model) simulates the national population based on three different age groups: those under 35 years, 35-60 years, and over 60 years.
- ❑ A *household module* uses the output of the population model and assumptions about household structure to calculate the total number of houses of different types.
- ❑ A *final consumption module* specifies the demand for each of the different types of good. (Present versions use a disaggregation into 16 categories of final consumption.) The number of houses of each type will affect the demands for each of the types of goods and services. Assumptions can be made about change over time of the pattern of demands for goods from each household type.
- ❑ The *production module* relates the demand for the different goods types back to the different production sectors of the economy. This uses an input-output representation of a multi-sector economy. Six main sectors are distinguished, and a modular disaggregation process can then be applied for specific purposes. A matrix describes the proportions in which the different categories of goods are derived from the production sectors.
- ❑ For model closure, the domestic production sectors are complemented by *imports and exports* ; and household (final) consumption is complemented by *government expenditures*.

- ❑ For the quantification of *environmental pressures*, the specification of production sectors and of final consumption is augmented by coefficients specifying average natural resource requirements, and/or pollution emissions from, each sector in categories of interest.

In a 1994-1996 study, a set of simple scenario themes were developed for *M3ED* analysis of the quantitative relation between household consumption and atmospheric emissions for France and the Netherlands. In this analysis, scenarios were developed for atmospheric emissions linked to energy use (notably CO₂, NO_x, VOCs, and SO₂). The four scenario themes were:

- ❑ 'Stagnation' (Tendencial Bleak);
- ❑ 'Business As Usual' (Tendencial Rosy);
- ❑ 'Sustainability through Technological Breakthrough' (Technology);
- ❑ 'Sustainability through Reflexive Consumption' (Sus-Cons).

In the 'Sus-Cons' scenario the choice 'for sustainability' is made by renouncing economic growth as the primary policy priority; in the 'Technology' scenario, the technological progress permits output growth and environmental quality and safety to be achieved simultaneously.

A lot of empirical data are implied in the model specifications, based on national statistics on inter-sectoral flows (input-output tables) and hypotheses about technological changes prospects for efficiency and mix of primary and refined energy uses. The latter illustrate the sense in which this "strong" approach seeks to characterise ecological and economic system potentials in physical and technical terms, rather than relying on prices as putative signals of opportunity costs. Model simulation results for economic output and carbon dioxide emissions for France over a forty year horizon, are shown in Figure 4.

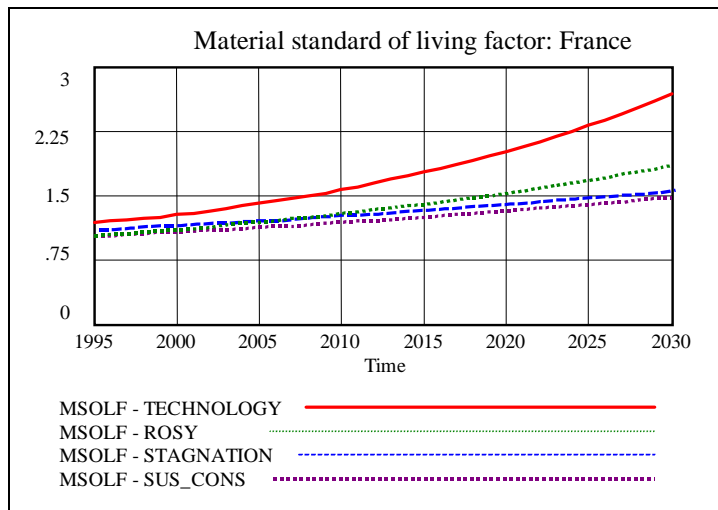


Figure 3 Material standard of living factor

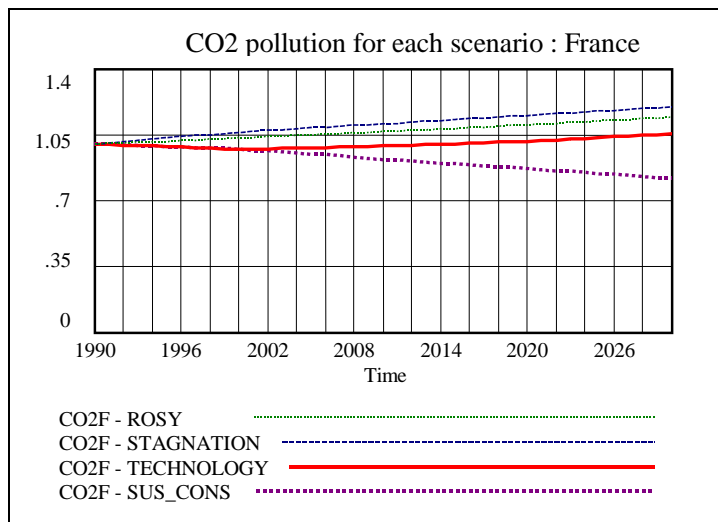


Figure 4 — Economic output and CO₂ emissions scenarios for France

The *M3ED* scenarios for ‘Technological Breakthrough’ and ‘Reflexive Consumption’ provide estimates of feasible final consumption of economic goods and services in an economy where technical innovation and/or consumption change measures are taking place, motivated by the objective of reducing environmental pressures. We have defined a ‘greened economy GDP’ as the national final consumption that can be delivered while respecting specified environmental norms for the scenario time-horizon. A ‘greened economy GDP’ measure, or time-series (as obtained with the scenario models), is intended as an indicator about possible future performance integrating economic output and environmental standards as complementary criteria of performance. The definition thus provides for the construction of time-series of greened-economy GDP figures (on a period by period basis), which could, for example, correspond to a scenario of transition towards an environmental performance judged sustainable in the long run.

Aggregate measures for ‘greened’ or ‘adjusted economies’ with differing severity of environmental constraints, have obvious policy relevance. Making the distinction just above helps keep the question of what really constitutes sustainability. In the post-Kyoto greenhouse gas emissions case just illustrated, the French economy is being required to meet politically decided standards; these may be only a drop in the global bucket as regards climate stabilisation requirements. Nonetheless, the idea of a measurable macro-economic adjustment cost associated with maintaining environmental standards is clearly illustrated.

For a benchmark, take the Tendencial Rosy (Business as Usual) scenario. For France, in Figure 4, household aggregate consumption increases by 80 per cent from 1995 to 2030, and CO₂ emissions are rising monotonically to reach about 20 per cent higher than the 1990 level in 2030 (the lightly dashed curves labelled ‘Rosy’ in the graphs). Relative to this benchmark, the environmental norm of zero per cent increase in French emissions might be obtainable by:

- ❑ consumption pattern or lifestyle change measures that reduce consumption of material goods, perhaps in favour of greater appreciation of environmental amenities (thus, in the graphs, the heavy dashed scenario outputs labelled ‘Sus-Cons’, sustainability through reflexive consumption); or
- ❑ natural capital augmenting technological innovation measures that (one way or another) decrease per unit environmental pressure associated with economic production and/or final

consumption (thus, in the graphs, the scenario outputs labelled ‘Technology’, sustainability through technological breakthrough).

The ‘adjustment cost for sustainability’ is measured as the dynamic trade-off between final consumption and reduction in environmental pressures — viz.

- ❑ *the cost* in terms of foregone consumption signalled by the ‘gap’ between two curves in the upper graph, representing respectively ‘Business as Usual’ (the Tendencial Rosy scenario) and a path for transition towards sustainability; and
- ❑ *the benefit* of achieving the path of reduced environmental pressures signalled by the gap between the ‘Rosy’ and the specified sustainability scenario emissions curves in the lower graph.

From comparison between ‘Rosy’ and ‘Technology’ curves, it appears that, for the next two or three decades, a *win-win* (or double-dividend) policy path might be feasible, where a high pace of natural-capital-augmenting technological innovation, appropriately targeted, can improve prospects for final consumption while also improving environmental performance to respect sustainability norms. From comparison between ‘Rosy’ and ‘Sus-Cons’ scenarios, it appears that a substantially improved environmental performance may be achievable while still achieving modest consumption growth. Indeed, if the benchmark were taken as the more pessimistic ‘Stagnation’ (Tendencial Bleak) scenario, also shown on the graphs, then it can be suggested that changes in social attitudes plus technological change plus public investment may improve greatly environmental performance without impairing macroeconomic output performance at all.

The same approach can be adapted for a regional economy analysis, at a sectoral level, and this is what we will now present, for Brittany agricultural production in relation to environmental pressures bearing on water resource quality.

2.2. Agricultural activities in the Brittany area

Less than half a century ago, Brittany was described as a relatively poor area dominated by subsistence small scale mixed farming. In only one generation time scale, a model of intensive agriculture, largely open to the market economy, was introduced in this area and provided up to 12% of the value of total French production from only 5% of the agricultural surface (Canevet, 1992). After more than 30 years of continuous growth, the porcine, poultry and dairy production of this area is now ranked very high at the national level. The dynamism of Brittany, its complex network of professional organisations and the density of the farm-produce industry plants have upset the mixed farming system and favoured the development of an industrial type of agriculture.

Using the *Tableaux de l'agriculture Bretonne* (Agreste, 1997), it is possible to organise the economic information on agriculture in Brittany as follows (Table 5)

| AGRICULTURE IN BETAGNE | | 1970 | 1996 |
|--|--|--------------|--|
| <i>Importance of agricultural activities</i> | Proportion of farmers in the area | 24% | 8% |
| | Weight of Brittany agriculture at the national level | | 3,1 % du PIB brut |
| | Weight of agricultural activities at the regional level | | 7,1 % du PIB brut |
| <i>Agricultural structures</i> | Farms | 150 915 | 61 300 |
| | Families of farmers | 590 600 | 217 539 (1995) |
| | Permanent salaried employees | 33 800 | 6 189 (1995) |
| | Used agricultural surface (ha) | 1 986 559 | 1 838 800 |
| <i>Agricultural incomes</i> | Values of animal deliveries (million francs) | 4 064 | 36 106 |
| | Values of vegetables deliveries (million francs) | 759 | 5 309 |
| | Intermediary consumption (million francs) | 1 523 | 28 058 |
| | Amount of subsidies | | 1 781 858 000, i.e. 42 651 francs per farmer |
| <i>Activities linked to agriculture</i> | Net turnover of farm-produce industries [IAA] (million francs) | 14 133 | 95 665 |
| | Gross Value Added at factor costs | 1 842 (1975) | 11 698 (1995) |
| | Average number of salaried employees in the IAA | 30 645 | 51 007 |

Table 5 : Economic Situation of the agricultural sector in the Brittany area (Agreste 1997)

These figures reveal the importance of agriculture for the local economy: thus, in 1997, it contributed to 7.1% of the gross regional product and to 3.1% of the gross domestic product. The 61 300 regional farms, although of middle size (on average 29 hectares in 1996), provide 21% of the national production in milk, 56% of the production of pork, 31% of that of veal, 47% of that of chicken, 49% of that of turkey, 75% of the production of cauliflower, 72% of that of artichokes and 36% of the production of early potatoes. Following the agricultural growth, the farm-produce industry has become a fundamental economic sector in Brittany. The transformation of animal production ensures half of its turnover.

