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Evaluating Economic Policy Instruments for Sustainable Water Management in Europe

WP4 EX-ANTE Case studies

Ecosystem services and conservation in the Seine-Normandie River Basin (France)

Part A - PES scheme and nitrate tax in the *Bassée-Voulzie* area

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Executive Summary

The *Bassée-Voulzie* Hydrographic Unit (HU) is a part of Seine-Normandy district facing two environmental challenges, namely: i) fighting against diffuse pollution to preserve drinking water, from a qualitative and a quantitative point of view and ii) contributing to the reduction of flood risk for cities downstream, including Paris.

With regards to diffuse pollution, several measures based on regulatory and voluntary approaches (eminent domain constraints, *fertimieux* programmes, agri-environmental measures, etc.) have already been experimented and implemented to meet the objectives of the Nitrates and Water Framework Directives. However, nitrate pollution remains a major issue in the basin leading to high treatment costs and the closure of a few water abstraction sites. The reduction of flooding episodes is relatively well managed by the EPTB *Seine Grands Lacs* thanks to the construction in the past years of upstream reservoirs. However, potential damage costs of a 100-year flood still remain very high and additional costly infrastructure is being considered.

The *Bassée-Voulzie* hydrographic unit is a rural area with agriculture as the dominant land use (more than 75 % of the total area, mainly covered by crops). Favouring new environmentally friendly practices for farmers could lead to reduce pressures on surface and ground water and may contribute to improve flood control. As an alternative to existing instruments, we assessed the impacts of the following Economic Policy Instruments (EPIs):

- **A tax on fertilisers containing nitrogen** as an economic incentive to reduce nitrogen surplus;

- **A Payment for Environmental Services (PES)** for nitrogen loss avoided through changes in practices, a type of scheme not well developed in France due to institutional barriers, among others.

In addition, **coupling a PES scheme with a nitrate tax** has also been assessed. As suggested by Bourgeois (2012), combining a tax with a subsidy on perennial crops could be cost-effective compared to the implementation of a nitrate tax alone and can lead to some levels of abatement which are difficult to reach if the policy is only based on one economic instrument.

The assessment of the EPIs entails the comparison between a scenario with the economic instrument and a baseline scenario without. Several key drivers were indentified to constitute the baseline scenario including climate change impacting both ecosystem services provided by the *Bassée-Voulzie* area and agricultural practices, future measures that will be implemented within the future Common Agricultural Policy (CAP) reform (2014) and the evolution of agricultural input and output prices. Regarding nitrate pollution, the baseline scenario defined lead to a stabilization of current trends. This assumption must however be mitigated given the high dependence of cereal and fertilizer prices on various factors which leads to an uncertainty on the changes in

farmers practices (in particular the evolution of the consumption of nitrogen fertilisers) and crop allocation. Regarding flood regulation, we propose to set a baseline scenario consistent with the degradation of the service of natural flood regulation in the *Bassée* floodplain.

In terms of the assessment of the economic and environmental impacts of the two environmental services considered by EPIs, an economic optimization model was developed. It simulates the potential land-use reallocation related to the implementation of the EPIs by modelling the gross margin associated to each crop. Farmers, as rational economic agents, are expected to react to the signals (level of payment) by changing the allocation of their land, their production levels and the level of inputs used. Then, the changes are translated into environmental impacts and benefits, allowing to consider both sides of the equation (producers and beneficiaries) when defining the level of payments / level of tax. The MODCOU hydrological model was then used to determine the concentration of nitrates in groundwater. The public Soil Water Assessment Tool ArcSWAT has been selected to assess the potential impact of land use changes on the water balance.

The coupling of the nitrate tax with the PES scheme enables to lower the level of the tax and the PES for the same environmental outcome on the *Bassée-Voulzie* area compared to the effects of each EPI considered separately, thus to the reduction of the negative economic impacts of the tax and the deadweight effects of the PES. Payment for environmental services allows reducing the nitrogen loss significantly (-50%) for payment higher than 4 €/kg of nitrogen loss avoided. Combining it with a tax allows achieving a similar objective in terms of nitrogen loss reduction while reducing the amount of payment: nitrogen loss can be reduced by almost 50% with a payment of 3 € when the tax on nitrogen fertilizer is fixed at 50%.

Along the modelling exercises, preconditions for the implementation of the economic instrument were approached through a series of interviews and meetings with local and national stakeholders. A few barriers to the implementation of the EPIs were identified, among which the high transaction cost associated to the definition of a payment for flood control and institutional barriers to the design of a PES scheme involving the beneficiaries of a good water quality (*Eau de Paris* and local water utilities).