The Brittany area has become the first agricultural area of France, in which agricultural activities are characterised by their strong integration in the market economy. This is reflected, on the one hand, by the importance of intermediary consumption (fertilisers, phytosanitary products) and, on the other hand, by the ability of market fluctuations to affect the agricultural sector. Recent developments are

also characterised by a concentration of the means of production and the focus on certain products (see Table 6).

| Agricultural production in the Brittany area | 1966 | 1996 |
|--|-----------|-----------|
| Bovine meat (tonnes) | 148 997 | 275 651 |
| Porcine meat (tonnes) | 241 370 | 1 140 806 |
| Chicken (tonnes) | 125 531 | 548 589 |
| Turkey (tonnes) | 3 193 | 300 691 |
| Delivered milk (million litres) | 1 597 | 4 667 |
| Surface where fodder plants grown (ha) ... | 1 165 615 | 1 129 250 |
| ... amongst which sweet corn (ha) | 76 774 | 353 000 |
| Wheat (tonnes) | 513 000 | 2 108 800 |
| Sweet corn grains (tonnes) | 30 000 | 664 600 |

Table 6: Agricultural production in the Brittany area in 1996 (Agreste, 1997)

All the signs illustrate a strong quantitative growth in the agricultural sector. Brittany appears to be highly specialised in animal production. Canevet (1992:26) notes that 'despite the non negligible specialisation in the production of certain vegetables (which made the reputation of the area), the intensification of animal production is such that animal products still represent from 88% to 90% of the final agricultural production while, on a national average, plant crops dominate slightly'. This specialisation is based on two major types of production (dairy and porcine products) and on poultry and bovine meat products whose production, far from being negligible, is less preponderant. Consequently, despite the recent shifts in production created by the quotas imposed on dairy products and the crisis of porcine production, 90% of the land use in Brittany remains focused on products such as sweet corn, used to feed the cattle.

2.3 Classification of agricultural practices

From these observations on the Brittany area, we have identified one form of '*tendential*' agriculture and three alternative agricultural systems (the '*reasoned* agriculture', the '*economical* agriculture' and the '*biological* agriculture').

2.3.1 The intensive-productivist type of agriculture

The tendential agricultural practice pursues an intensive-productivist type of agriculture and does not take ecological disruptions into consideration. Any agricultural impact on the environment, and more specifically on water, can be limited - only - by using restoration methods (de-nitrification equipment and treatment of water).

The intensive-productivist type of agriculture is the type of agriculture that, at present, we find most in France and in the Brittany. It has permitted, for several decades, a process of economic accumulation, and it is thanks to it that the country has become more than self sufficient in food products. But this success also has had a variety of undesirable effects on the natural environment, as we have already discussed.

2.3.2 The *reasoned* agriculture

The 'reasoned' intensive-productivist agriculture scenario uses management practices that aim to improve farming efficiency through a comprehensive approach, for the physical, social and economic dimensions of farming. Production techniques and programming are suggested, that are adapted to the specificities of each plot of land and of each agricultural practice. The intensive character does not disappear, but the wish to limit the impacts of the activity on the natural environment encourages the development of a 'precision' type of agriculture.

In order to formulate this scenario, we have been guided by the programme of action developed by the National Association FARRE⁴. This NGO considers that 'reasoned agriculture constitutes a return to traditional principles of agronomy and agricultural practices, but implemented with new rational management methods that have been introduced through 'systematic agriculture' (Besnault, 1998). A convention has codified the rights and obligations of the farmers, in the context of this network.

The 'reasoned agriculture' scenario thus represents practices aimed at reconciling the use of fertilisers to the real needs of the crops, while taking account of the presence of certain elements in the soil and of the production potential of the plant. This implies a specialisation of agricultural systems and leads to an increase in the efficiency of the production techniques. It therefore requires pedological analysis to identify the effects that fertilising agents will have on the soil, and also some methods of calculation to estimate the plants' needs. Concerning the protection of plants, the 'reasoned' methods reject systematic treatment. They start with the observation and the identification of 'thresholds of harmfulness', at which point it would become necessary to implement treatment techniques. Reasoned agriculture also deals with cattle breeding and, more specifically, with the feeding of animals, the construction of buildings in which cattle breeding is taking place, and the management of effluents.

In short, the reasoned type of agriculture 'sets some balanced production objectives, influenced by the objective analysis of environmental risks and of the fragility of the milieu, but capable of providing some economic results optimised by the farmer' (Thiaux, 1995:12).

2.3.3 The *economical* agriculture

A type of 'economical agriculture', which aims at substituting the extension of used surfaces for the sole objective of productivity, does not present the characteristics of an *extensive* type of agriculture. On the contrary, economical agriculture, while respecting certain economic constraints concerning the amount of required output, attempts to respect the agronomic principles of balance between soils, plants and animals. It is an intensive-productive type of agriculture which relies on an economical and autonomous approach of agricultural practices (less energetic wastes, less European funding). This type of agriculture is largely inspired by the research of the CEDAPA⁵. The economic efficiency comes within the scope of an approach of crop and cattle breeding agricultural practices that are viewed as 'economical' and these must not be considered as separate from technical choices and production methods, from their coherence concerning their link to the global management of the production unit' (A. Pochon, 1997:176)⁶. The CEPADA has summarised this process in 6 key points:

⁴ FARRE means Forum for reasoned Agriculture that respects the Environment. In this scenario, we have focused on the 'reasoned' dimensions of agricultural practices. However, the figures that we reached do not seem to correspond with that provided by this association (FARRE, 1 rue Gambetta, 92100 Boulogne).

⁵ CEPADA, 2, av. Du Chalutier sans pitié – Bat. Groupama – BP 332 – 22 193, Plerin, cedex.

⁶ Also see Pochon, A. (1991) From the field to the source; rediscover pure water. CEPADA, and Pochon, A. (1998) The fields of possibility: advocating sustainable agriculture. Syros and Alternative Economics.

The principles of *economical* agriculture

1. Balance between plants, soil and animals.
The idea is that what is produced by the soil must adequately correspond to what the animals consume. The excrements of the animals should provide to that same soil the nutrients needed to maintain the fertility of the soil and its humus.
2. The balance between cattle breeding and crops allows to vary the systematic rotation of crop. The fallow years allow the reconstitution of humus; earth worms proliferate, the structure of the soil becomes softer and easier to cultivate. The crops that will follow will benefit from the mineralisation of the nitrate.
3. The cultivation of crops that are adapted to the soil and to the climate.
4. Cattle breeding in buildings where the ground is covered with straw rather than concrete.
5. Ruminants, bovines and ovine animals must be fed with grass for as long as possible. Big quantities of grass can be obtained at low cost and without having to use fertilisers, through the cultivation of leguminous plants such as the white clover.
6. A good investment is a 'reasoned' investment. Agricultural productivity depends a lot on the fertility of the soil base. The maintenance of this fertility constitutes a real productive investment; it can be done through the restitution of the elements generated by the plants from the crop.

The principles of *biological* agriculture

1. To produce sufficient quantities of agricultural products with highly nutritive value
2. To work in agreement with natural ecosystems rather than trying to dominate them
3. To promote and diversify the biological cycles in the management of agricultural systems while respecting micro-organisms, the fauna and flora, the crops and the cattle.
4. To maintain and improve the soil fertility in the long run
5. To use natural resources that are renewable locally, as much as possible
6. To install agricultural systems that are as self sufficient as possible concerning organic matters and nutritional elements
7. To ensure that the living conditions of the animals allow them to exteriorise their specific behaviour
8. To avoid any form of pollution resulting from agricultural practices
9. To maintain genetic diversity of agricultural systems and their environment, including the protection of wild plants and animals
10. To reward farmers for their work in a fair way and provide them with a safe and secure working environment
11. To take into account the impact that crops techniques can have on the environment and on the social fabric.

2.3.4. *Biological* agriculture

The scenario for a *biological* type of agriculture represents a category of alternative practices that, like the previous type of agriculture, are based on the questioning of an intensive-productive system. It puts great attention on the *quality* of the products and *human health*. Also called 'sustainable agriculture', due to its technical, economic and social aspiration (since it is aimed at the protection of the environment), it is based on the precise knowledge of the bio-geo-chemical cycle of the plant rather than on the narrow analysis of the nutritional requirements and of their systematic chemical protection. Sustainable agriculture encourages us to think in a coherent and integrated way about our activities and about the ecosystem and the biosphere (recycling of organic matter, management of the soil and of plots of land, biological fight against crops'

diseases and parasites).

The economic actors who implement 'biological agriculture', in particular the farmers, use a variety of practices that respect the ecological equilibrium, the soil fertility, the environment and animals welfare. For example, they use crop rotation techniques, they choose crop varieties that are adapted to the soils and the climate, and they forbid cattle breeding in confinement. The data that we have used in this study have been provided by the Groupement des Agriculteurs Biologiques des Cotes d'Armor⁷ (Association of Biologic Farmers of Brittany) or have been collected in the documents related to the

⁷ GAB, 2, av. Du chalutier sans pitie – Bat. Groupama – BP 332 – 22193, Plerin, cedex.

schedule of conditions of biological agriculture (Ministry of Agriculture)⁸. The International Federation of Biological Agricultural Actions (IFOAM) has specified, in such a document, that the main objectives of biological agriculture are given in the frame presented above.

The biological agricultural methods are based on the maintenance of living beings in the soil (especially bacteria and earthworms), thanks to crop rotation and to the maintenance of a high organic matter content. The products that can be used as fertilisers and to eliminate insects and crops diseases carefully listed. Chemical fertilisers, herbicides, insecticides, and synthetic fungicides are forbidden. Biological agriculture favours the use of organic manure (from the cattle, guano, sea algae, plant wastes). Raw organic matter must be composted before being used, i.e. subjected to an aerobic fermentation process. Finally, the spread of nitrates must not exceed 170 kg/ha, except in the case of fertilisers that are derived from pork breeding, for which the limit is 140 kg/ha.

2.3.5 Key concepts related to these four types of agriculture

The types of agriculture presented above reflect the diversity of the *scales* taken into consideration, as well as the *priorities*. Established by using our observations, a hierarchy of the main *social values* related to the scenarios –economic profitability, environmental protection, and impacts on the territory – has been formulated. The numbering system illustrates the order of priority (see Table 7).

| SOCIAL VALUES/ SCENARIOS | <i>Economic profitability</i> | <i>Protection of the environment and of the quality of products</i> | <i>Territorial impacts</i> |
|--|---|--|--|
| <i>Intensive-productivist agriculture</i> | ① Necessary for the survival/maintenance of the local economy and agricultural activity, Mass production, Reliance on the market and aspiration to minimal costs | ③ Only constitutes one necessary element in the production process (production factor) | ② Territorial development is necessary to ease commercial exchanges (motorways, airports...) |
| <i>Reasoned Agriculture</i> | ① Aspiration to a minimal cost and to a gross excess of maximal exploitation, importance of intermediary costs and importance of the market | ② Selling argument for agricultural products or used in the management of framsdans (norm 'ISO'), importance of the image given, better use of inputs | ③ Objective: maintenance of agricultural activity in the Brittany area, strong links with the farm-produce industries |
| <i>Economical Agriculture</i> | ② Objective: high value added, less inputs used, less European fundings | ① Integration of environmental considerations at the farm scale (as production factor) and from a more general angle | ③ Dynamic type of agriculture preferred, especially if it creates jobs |
| <i>Biological Agriculture</i> | ③ Objective; high value added | ① The agricultural activity evolves in harmony with natural processes | ② Objective: human and animal welfare, job creation |

Tableau 7 : Formulation of a hierarchy of priorities in each type of agriculture

This typology allows us to highlight the key ideas concerning each type of agriculture and a comparison of the hierarchy of priority can be formulated. Economic profitability is expressed as a recurrent theme in terms of aspiration towards *low cost mass production* in the two first cases of agriculture. In the two last types of agricultural system, it is a *high value added* that is pursued. Another major theme is the protection of the environment and of the quality of agricultural products.

⁸ Decree of the 21/12/92 on the approval of the texts on biological modes of production in cattle farming as well as the law no.80-502 of the 4th of july 1980 on the orientation of agriculture as amended by the law no.1202 of the 30/12/88 (JO. 31/12/88).

These are not viewed as a good commercial argument in the case of the two first types of agriculture whilst they constitute an integral part of the production process for economical and biological agriculture. Finally, territorial impacts are viewed as modes of development (national and regional development, infrastructure, employment...).

If the economic dimensions can be approached by using economic indicators such as agricultural production, productivity, profitability ... (see Section 2.2), environmental dimensions present a problem of choice between pressure indicators. The next Section focuses on this particular issue.

2.4 Definition of environmental pressure indicators

The objective of this fourth Section is to identify the indicators that illustrate the environmental pressures that come from agricultural activities.

Until 1990, the analysis of the degradation of water quality was limited to the notification of any increase in the nitrate content of water and of the eutrophication of continental waters. The importance of non point (diffuse) water pollution, created by phytosanitary products, has been progressively realised and highlighted.

Very probably, it is the visibility of their impact that has made nitrates the main focus of attention. Indeed, this pollution is characterised by eutrophication phenomena that give rise to a lack of oxygen in natural environments and to the development of 'green tides' (43 000 tonnes of algae (*ulves*) were collected in 1997). The whole of the Brittany area has been classified as a Nitrate Sensitive Area under the Nitrates European Directive (no.91/676 of the 12 December 1991), and 71 districts have been listed as Zones of Structural Excesses, in which more than 170 kg of nitrates of animal origin are found per hectare⁹. This clearly shows the importance of damages created by nitrates.

Analyses of water quality in the Brittany area, observed since 1971, highlight an increase of average nitrate content from 8.5 mg/l in 1972 to 39 mg/l in 1994 (DIREN and Region Brittany, 1998). Numerous water samples exceed, or have occasionally exceeded, the threshold of 50 mg/l that is imposed by the Drinking Water Quality European Directive 80/778. Some water abstraction units have had to invest in de-nitrification equipment, as has been the case, for instance, on the Horn and the l'Arguenon. The forecasts for 2005 anticipate an excess of nitrate norms for two third of the water abstractions in Brittany if nothing is done to change the situation.

Soils are also affected by the risk of eutrophication, when excessive quantities of nutrients generate a decrease in oxygenation in the soils and stop micro-organisms from functioning normally.

Nitrates come mostly from agricultural activities under the form of animal faeces, synthetic fertilisers and industrial and domestic wastes. The main source of pollution, which generates 60% of nitrates of animal origin in the Brittany area, is cattle (bovine) farming. However, this activity does not constitute our main anti-pollution target, probably because of the diffuse character of the pollution it generates and because of the decrease in the size of the livestock that has taken place as a consequence of the imposition of milk quotas. Instead, the main accused target sector is pig raising. The 25% of nitrate pollution that this latter activity generates have a more concentrated impact that is also much more visible and odorous.

Excessive fertilisation is another main cause of pollution by nitrates. It generates two main problems:

⁹ The four 'departements' of Brittany have been classified as 'vulnerable zones' by the Prefect of the area, who is also the Co-ordinator of the Loire-Brittany Basin, on the 14th of September 1994.

- An excess of nitrates, compared to the expected crop uptake: this can be caused by a superfluous use of nitrates aimed at ensuring a good return, or by a bad estimation of what amount of nitrates does actually remain in the soil. In this case, improving the measurement of crops' requirements and soils' contents constitute a means to limit an otherwise excessive application of fertilisers.

-An excess of nitrates related to the difference between the expected and the actually realised crop output: this corresponds to an ex-post excessive fertilisation. The higher the expected output, the greater the chance that another factor will become an obstacle in the growth of the plant and that some unused fertiliser will remain in the soil. Aiming for a high productivity hence increases the probability of not achieving the original objective, due to the deficiency of another growth factor. Even if agronomic techniques can improve the adequacy between the expected output and the outcome actually generated, external parameters can still, at any time, limit the size of the crop compared with what it was originally hoped to be, even if these techniques have been carefully and rigorously analysed.

Two further causes for the increase of nitrate in water can be added: the evolution of agricultural practices (drainage, fallow lands during winter...), and the enrichment of the soils with inorganic nitrate.

It is therefore the very *logic of intensive agriculture* that is at the heart of the problem.

Since the 1960s, scientific analyses have shown the impacts of *pesticides* on the environment. However, in the Brittany area, these started being seriously taken into account only in the 1990s¹⁰. This can be put down to three reasons: the nature of the products, an insufficient knowledge of pollution due to the difficulties related to its measurement and, finally, the number of users of pesticides.

Following the generalisation of the use of pesticides (mixtures of active substances¹¹, additives and inert matter), a new type of pollution, more complex than that related to nitrates, had appeared. As described by R. Giovanni (1998:26) “*One can talk of a generalised type of micro-pollution (atmosphere, soils, water, sediments, living beings) because of the high number of molecules involved (200 of them can very likely be found in Brittany), of their uncertain diffusion in various environments, and of the difficulties in quantifying them (from nanogramms to a few micrograms) as well as stopping them from moving from the field to the tap or the sea*”.

The most often detected substances in rivers are soil insecticides and herbicides used in corn or cereal crops or in the maintenance of non-cultivated land. The main substances with high concentrations in the Brittany area are the triazines (atrazine, simazine) and substituted urea (isoproturon, diuron)¹². Studies carried out on eight catchments (Arguenon, Fremur, Gouessant, Rance, Flume, Meu, Seiche, and Aven) have showed the predominance of five molecules in the rivers (see Table 8).

| Character | Active matter | Number of studies | Number of detections | % of detections | Quantity spread | % number of sample > EU norm 0.01 µg/l |
|--------------|---------------|-------------------|----------------------|-----------------|-----------------|--|
| Agricultural | Alachlorine | 13 | 10 | 76.6 | 9 396 | 46% |

¹⁰ In Brittany, the way in which residues from phytosanitary products and biocenoses impact on water quality has been examined in numerous studies since the 60s – for example, see the Bulletin Technique des ingenieurs des Services Agricoles, no. 224, 1967; Cahiers de nutrition et de Dietetique, no. 4, 1979.

¹¹ European Directives define active substances as matters, micro-organisms and viruses that have a specific or general effect on harmful organisms or on plants, part of plants or plant products.

¹² Prefectorial decrees have regulated the use of atrazine and diuron for the four departments in Brittany since the 1st of September 1998.

| | | | | | | |
|--------------------------|-------------|----|----|------|--------|------|
| weed-killer | | | | | | |
| Agricultural Weed-killer | Atrazine | 53 | 48 | 90.5 | 55 115 | 92% |
| Metabolite of atrazine | DEA | 52 | 47 | 90.4 | | 71% |
| Agricultural weed-killer | Isoproturon | 21 | 19 | 90.4 | 38 134 | 86% |
| Insecticide | Lindane | 13 | 12 | 92.3 | 17 341 | 767% |

Table 8: Results from the analysis of pesticides in 8 catchments

The consequences of the contamination by pesticides are extremely complex since, although they are, *a priori*, used against very specifically targeted organisms, the pesticides are liable to also have a toxic effect on organisms which had not originally been targeted. The problem is very serious since these substances are xenobiotic (whose objective is to kill): during the phytosanitary treatments, from 40 to 75% of the spread substances fall on the ground, or volatilise, hence potentially reaching the nearby ditches, and then streams.

The effects of pesticides on the environment are difficult to study in the field. They depend on the multiplicity of substances that are used, whose impact is not correlated just to *quantities* but also to a *set of chemical and physical factors*: the run-off, the solubility, the life expectancy (indicator of half-life), the absorption (KOC, measure which allows to compare the soils from the share coefficient between carbon and water), the volatility, and the responses to ionisation and degradation (metabolites: i.e. the decomposition of the mother-molecule into other molecules that are just as toxic).

Finally, the variety of users (farmers, SNCF, local authorities, private households...) also constitutes a source of difficulty concerning the implementation of measures aimed at limiting the impacts of pesticides. In the case of the Brittany area, agricultural activities use 4000 tonnes of active substances, but these are the cause for only half of water pollution problems in Brittany, the other half being attributed to the use of merely 100 tonnes of these substances by non farmers ('Sunday gardeners' use 50 tonnes and the other 50 tonnes are used by SNCF, Direction Departementale de l'Equipement...).

So, the sectoral profile in the case of pesticides is not the same as in the case of nitrates. In the latter case, agricultural activities are responsible for 80% of degradations linked to excessive use of nitrate fertilisers, and thus, are appropriately the main target. The same is not true in the case of phytosanitary products. Indeed, these products are used for both agricultural and non-agricultural activities. Also, the contamination patterns evolve differently depending on whether the molecules are mobile and residual or not. Lindane, for example, is less mobile than atrazine.

For all these reasons, the pesticide situation seems more complex than the case of pollution by nitrates.

Following this, we will specifically focus on the problem of *nitrates* since it is easily integrated in the M3ED modelling analytical representation (see Section 3). The case of pesticides will be examined later.

3. Modelling the scenarios

So far, our approach has consisted in (i) the identification of an environmental problem - that of the degradation of water quality in the Brittany area- and (ii) the presentation of the analytical framework and of the derivation of variables that seem to us to be particularly relevant to help in implementing some alternative measures, developed in view of limiting the impact of agriculture on the environment.