Table of Contents

List of figures

List of tables

List of acronyms

CAP: Common Agricultural Policy

EC: European Commission

EPI: Economic Policy Instrument

EPTB: *Etablissement public territorial de bassin* (Local public river basin organisation)

HU: Hydrographic Unit

PES: Payment for Environmental Services

SAA: Small agricultural areas

1. Introduction

1.1. The Seine-Normandy basin and its main environmental issues

The *Seine-Normandy* river basin district covers around 100 000 km² which represents one fifth of the total French territory (Figure 1-1). The Seine is the major river of the basin: it rises in the South-East of the basin, passes through Paris – which is located in the centre of the basin, and flows into the English Channel. The basin is characterized by a strong urbanization in the Paris metropolitan area (more than 10 million inhabitants) and an intensive cereal-based agriculture in the Paris basin.

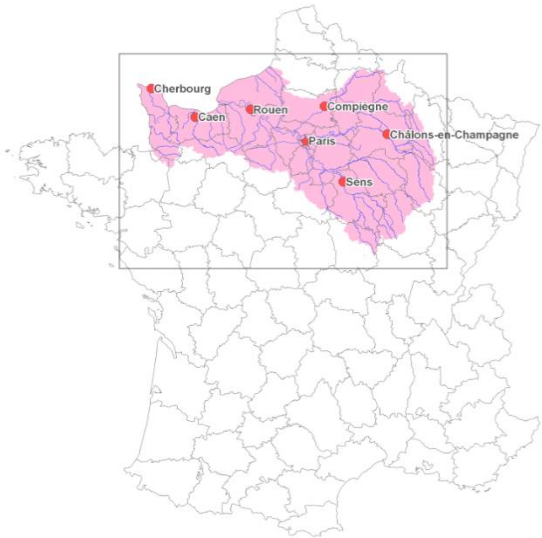


Figure 1-1. The Seine-Normandy basin river basin district

Source: Authors, based on the Seine-Normandy basin SDAGE, 2010.

The *Seine-Normandy* basin currently faces major environmental issues, in particular, (AESN, 2012a): i) fighting against diffuse pollution to preserve the quality of water resources, and ii) ensuring the protection against floods of cities downstream of the Seine including Paris.

Pollution by nitrates is one of the major causes of water pollution in France. Nitrates that are released in French water resources mainly come from agricultural activities following the use of nitrogen fertilizers and the application of livestock manure (CNRS, 2012). On the Seine-Normandy river basin district, nitrates concentration in groundwater has increased since the 1950s and the PIREN-Seine (AESN, 2009a) measured an increase of 0.64 mg/l in average between 1970 and 2000. Today, this situation appears to have stabilized but nitrate concentration is identified as a risk of not achieving the objective of achieving good ecological status, as required by the Water Framework Directive, for almost all groundwater bodies in the basin (AESN, 2004). Nitrate pollution remains a major issue in the basin leading to high treatment costs and the closure of a few water abstraction sites.

The reduction of flooding episodes is relatively well managed by the EPTB[2] *Seine Grands Lacs* thanks to the construction in the past years of upstream reservoirs. However, potential damage costs of a 100-year flood still remain very high and new costly infrastructures are being considered.

1.2. Current challenges in the *Bassée-Voulzie* area

The *Bassée-Voulzie* Hydrographic Unit (HU)[3], a restricted area of the Seine-Normandy basin, faces environmental issues representatives of those at the scale of the *Seine-Normandy* basin (Figure 1-2). Covering around 1 700 km² and located upstream of Paris, this HU includes one of the main groundwater catchment areas used by the utility *Eau de Paris*, in charge of supplying the city of Paris with drinking water. Agriculture is the dominant land use (more than 75 % of the total area, mainly covered by crops) and also constitutes one of the main pressures on the territory, especially on water quality.

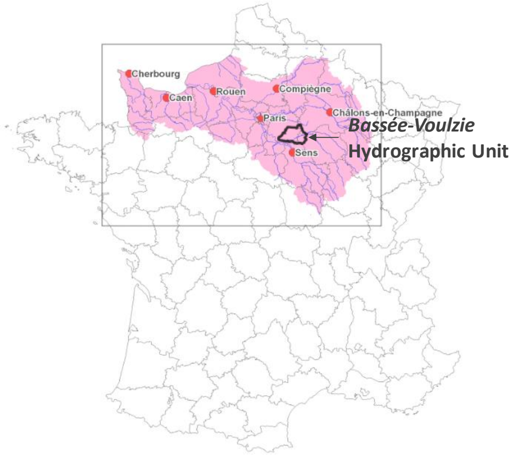


Figure 1-2. The Bassée-Voulzie Hydrographic Unit as part of the Seine-Normandy basin

Source: *Authors, based on the Seine-Normandy basin SDAGE, 2010.*

The Water Development and Management Master Plan[4] of the *Seine-Normandy* basin provide specific recommendations regarding the quality and the quantity of groundwater bodies that belong to the HU (SDAGE, 2010). Besides, this document emphasizes the need to preserve the *Bassée* floodplain area, which has kept a natural functioning in terms of river dynamism and flood retention.