In this third Section, our objective is to develop a modelling technique, the M3ED-AGRI, in view of, first, envisaging the trends taken by the previously identified types of agriculture. Then, the M3ED-AGRI will be used as a methodological basis to formulate a cost-effectiveness type of analysis which will integrate economic and environmental considerations.

To do so, four steps will be followed: we will first present the M3ED-AGRI (Section 3.1), then the cost-effectiveness analytical tools (Section 3.2), then the scenarios results (Section 3.3) and, finally, the discussion concerning these results (Section 3.4).

3.1 The regional AGRI model

The AGRI model focuses on the supply of multi-agricultural products and is applied here only in the context of the Brittany region. First, we present the structure of the model M3ED-AGRI (sub Section 3.3.1). Then we give details concerning the agricultural production (sub-Section 3.3.2) and the environmental pressure indicators (sub-Section 3.3.3).

3.1.1 The structure of the M3ED-AGRI model

The M3ED-AGRI model is a module that represents agricultural activity in the Brittany area.

The link between the M3ED and the M3ED-AGRI concentrates on the *growth rate* of the national economy - and, more precisely, on that of the agricultural sector -, rate provided by the M3ED and used in the M3ED-AGRI (see Douguet and Scembri, 2000).

The M3ED-AGRI is used to examine the influence of the variability of water quality norms on physical yields coming from agricultural production. In other words, we are trying to stress the existence of the adjustment costs that the agricultural sector would be submitted to if such or such measure were to be adopted in view of protecting the environment. The modelling technique, based on the dynamic dimension of systems, seeks to highlight the elements of conflicts that occur when resources are being allocated between the plant and the animal production sectors, as well as to establish some limits to a growth path in the long run.

The desagregation of the agricultural module M3ED-AGRI is carried out by respecting the existing main posts in agricultural production, that is, the plant and animal production activities. It then seeks to differentiate between the various types of crops and breeding. Each 'plant production' sub-module provides some information concerning nitrate, phosphoric and potassium products, the needs for phytosanitary products, and this information is then related to the used surface. Similarly, each sub-module 'animal production' indicates the quantity of water being consumed and the dejection related to that activity. Each sub-module also illustrates the quantity of required technical capital.

Another particularity of this approach is that the modelling technique takes into account the nitrate, phosphate, and potassium (coming from animal origin) inputs, on the one hand and, on the other hand, the export of the these same elements by the plant crops. In a certain way, we re-trace the nitrate cycle.

This approach seemed essential to us, both from a methodological perspective and because of the importance of animal production in the Brittany area. These two categories appear in two tables at the end of Table 9.

| INPUT TABLE | | PRODUCTION | | | | | | EXPORTS |
|-------------------|-------------------|----------------------|-------------------|------------------|---------|------------------|--|------------------|
| | Production animal | | Animal Production | Plant Production | Surface | Total Production | | Plant Production |
| Organic Emissions | Ai | Organic fertilisers | - | Bi | Si | | | Exi |
| | | Chemical fertilisers | - | | | | | |
| | | Pesticides | - | Pi | Sp | | | |
| | | Water | Oa | Ov | | | | |
| | | Surface | Sa | Sv | St | | | |
| | | Total Production | Xa | Xv | | Xt | | |
| | | Proportion in France | | | | Xf | | |
| | | Proportion in Europe | | | | Xe | | |
| | | Export | | | | Ext | | |

Tableau 9 : The structure of the M3ED-AGRI module

Ai represents the nitrate, phosphorus and potassium emissions that come from animal production;

Bi represents the plants' needs in nitrate, phosphorus and potassium, per hectare

Pi is the rate of use of pesticide per crop

Oa is the water consumption by the cattle; *Ov* is the water consumption for irrigation

Sa is the animal density

Sv is the yield per hectare

Xa and *Xv* are, respectively, the animal and plant productions

Si is the nitrate, phosphorus and potassium concentration

Sp is the rate of use of pesticides per hectare

St is the total usable agricultural land; *Xt* is the total agricultural production in the Brittany area

Xf is the weight of the agricultural production in France, while *Xe* is the weight of French agricultural production in Europe

Ext is the agricultural production which will be exported

And *Exi* represents the levels of nitrate, phosphorus and potassium that are exported by the plant crops.

3.1.2 Agricultural production

The AGRI model of agricultural supply thus integrates the diversity of structural farming conditions in the Brittany area, as well as the potential for substitution between the various agricultural and cattle breeding practices¹³. The model allows us to estimate, at a regional level, what the adaptation costs of the farmers' supply might be, following the setting of regulations aimed at protecting water quality.

The regional production, which is made up of crop and animal components, can be formulated as follows:

$$Q_{AGR}(t) = a_v(t).Q_{AGR}(t) + a_a(t).Q_{AGR}(t)$$

$$a_v(t) = \frac{\sum Q_n(t)}{Q_{AGR}(t)} ; n \in N$$

$$a_a(t) = \frac{\sum Q_b(t)}{Q_{AGR}(t)} ; b \in A$$

In the equation, t represents the date at which the various alternative agricultural options start being implemented (year 2000 in the context of our simulations). Any x parameter acts as a control parameter, in the formulation of tested scenarios.

3.1.2.1 Plant productions

The plant (vegetal) crop production depends on the yield per hectare, on the used surface and on a growth factor linked to the demand for agricultural products:

$$Q_n(t) = \begin{cases} \rho_n(t).S_n(t).\varpi_v(t) & \text{pour tout } t < \bar{t} \\ \rho(\Phi(\varepsilon_n, t), \bar{\rho}_n).S_n.\varpi_v(t) & \text{pour tout } t \geq \bar{t} \end{cases}$$

$$\varpi_v(t) = \frac{Q_v(t)}{Q_v(0)}$$

$$\rho_n = \frac{Q_n(0)}{S_n(0)}$$

ρ_n corresponds to the yield per hectare for the crop n.

ε

represents the time that is necessary to reach an objective of productivity.

is a function of distribution of a time lag and

$\Phi(\varepsilon_n, t)$

¹³ The data needed for the modeling come from IFEN, EUROSTAT and the AGRESTE. In the context of the integrated model AGRI, the agricultural output is estimated in volume (initial/ base year: 1990).

S is the surface and ω is the growth factor.

Depending on the objective of productivity previously defined, we can measure the impacts of different types of agricultural practices on the use of pesticides, and the net emissions of nitrates.

(See Table 10)

Table 10 : Parametric configuration in the case of (plant) crop productions

| | wheat | corn | barley | oat | Fodder | colza |
|---------------------------------------|---------|--------|--------|--------|---------|--------|
| Exports* | | | | | | |
| Kg of nitrate per quintal | 1.9 | 1.5 | 1.5 | 1.9 | 1.2 | 3.5 |
| Kg of phosphorus per quintal | 0.9 | 0.7 | 0.8 | 0.8 | 0.55 | 1.4 |
| Kg de potassium per quintal | 0.7 | 0.5 | 0.7 | 0.7 | 1.2 | 1.0 |
| Production | | | | | | |
| Surface in ha** | 165 384 | 62 642 | 67 100 | 20 272 | 284 504 | 21 280 |
| Return q/ha** | 78 | 70 | 70 | 55 | 111 | 32 |
| Phytosanitary products | | | | | | |
| Emission rate | 0.037 | 0.037 | 0.037 | 0.037 | 0.037 | |
| <i>Average number of treatment***</i> | | | | | | |
| Herbicides | 1.4 | 1.4 | 1.2 | 1.5 | 1.5 | |
| Insecticides | 1.5 | 1.1 | 1.3 | 2.6 | 1.2 | |
| Fungicides | 2.2 | 1.1 | 1.7 | 1.7 | 2.3 | |
| Fertilisers** | | | | | | |
| Kg of nitrate per quintal | 3 | 1.79 | 2.64 | 4.14 | 1.40 | 8 |
| Kg of phosphorus per quintal | 0.53 | 0.49 | 0.97 | 0.74 | 0.307 | 1.308 |
| Kg of potassium per quintal | 0.862 | 0.8 | 0.99 | 1.218 | 0.505 | 2.154 |

* norms CORPEN ** AGRESTE (1991) *** Bonny et Carles (1993)

3.1.2.2 Animal productions

The level of animal production must respect the prerequisite requirements concerning both population dynamics and the nutrition of the cattle.

The animal production depends on various things, including the surface that is needed, and the growth factor linked to the demand for cattle.

$$Q_b(t) = \kappa_b \cdot N_b(t) \cdot \alpha_b$$

$$N_b(t) = \begin{cases} \left(\varphi_f^b\right)^{-1} \cdot \sigma_b \cdot \varpi_a(t) & \text{pour tout } t < \bar{t} \\ \varphi \left(\Phi \left(\varepsilon_b, t, \left(\varphi_f^b\right)^{-1} \right) \right) \sigma_b \cdot F_f^b(t) & \text{pour tout } t \geq \bar{t} ; \end{cases}$$

$$\kappa_b = \frac{Q_b(0)}{\alpha_b \cdot N_b(0)}$$

$$\sigma_b = \frac{N_b(0)}{S_{ep}(0)}$$

$$\phi_f^b = \frac{F_f^b(0)}{S_{ep}(0)}$$

Q_b represents the quantity of meat actually produced and N is the number of animals in the cattle.

K_b refers to the net average weight.

σ_b is the number of animals per unit of spreadable agricultural surface (that can be dosed with pesticides)¹⁴.

$$\phi_f^b$$

refers to the quantity of fertiliser f of animal origin b per unit of surface that can be spread with fertilisers.

α_b is the fraction of the cattle that is slaughtered at the end of the initial year.

ϖ_a is the growth factor related to the demand for agricultural products of animal origin.

See table 11

Table 11 : Parametric configuration for animal productions

| | bovine | Porcine Pork butcher | sows | poultry | ovine et caprine (goat) |
|-------------------------------------|--------|-------------------------|-------|---------|----------------------------|
| kg of nitrate per head cattle* | 47,68 | 10 | 9,88 | 0,44 | 8 |
| kg of phosphorus per head cattle* | 19.9 | 3 | 15 | 2.55 | 3.6 |
| kg of potassium per head of cattle | 50.25 | 2.2 | 11 | 1.45 | 9.6 |
| Average net weight in kg** | 327,6 | 89,8 | 149,7 | 1.25 | 14,05 |
| Proportion of slaughtered animals** | 0.239 | 2.22 | 0.148 | 0.0043 | 0.96 |
| Load per ha*** | 1.389 | 3,9 | 1,1 | 35 | |

*norms CORPEN ** AGRESTE (1991) *** size of the sample (AGRESTE 91) compared to the size of spreadable surface

3.1.3 Ecological pressure indicators

Concerning the emission of pollutants, the model calculates the ‘pressures’ on the environment that are caused by agricultural production. Each type of emission has different weights allocated per type of crop or animal husbandry. We calculate the average quantities of phytosanitary products needed, while taking into account the annual frequencies of spreading of manure. It results from this that all crop production can require the use of some phytosanitary products if it is to meet the outcome objectives.

¹⁴ This surface supposedly represents 70% of the ‘useful’ agricultural surface.

$$P_p^n(t) = \begin{cases} \pi_p^n \cdot \rho_n(t) \cdot \nu_p^n \cdot S_{ep}^n(t) \cdot \tau_p^n \cdot \varpi_v(t) & \text{for any } t < \bar{t} \\ \bar{\pi}_p^n \cdot (\rho(\Phi(\varepsilon_n, t), \bar{\rho}_n) \cdot \nu_p^n \cdot S_{ep}^n) \cdot \bar{\tau}_p^n \cdot \varpi_v(t) & \text{for any } t \geq \bar{t} ; \end{cases}$$

$$\pi_p^n = \frac{P_p^n(0)}{Q_n(0)} \text{ with } p \in P$$

$$\nu_p^n = \frac{Q_n(0)}{S_{ep}^n(0)}$$

π_p^n corresponds to the quantity of phytosanitary product p that is used to obtain a 1/5 of the type of crop n .

τ_p^n is the average number of treatments in a year.

ν_p^n is the agricultural product referred to the surface that has been treated by the product of type p .

-Note that the exponent p covers herbicides, insecticides and fungicides.

Concerning the chemical fertilisers, we calculate the average quantities of fertiliser that are spread per hectare, to which the supply rates in nitrate, phosphorus and potassium are applied. In this way, all crop production is associated with a certain amount of consumption of fertiliser, written as follows:

$$F_f^n(t) = \begin{cases} \phi_f^n \cdot \rho_n(t) \cdot S_n^f(t) \cdot \varpi_v(t) & \text{for any } t < \bar{t} \\ \bar{\phi}_f^n \cdot \rho(\Phi(\varepsilon_n, t), \bar{\rho}_n) \cdot S_n^f \cdot \varpi_v(t) & \text{for any } t \geq \bar{t} ; \end{cases}$$

$$\phi_f^n = \frac{F_f^n(0)}{Q_n(0)} \text{ with } f \in \Phi$$

ϕ_f^n represents the quantity of fertilisers used to obtain a 1/5th of the agricultural product p . The index f includes the nitrate, phosphorus and phosphate-enriched fertilisers.

Moreover, all animal production is characterised by the use of nitrate, phosphorus and potassium.

$$F_f^b(t) = \begin{cases} \eta_f^b \cdot N_b(t) & \text{for any } t < \bar{t} \\ \eta(\Phi(\varepsilon_f^b, t) \bar{\eta}_f^b) \cdot N_b(t) & \text{for any } t \geq \bar{t} ; \end{cases}$$

$$\eta_f^b = \frac{F_f^b(0)}{N_b(0)}$$

η_f^b represents the average use of nitrate, phosphorus and potassium for each animal, over a year¹⁵.

¹⁵ The organic nitrate generated by cattle farming is measured from the number of animals that are present on the farm and from the norms defined by the CORPEN (Orientation Committee for the reduction of the Pollution of Water by Nitrates)

Animal excrements constitute an important source of nitrate. The development of intensive cattle breeding leads to an increase in the quantity of polluting substances. Moreover, the geographic concentration of these practices makes the sewage farm lands progressively saturated. In such situations, the quantities of nitrate being applied exceed the capacity of both soils and crops to abate the pollution, hence generating important ecological perturbations.

Our ecological pressure indices are designed to give a synthetic assessment of the residual or ‘net’ quantities of nitrate, potassium and phosphorus in the Brittany area:

$$B_f(t) = \sum_b F_f^b(t) + \sum_n F_f^n(t) - \sum_n \psi_f^n \cdot Q_n(t)$$

where

$$\psi_f^n = \frac{f_n}{Q_n}$$

B_f corresponds to the remaining quantities of pollutants generated by agricultural activities.

Such an approximation focuses on the various inputs (such as the fertilisers of organic origin (F_f^b) and the fertilisers of mineral/ inorganic origin (F_f^n)), as well as the outputs (exports secured by the crops) ($\psi_f^n \cdot Q_n$).

A general assessment can therefore be conducted for the nitrates, phosphorus and potassium. Our analytical approach aims at measuring the environmental performance of agricultural activities at a regional level.

It should be emphasised that, with the use of this type of composite indicator, the loss of some information is inevitable, since we are constrained by the need to produce a model that can easily be understood as well as used in a rigorous way. So, an important part of our research exercise also consists in highlighting the existence of compromises and uncertainties, with regards to the availability of information, its quality, and also to the agricultural practices and other climatic conditions.

Any exhaustive/comprehensive understanding of the relations of causality that link agricultural activities and water quality seems out of reach, at least given the current state of our knowledge. Therefore, uncertainty has to be completely integrated into the decision-making processes for water management. Seeking to go beyond current debates, that turn around the calculation of precise measures of water quality, the modelling exercise initiated here aims at defining a few environmental pressure indicators, designed at the regional scale and in a dynamic way, which can be used in the context of a regional cost-effectiveness analysis.

We advocate that the evaluation of policies dealing with the control of water quality is conducted within a scenario or foresight studies framework. In what follows, we relate a specific scenario to each particular specification of the required ecological pressure indicators. In this framework, the evaluation exercise consists in measuring the gap between the various simulated tendencies. This gap constitutes an estimated value of the adaptation cost of the system, which results from the shift from one tendency to another. In the cost effectiveness analysis, we thus need to compare the evolution paths of the main economic aggregates and of the ecological pressure indices. The estimation of economic control costs therefore results from the analysis of the difference between the trend that the evolution of an economic aggregate is taking and that that this same aggregate would follow if it remained ecologically non-adjusted. Furthermore, it is the gap between the tendency with which an

ecological pressure index evolves and that which is observed when an environmental norm is applied which parametrises the ecological performance of control.

3.1.3 The interpretation of the scenarios in the context of the M3ED-AGRI modelling context

Four scenarios, which all illustrate the pursuit of previously set objectives, have been distinguished.

➤ **Scenario 1: An intensive-productivist scenario - 'Laissez-faire'.**

It retraces the continuity of the tendencies that can currently be observed concerning the agricultural production system in the Brittany area.

More precisely, the logic of the market is at the heart of the development process. There is a strong integration of agricultural activities in the context of the farm-produce industry. The latter offers numerous prospects of jobs creation in the agricultural sector, but the imperatives, in terms of quality, price standardisation and prices, are also important. This scenario is characterised by the pursuit of profits, relying on mass production of agricultural goods that requires the use of a considerable quantity of inputs. The environment is thus primarily viewed as a production factor (e.g. land).

➤ **Scenario 2: intensive-productivist 'reasoned' type of agriculture.**

The 'reasoned agriculture' embraces a systemic (links between the functioning of the farm and of the environment), competitive and scientific perspective (Besnault, 1998) and aims at generating a product of high quality, as well as respecting and protecting the environment within which it functions.

The intensive character of agricultural practices does not disappear, but the wish to limit the impacts of the activity on the environment is highlighted. This approach deals with the rationalisation of the use of inputs at a small scale (plot of land) or at the scale of the farm, which leads to the development of a type of agriculture which uses precision techniques. The prime objective remains the pursuit of profit maximisation. At the commercial level, this type of sustainable agriculture is described by using the 'reasoned agriculture' label.

➤ **Scenario 3: 'economical agriculture':**

This scenario deals with the issue of efficiency, hence of productivity, while respecting the agronomic principles that underlie the balance between soils- plants and animals. It seeks to find ways to best use resources from the soil, water and natural energy (such as photosynthesis). It is therefore of an intensive-productivist character, although it is different from the 'intensive-productivist' scenario "which relies on fossil fuels, nitrate fertilisers, pesticides and imported proteins" (Pochon, 1998: 202).

The premise of this approach is that economic efficiency, in the agricultural sector, is not determined by a question of size of the farm or of the cattle but, rather, by technical choices and production methods, as well as by the general coherence in which the production unit is being organised. This approach aims at protecting the environment in the long term, as well as creating jobs in the rural environment (see CIVAM, 1999).

➤ **Scenario 4: Biological agriculture:**

It suggests an alternative mode of agricultural production which relies on a good physiological state of living beings which reinforces their capacity to resist against external stresses. If prevention is not enough, it is possible to choose some treatment methods that are based on the use of natural products, which consequently reduce the need for chemical substances. Biological agriculture is conscious of the quality of products and of human and animal health. An adaptation period is necessary to be able to

install a system of biological agricultural production. It generally takes two years, which corresponds to the period of the third crop after having stopped using chemical inputs.

This global perspective is very much based on the respect of the ecosystem and biosphere functioning (recycling of organic matter, management of soil and plots of land). The commercialisation of these products is submitted to a labelling.

The differentiation between scenarios in the M3ED-AGRI is thus very much related to the differences in value of the technical coefficients.

Concerning agricultural production, the plant production yield, the density of animal production and thus the surfaces constitute the main limiting factors. The emissions of nitrates depend on the yield of the plant of production, on the animal density, but also on the limitation of the spreading per hectare. If, in the Laissez faire scenario, there is no limit, the 'reasoned' and 'biological' scenarios follow the rationale of the approach which respects the Nitrates Directive, while the economical scenario goes well beyond this threshold. Finally, in the current form of modelling, the rates of use of pesticides remain the same in the case of the three scenarios. The biological type of agriculture does not rely on these types of products.

Presented as such, the scenarios highlight the differences that exist at the level of the technical coefficients. However, the use of such parameters in the long term, highlights the problem of credibility concerning these changes, both in terms of modelling results and at the level of perspectives of political evolution.

| | | Laisser – Faire | | Reasoned | | Economical | | Biological | |
|-----------------------------|--------------------------------|-----------------------------------|--|---|---|---|--|---|--|
| | | <i>Plant Production</i> | <i>Surface</i> | <i>Plant Production</i> | <i>Surface</i> | <i>Plant Production</i> | <i>Surface</i> | <i>Plant Production</i> | <i>Surface</i> |
| Organic fertilisers | wheat sweet corn cereals | <i>See technical coefficients</i> | No limit | <i>Same coefficients as in the scenario Laissez – Faire</i> | Max. 170 kg of nitrate/ha | <i>Same coefficients as in the scenario Laissez – Faire</i> | Max. 140 kg nitrate/ha | <i>Same coefficients as in the scenario Laissez – Faire</i> | Max. 170 kg nitrate /ha |
| Chemical fertilisers | | | No limit | | No limit | | No limit | | - |
| Pesticides | wheat sweet corn cereals | 0,037 0,087 0,037 | - | <i>Same coefficients as in the scenario Laissez – Faire</i> | - | <i>Same coefficients as in the scenario Laissez – Faire</i> | - | 0 | - |
| Surface | Sweet corn – cereals | 111 (qx/ha) | Animal density : Bovine : 1,33 Porcine: 2,7 Sow : 0,87 Poultry : 35 | 111 (qx/ha) | <i>Same coefficients as in the scenario Laissez – Faire</i> | 111 (max 33% SAU) | Animal density : Bovine : 1,33 Porcine: 2,23 Sow : 0,66 Poultry: 35 | 111 (max 33% SAU) | <i>Same coefficients as in the economical scenario</i> |
| | Sweet corn – grains | 90 (qx/ha) | | 90 (qx/ha) | | 90 (qx/ha) | | 90 (qx/ha) | |
| | Other cereals | 85 (qx/ha) | | 85 (qx/ha) | | 70 (qx/ha) | | 40 (qx/ha) | |
| | Grains | - | | - | | 7-8 T (max 55% SAU) | | 7-8 T (max 55% SAU) | |

Tableau 12 : Presentation of technical coefficients for each scenario

Concerning the agricultural production, the yields of the plant production, the density of the animal production and, thus, the surfaces, are the two main limiting factors. The emissions of nitrates here depend on the yield of the plant production, the animal density, and also on the limitation of the spread of nitrates per hectare. If, in the case of the Laissez Faire, there is no limit, the reasoned and biological scenarios, the reasoned and biological scenarios, on the other hand, respect the Nitrate Directive, while the economical scenario goes well beyond the thresholds. Finally, in the current form of modelling, the rates of use of the pesticides remain the same as in the first three scenarios. The biological type of agriculture does not use this type of products.

3.2 The cost-effectiveness analytical tools

This evaluation perspective suggests a dynamic measure of the environmental performance and of the adaptation costs associated to the implementation of the policies aimed at controlling water quality. One can deduce from this that the analysis of the economic adaptation cost consists in taking an economic aggregate as a reference (in this case, regional agricultural product), and then confronting its time path to that which would be observed following an ecological adjustment. In this respect, we wish to insist on the *dynamic* dimension of the evaluation approach, since it allows the comparison of simulated tendencies, as opposed to the comparison of produced data, at a specific moment in time. In tandem, the study of environmental performance is conducted in terms of comparisons between the tendential and ecologically adjusted evolutions for certain ecological pressure indices - such as the emissions of phytosanitary products, the emissions of nitrate and the assessment of nitrate residues.

If $Q_{agr}^{ref}(t)$ represents the tendential agricultural product, for an economy which is not subjected to the constraint of environmental control, and $Q_{agr}^i(t)$ is the ecologically adjusted agricultural product, for an economy in which specified measures have been taken, then a measure of the economic adaptation cost results from deriving from the tendential product the part that is 'destroyed' as a consequence of respecting the ecological constraint.

$$C_i(t) = Q_{agr}^{ref}(t) - Q_{agr}^i(t).$$

The loss of economic growth due to the ecological constraint is a measure of the opportunity cost, which can be set in proportion to the tendential product.

$$X_i(t) = \frac{C_i(t)}{Q_{agr}^{ref}(t)}.$$

This measure also constitutes an estimate of the total economic cost associated with the transition towards ecologically adjusted agricultural practices. In this way, we suggest a dynamic interpretation of the 'loss in growth', since the model that is used shows the evolution of the economic cost over the whole temporal horizon considered.

We adopt the same approach to define environmental performance. The index of ecological pressure that we have selected is the remaining quantity of nitrate generated by each alternative regime of agricultural activity that we test. The calculation of the environmental performance is made by comparing the net emissions of nitrate generated by the tendential scenario with those derived from the alternative scenario i:

$$\Delta P_i(t) = B_f^{ref}(t) - B_f^i(t)$$

In this way, the fractional improvement of the environmental quality can be written as follows:

$$\Pi_i(t) = \frac{\Delta P_i(t)}{B_f^{ref}}$$

What remains to be defined is an adequate framework to classify and parametrise each regime of agriculture. It is clear that any chosen classification is likely to animate some controversy, and so the development of a workable classification is a non-trivial part of our exercise of modelling of agricultural practices. With this in mind, we chose to conceptualise any agricultural practice as follows:

Proposition 1:

An agricultural practice i is parametrised as an ecologically adjusted action which increases (decreases) the probability of improving water quality by decreasing (increasing) the emissions of nitrate for a given economic cost (gain), in terms of additional loss (gain) of growth which would be associated with implementation of the practice.

By proceeding in this way, our criterion for classification has straight away a formalised multidimensional character since it includes, under a same expression, the cost and the performance associated with each of the agricultural practices taken into consideration. Write:

$$R_i(t) = \frac{X_i(t)}{\Pi_i(t)}.$$

This parameter for classification of agricultural practices measures in a precise way the percentage of loss of growth per percentage of improvement of the environmental performance. This form of elasticity measure is, thus, a precise expression of the marginal economic cost associated with the agricultural practices being adopted.

- When $R_i(t) > 1$, the % loss of economic growth exceeds the % gain in environmental performance.
- Inversely, when $R_i(t) < 1$, the % loss of economic growth is less than the environmental performance gain.
- A strict proportionality between the % loss in economic growth and the % gain in environmental performance would be observed when $R_i(t) = 1$.

The measure $R(t)$ thus constitutes a parameter of relative economic feasibility for reaching environmental objectives. The highly heuristic dimension of the criterion is very clear, and refers to the necessarily stylised multi-dimensional character of the evaluation of environmental policies.

We also note that this criterion, being associated with specified forms of regimes of agricultural practice, highlights the importance of structural changes to which the agricultural sector will have to be subjected if it follows such or such mode of adjustment. This being the case, it is obvious that the opinion of farmers - their wish to adhere to such or such change - also becomes a fundamental factor in real feasibility. Farmers' attitudes will be at the origin of inertia or evolution in the production and consumption behaviours.

With such considerations in mind, we insist that the cost-effectiveness type of evaluation method, approached here from a dynamic angle, must also consider the evolution of the criterion itself throughout time.

Proposition 2:

The implementation of any agricultural practice i implies an adaptation cost which can be measured in terms of additional loss of growth, net of the surplus of realised performance.

This mode of evaluation allows us to highlight the importance of adaptation periods when we compare the economic and ecological criteria of evaluation for the various suggested scenarios. This is a well known issue in economics, the difficulty associated with the time-lag between the sacrifice implied by the implementation of pollution control measures that occurs in the short term, and the beneficial effects on the environment that can be observed in the long run. With this in mind, our second criterion of classification is calculated as a difference of rates, i.e. by subtracting the % gain in environmental performance from the % loss in the economic growth rate, for each alternative agricultural practice.

$$G_i(t) = \frac{\Delta R_i(t)}{R_i(t)} = \frac{\Delta X_i(t)}{X_i(t)} - \frac{\Delta \Pi_i(t)}{\Pi_i(t)}$$

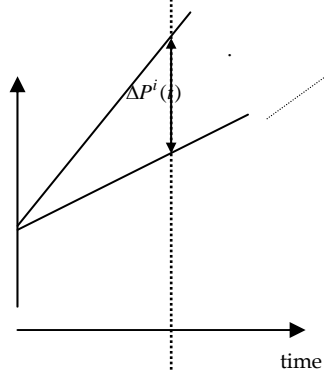
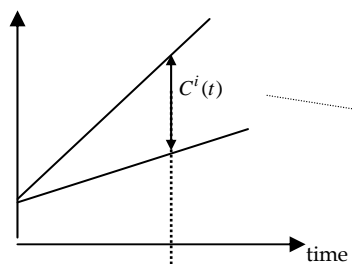
This fundamentally dynamic criterion allows us to highlight the importance of time-lags necessary to implement the adjustment modes selected, as well as the economic cost which is associated to them.

- When $G_i(t) > 0$, the marginal economic cost is increasing per unit of realised performance.
- When $G_i(t) < 0$, the marginal economic cost is decreasing per unit of realised performance.
- Finally, when $G_i(t) = 0$, the marginal economic cost is constant per unit of realised performance.

If, for example, there is a slowing down of the annual average growth rate of the marginal cost, this may be evidence of the importance of learning effects associated with the implementation of the alternative forms of agriculture.

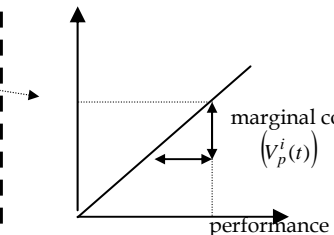
SIMULATION OF THE SCENARIOS

GDP

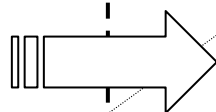
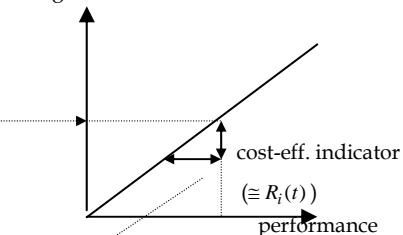


CONSTRUCTION OF REDUCTION
COST CURVES
(comparative static evaluation)

Total cost



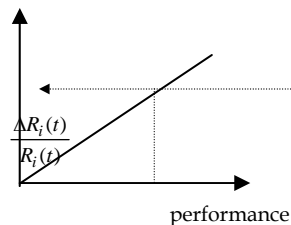
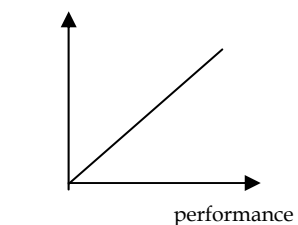
marginal costs



emissions

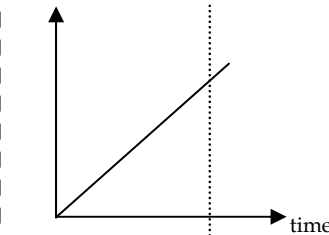
rate of variation of the indicator

cost-eff. indicator

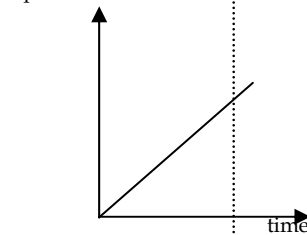


EVALUATION OF ADAPTATION COSTS
(dynamic evaluation)

total cost

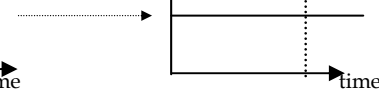
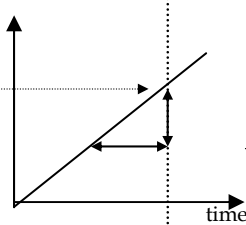


performance



$\frac{\Delta R_i(t)}{\Delta t}$

rate of variation of the indicator



3.3. The results of the scenarios

The simulations have been made using the M3ED-AGRI modelling over a period of twenty years (2000-2020). We first present the situation of agricultural activities at the start of 2020. Two dimensions are highlighted in this first Section (Section 3.3.1): they focus on the agricultural production and the emission of nitrates. Similarly, the economic costs and the performance - in terms of the reduction in nitrates emissions - are formulated for each scenario (Section 3.3.2). Finally, in a third sub-Section, we will examine the adaptation costs generated when the constraints imposed by the Nitrate Directive are being respected (Section 3.3.3).

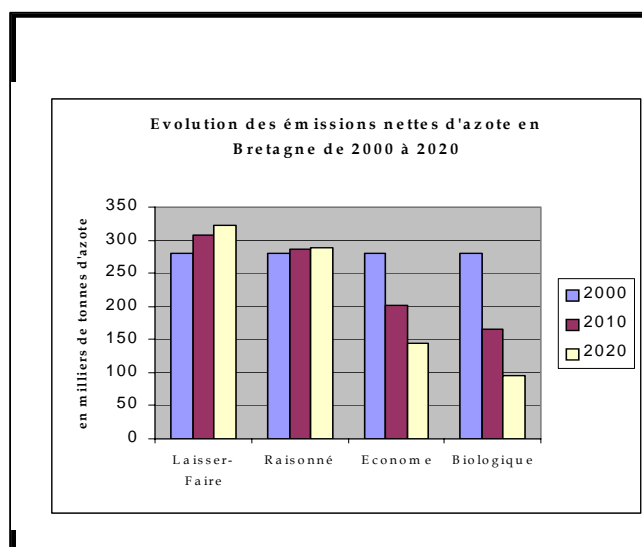
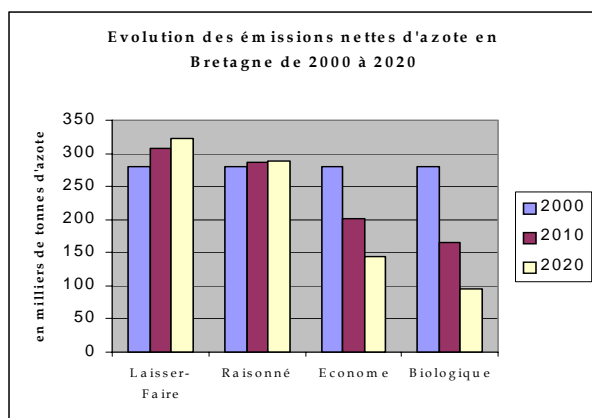
3.3.1 Evolution of agricultural production and nitrate emissions

Our first result is that the value of agricultural production (in million francs 1990) may experience a double evolution, depending on the scenario (see Figure 5).

In the *Laissez Faire* and *reasoned* scenarios, the evolution of production increases. This growth is less important in the case of the *reasoned* scenario. However, a slowing down phenomenon can be observed in both cases.

The *economical* and *biological* scenarios are characterised by a stabilisation of production in the long run. Nevertheless, this situation does not reflect a similar evolution since, in the economical scenario, it is the animal production which decreased most. In the biological scenario, the plant production diminishes considerably due to a least yield per hectare.

Concerning the net emissions, the same divergence is found in the results. The evolution of net nitrates emissions, i.e. the difference in quantity of nitrates between the quantity of nitrates spread by the farmers and that absorbed by the plants, seems to increase in the *laissez-faire* and *reasoned* scenarios (see figure 6). In the *reasoned* scenario, the increase is smaller.



In the two other (economical and biological) scenarios, the nitrates emissions strongly decrease because of the less important yield, the fact that the surface used to develop the cultures/ crops, and because of the lower density of animals.

By referring only to nitrate emissions in the various possible evolutions of agriculture in the Brittany area, we are limiting the impact of our analysis. It is

clear that the problem related to the use of pesticides is also an important source of concerns.

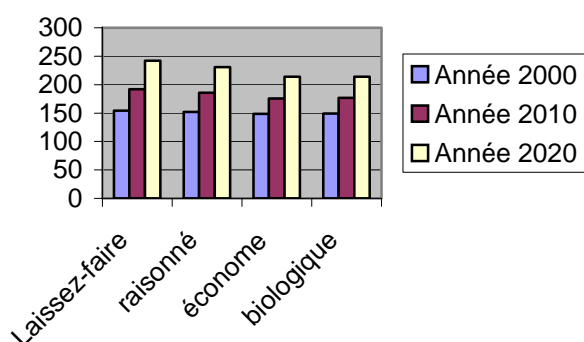
However, it is difficult to take into account the emission of pesticides because of the complexity of polluting effects that depend not only on quantity of pollutants emitted but also on the levels of toxicity of products.

In the model, the changes in technical coefficients are limited to a more or less important use of these products.

By integrating the international dimension of the Brittany production, through international exports, we have highlighted the results derived from the M3ED modelling. Two tendencies can be highlighted in the figure presented here. The Laissez faire and reasoned scenarios generate a level of exports that is substantially higher than in the case of other scenarios (economical and biological).

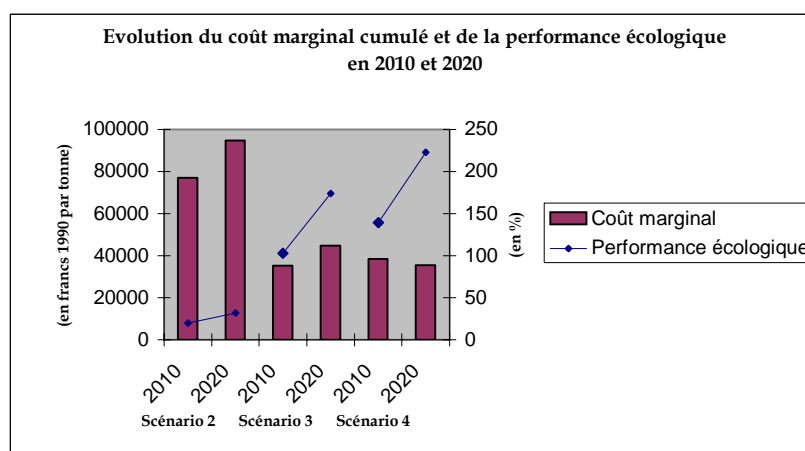
It is important to note that the same rate of export has been applied to the whole set of scenarios. However, it is realistic to stress that the objective of export of the reasoned type of agriculture does not correspond to the same criteria than other types of agriculture. One shift from a type of agriculture whose rationale is based on mass production (laissez faire and reasoned scenarios) to a production rationale based on the creation of value added (economical and biological scenarios).

Exportations nationales en produits agricoles (hors agro-alimentaires)



3.3.2 Economic costs and ecological performance of the sustainable agriculture scenarios

Economic costs are apprehended by reference to the decrease in the level of agricultural production, by comparison to the level of production in the scenario 1. The environmental performance is judged by comparing the net emissions of nitrate in the reference scenario with that of other scenarios of sustainable agriculture.



With all the necessary precautions taken to interpret the figure presented in this Section (Figure 8), we can conclude that the second scenario (reasoned agriculture) is characterised by a marginal cost of de-pollution which is high for an environmental performance that is relatively low.

Concerning the economical (scenario 3) and biological (scenario 4) scenarios, the variation in economic costs generated by activities that will limit the potential for pollution is less important than in the case of the ecological performance.

3.3.3 Adaptation costs to respect the European Nitrate Directive

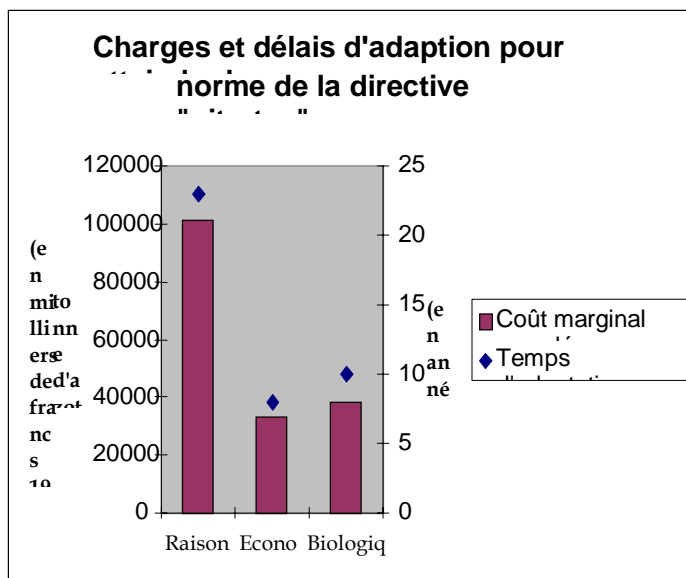
Assuming that until the year 2000, all farmers can agree to respect the European norm for nitrates in a uniform way (170 kg of nitrates of animal origin per hectare), we then focused on the identification of the adaptation costs generated by such an initiative.

While the adaptation cost required is close in the case of the economical and biological scenarios, it would take around twenty years and an annual cost of 2 billion francs -1990 base-, in other words 100 000 francs per tonne of nitrate, for the form of 'reasoned agriculture' to meet this requirement (see figure). We can also observe that the form of economical agriculture, which requires a more stringent norm on nitrates of animal origin (140 kg of nitrate per hectare), gives the best economic cost per unit of environmental performance.

The results obtained reveal the importance of the economic adaptation cost that the agricultural sector will have to suffer if it shifts to the economical or biological option. Beside, while respecting the European norm on nitrates, the reasoned type of agriculture generates an environmental performance that is lower for an economic costs that seems to be more significant. In the end, these three types of agriculture generate marginal costs that increase per unit of ecological performance. So we can highlight the importance of the inertia cost associated to agricultural practices and the time of adaptation that is necessary for the transition towards sustainable types of agriculture to take place at a regional level.

3.4 Discussion

In this last Section, we seek to discuss the implementation of the pre-defined scenarios: the *reasoned* scenario (sub-Section 3.4.1), the *economical* scenario (sub-Section 3.4.2) and the *biological* scenario (sub-Section 3.4.3). The objective is to highlight the meaning of the various indicators for each scenario and to examine the practical implications. A summary table is presented in a last part (sub Section 3.4.4).



3.4.1 Sustainability in the reasoned scenario

Economic growth, in this study, is estimated to be LL%. This means that, after a period of twenty years, the economy will have grown by KK%. The economic surplus is represented, in the scenario, by a growth of XX% in the agricultural production and in the funding of programmes aimed at improving agricultural practices and wastes treatment which, as stressed in Figure 9 ('Adaptation costs when the nitrate directive norms are respected', in sub-Section 3.3.3), constitutes an important investment.

The improvement of ecological performances is essentially linked to a limitation of quantity of nitrate fertilisers of animal origin being spread. However, and as figure 5 shows ('Evolution of net emissions of nitrates', sub-Section 3.3.1), a stagnation of the pressure indicator is envisaged in the long run. Respecting the Nitrate Directive, as it is suggested in the reasoned scenario, does not involve any real improvement in the environmental situation.

This scenario is characterised by a strong dependency on world markets, when it comes to selling the agricultural products.

Eventually, during this period, the evolution of the social climate does not show signs of slowing down. Indeed, although the scenario is included in a perspective of respect of the Nitrates Directive, social expectations are not really taken into account. First, the cost associated to the implementation of the scenario are the highest. However, as stressed many times in this report, the citizens lobby denounced this point. Moreover, the intensive-productivist perspective has not been suppressed as a consequence of this denunciation, which is therefore at the basis of another of their claims.

This lead us to stress the fact that the 'reasoned scenario' presents a type of agriculture whose evolution is based on technologies and on the respect of social norms, and which highlights the importance of the interrelations between human activities and the physical environment. In other words, this scenario emphasises the existence of the environmental functions of natural capital provided to human activities at the expense of other environmental functions that are internal to the natural capital. In our view, the idea of substitutability between environmental functions underlines this scenario.

3.4.2. Sustainability in the economical scenario.

The economical scenario assumes an economic growth of MM%. The stagnation of the production, ultimately, seems to be characteristic of an economical scenario. However, the size of fundings, as we had envisaged (see figure 9 - 'Costs and adaptation time lags to reach the norm of the Nitrate Directive in the sub-Section 3.3.3), is supposed to be much smaller than that which are needed in the case of the reasoned scenario. The amounts taken from the economic surplus to fund the activities whose objective is to improve agricultural practices and waste treatment are lower.

Another characteristic of this scenario is that the levels of prices of agricultural products are not different depending on the alternatives considered in this approach. However, we previously stressed the fact that the *economical* and *biological* types of agriculture are characterised by the creation of a high value added. This aspect is not highlighted here. The 'volume' effect which explains the growth observed in the case of the reasoned type of agriculture does not exist in the case of the other types of agriculture (see figure 'Evolution of agricultural production in the Brittany area, in sub Section 3.3.1).

Concerning the indicators of ecological performance (see figure 5 - 'Evolution of net emissions of nitrates in the Brittany area, in sub Section 3.3.1), we note that the improvement of the situation is particularly related to a change in modes of production, which reduces the quantities of fertilising substances of animal origins that are spread. This is an important consequence of this perspective since

it does not seek to respect the Nitrates Directive as the main objective of the approach, but to focus on some lower levels of spreading of nitrate substances of animal origin. This approach embraces an agronomic dimension.

As we presented it, the economical scenario advocates the pursuit of the satisfaction of national needs prior to any concept of export. The assumptions of the M3ED-AGRI modelling approach leads us to envisage a similar proportion of the exports for the whole of the alternatives, which limits the relevance of their results.

We note, like in the case of the biological scenario, that *social conflicts* have a role to play due to the integration of social demand in our analysis, both from the point of view of the funding of activities - subsidising of a type of agriculture that respects the environment instead of agricultural activities that have important impacts on the natural environment or waste treatment activities - and from the point of view of the quality of agricultural goods and national and regional development.

In the economical scenario, the evolution of the production is related to technical changes but also to the selected mode of production in a farm. Strong sustainability relies on the maintenance of a certain complementarity between environmental functions that are internal to the natural capital systems and that are integrated in economic activities.

3.4.3. Sustainability in the biological scenario.

The economical scenario assumes a growth of XX% over twenty years. A slight increase in the agricultural production occurs in the simulation period (see figure 7 - 'Evolution of agricultural production in the Brittany area in sub-paragraph 3.3.1). However, a very small part of the economic surplus is allocated to the funding of activities that are aimed at converting agricultural activities, and to the implementation of cleaning systems and treatment of wastes of animal origin (see figures 5 and 6 'Adaptation costs and delays to reach the Nitrate directive norm, in sub-Section 3.3.3).

The ecological performances are important (see figures 5 and 6 - 'Evolution of the net emissions of nitrates in the Brittany area, in sub Section 3.3.1). They are specifically related to the fact that nitrate fertilisers of chemical and animal origin are not used in this scenario. Here; like in the economical scenario, the respect of the directive is not particularly pursued. On the contrary, the objective is to modify the modes of production in the agricultural sector.

Concerning the demand:

Like in the case of the economical agriculture, we can note that the part taken by exports is constant in the M3ED-AGRI model. This constitutes a limit to our approach, in particular in the case of the biological type of agriculture in France, country in which the production of biological products does not meet the demand for such products. Consequently, the first step to take to implement this alternative, is to meet national needs as an absolute priority. Exports can then be considered as a later way of selling these products.

At a social level, social conflicts that occur as a consequence of a divergence in objectives are decreasing in number. This is because a large proportions of social claims have been taken into account in the scenario. Nevertheless, numerous problems remain and include the conversion of farmers who, until now, practised an intensive type of agriculture; the concern that the image of biological products will be damaged due to a certain intensification of agricultural practices linked to the increase in demand; and the lack of motivation and or funding (subsidies) that could lead to a stagnation of the situation.

In terms of sustainability, this leads us to conclude that the types of evolutions required by this scenario clearly relate to the production technique, since the biological type of agriculture presents some advanced technical skills and also some interesting elements of modes of production. This alternative is characterised by a complementarity between environmental functions, and the respect of environmental functions that are *internal* to the natural capital system, which is the premise for the provision of the environmental functions that are provided for human activities.

3.4.4. Summary table of the various sustainable agricultural perspectives.

Using Table 13, it is possible to synthesise the characteristics and implications of each scenario of sustainable agriculture that have been mentioned in our analysis.

In conclusion, we can note that these three forms of sustainable agriculture embrace the notion of *strong sustainability*, but in different ways. We highlight the importance of the substitutable or complementary character of environmental functions. Thus we highlight the criteria that characterise strong sustainability. The criticality is then presented in a new light, that is related to the competition between environmental functions.

Table 13

| | Reasoned scenario | Economical scenario | Biological scenario |
|---|---|--|---|
| Economic growth rate | <ul style="list-style-type: none"> ➤ Approximately LL% p.a. ➤ Increase in agricultural production | <ul style="list-style-type: none"> ➤ The economy should grow by JJ% p.a. ➤ Stagnation of agricultural production | <ul style="list-style-type: none"> ➤ The economy should grow by FF% p.a. ➤ Slight increase in the agricultural production |
| Distribution of economic surplus | <ul style="list-style-type: none"> ➤ Technical evolution of the agriculture ➤ Maintenance of important funding to improve agricultural practices and waste treatment systems | <ul style="list-style-type: none"> ➤ Structural and technical evolution of the agricultural sector ➤ Least funding of agricultural and depolluting activities | |
| Evolution of the demand | <ul style="list-style-type: none"> ➤ The economy keeps, in this perspective, its role in exportation ➤ Few elements concerning the demand can be included due to its exogeneity in the M3ED-AGRI modelling | <ul style="list-style-type: none"> ➤ It is clear, from the Figure dealing with exports, that the economical and biological scenarios seek above all to meet the needs of the local and national population. ➤ The role of agriculture at the international level, in both cases, is diminished | |
| Social climate | <ul style="list-style-type: none"> ➤ Social conflicts occur because: ➤ Some costs linked to the implementation of polluting techniques ➤ The acceptance or not of the degradation of water quality | <ul style="list-style-type: none"> ➤ The aspirations of the local population being more taken into account, the risk of social conflicts is diminished ➤ Changes in the orientations of the modes of institutional regulations (subsidies...) | |
| Environmental impacts | <ul style="list-style-type: none"> ➤ The evolution of the impacts of the degradation of the natural capital should remain constant in time. The functions that are internal to the natural capital system are not taken into account as such. | <ul style="list-style-type: none"> ➤ There could be an improvement in the health of natural capital systems, both from the point of view of the environmental functions provided to human activities and for international environmental functions. This is linked to the fact that environmental pressure decreases with time. | |
| Characteristics of the sustainability and competition between environmental functions | <ul style="list-style-type: none"> ➤ Weak sustainability ➤ Substitutability between environmental functions. The interest showed towards the natural capital system is bigger than that given to the environmental functions that are internal to the natural capital system ➤ Technical perspective | <ul style="list-style-type: none"> ➤ Complementarity between environmental functions. Priority given to the environmental functions provided by the natural capital while not neglecting the maintenance of environmental functions that are internal to natural capital. ➤ Citizens based approach | <ul style="list-style-type: none"> ➤ Complementarity of environmental functions. Priority given to environmental functions that are internal to the natural capital. The environmental functions provided to human activities are then added to the maintenance of the first ones. ➤ Insertion of agriculture in natural cycles and in a citizens approach. |

4. Conclusion

In the context of this research project, the approach we have followed consists in:

- 1) applying the analytical framework of CRITINC (Ekins and Simon, 1999) which allows us to understand the role of water not only from an ecological perspective, but also in the context of the Brittany society;
- 2) re-constructing the environmental problem in order re-organise it and structure it in view of developing some alternatives,
- 3) developing a modelling technique which takes into account the diversity of implications related to the implementation of options.

The globality of this work is integrated in the perspective of strong sustainability.

The originality of this approach is synthesised in the fact that:

- i) it uses the notion of *environmental functions* to highlight the role of water in the Brittany society
- ii) the notion of *CNC* is used to illustrate how much the situation is in crisis and consequently how some action is urgently required
- iii) it looks for the most relevant and useful indicators to characterise and illustrate the environmental problem and
- iv) it focuses on the development of a structural modelling approach which makes the presentation of a whole set of alternatives possible.

In general, any dynamic measure of environmental performance must necessarily integrate the part of uncertainty related to the impacts generated by human activities on the natural environment. From this, it then becomes clear that the spatial and temporal variability of these emissions make it difficult to estimate the impacts related to the use of fertilisers. Similarly, the notion of quality is difficult to approach by using a regional statistical database since its meaning is essentially of a *local* nature. In this context, it is clear that the emission rates and other norms of environmental quality become variables whose undetermined character greatly influences the analysis concerning the scale of their ecological and economic consequences.

In the context of this research, it is clear that this model acts both as a '*receiver*' of what is at stake when implementing water quality control policies and as an *exploratory tool* to investigate the possibilities related to the adaptation measures envisaged for the agricultural sector. This is why the variability of ecological norms encourages the use of a scenario-based approach. We relate a specific form of agriculture, i.e. an adequate scenario, to each particular specification of the required norms.

From this, we can conclude that taking into account the variability corresponds to measuring the gap between the various simulated tendencies. This gap then constitutes an estimated value of the adaptation cost of the regional agricultural sector and of the achieved environmental performance which results from the transitional shift between the tendency and the dynamic schemes that have been suggested.

We do not wish to draw a premature conclusion. The formulation of scenarios exploring the possible evolution of agricultural activities in the Brittany area is provisional, and the simulation results with their underlying parametrisation still need refining. This analysis nonetheless emphasises the importance and relevance of using structural modelling when measuring ecological performance and

economic costs and when the problematic of the situation looked at is fundamentally dynamic and extends in the long term.

With regards to the issue being looked at, even if the adaptation constraints seem inevitable, such modelisation however stresses the fact that decision making processes are not only based on preferences for such or such agricultural practice: the decision must also be take into account the context in which the choice is being made.

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