Any positive change of agricultural practices or land use allocation could lead to positive effects on water quality and also contribute to reduce runoff and (eventually) to the regulation of floods.

1.3. What could be the role of an Economic Policy Instrument?

European and French legislation (at the national and local level) have been implemented to address water quality and flood regulation issues over the past decade (the Nitrates Directive,

[2] EPTB: *Etablissement public territorial de bassin* (Local public river basin organisation)

[3] A French local water management unit

[4] In French *SDAGE (Schéma Directeur d'Aménagement et de Gestion des Eaux*). This planning document establishes the main orientations for water management at the scale of a river basin district in accordance with the Water Framework Directive (2000/60/CE) and the French Water Law (n°92-3 of January 3rd, 1992).

1991; the Water Framework Directive, 2000; the Floods Directive, 2007) contributing to define objectives of protection. Local actions have also been undertaken in particular to reduce nitrate pollution. However given the current evolution of nitrate concentrations in the hydrographic unit, regulatory policies that have been implemented seem not be sufficient to reduce nitrates release in water resources. The reduction of flooding episodes is relatively well managed by the EPTB *Seine Grands Lacs* thanks to the construction in the past years of upstream reservoirs. However, potential damage costs of a 100-year flood still remain very high and new costly infrastructures are being considered.

As an alternative to existing policies, we propose to assess the impacts of two Economic Policy Instruments (EPIs):

- **A nitrate tax** that will be set on all fertilizers containing nitrogen. We expect that the tax has an incentive effect on the amount of nitrogen fertilizers used by encouraging farmers to change their agricultural practices and thus contribute to improve the quality of water resources in the area.

- **A PES scheme** as a positive incentive for a change from current agricultural practices to more environmentally friendly practices. We expect that the change of land-use and the change of agricultural practices produced by the positive incentive might lead to the provision of multiple environmental services, in particular the provision of good water quality and flood regulation. This assessment primarily raises the question of the definition and the design of the PES scheme.
- **Combining the nitrate tax with a PES scheme:** combining a nitrate with a subsidy on perennial crops could be cost-effective compared to the implementation of a nitrate tax alone for the provision of good water quality (Bourgeois, 2012). Moreover it can lead to some levels of abatement which are difficult to reach if the policy is only based on a nitrate tax. A PES scheme could then be considered as a specific subsidy.

This report presents the results of the ex-ante impact assessment of the implementation of a PES scheme and a nitrate tax at the scale of the *Bassée-Voulzie* HU. The feasibility of coupling these two EPIs has also been assessed.
Chapter 2 presents more into details the main characteristics of the *Bassée-Voulzie* HU, the predominant role of agriculture on this area and the main environmental issues. Chapter 3 presents the main key drivers of change and the baseline scenario. It also discusses the time horizon of the assessment. Chapter 4 relies on an overview of existing EPIs, assesses their successes and failure and explains why a tax on nitrogen fertilisers and PES schemes may be relevant on the *Bassée-Voulzie* area. The methodology is described in chapter 5, insisting on the three models used for the assessment of the proposed EPI. Chapter 6 and 7 present the qualitative and quantitative results for each of these seven assessment criteria in order to ensure a broad assessment of both EPI and the combination of the two. And finally, chapter 8 concludes and develops policy recommendations as regards to the main lessons learned.

2. Key problems and challenges in the case study area

2.1. Overview of the *Bassée-Voulzie* Hydrographic Unit

The *Bassée-Voulzie* HU is a rural area where agriculture is the dominant land use: more than 75 % of the total area is agricultural land among which 75 % of crops and around 1 % of meadows, while woodland and waters cover only 18 % of the area. Forest and wetlands are mainly located along the *Bassée* River (figure 2.1).

The *Bassée-Voulzie* HU sits astride the *Aube* department (which is part of the *Champagne-Ardenne Region*) and the *Seine-et-Marne* department (which belongs to the *Ile de France Region)*

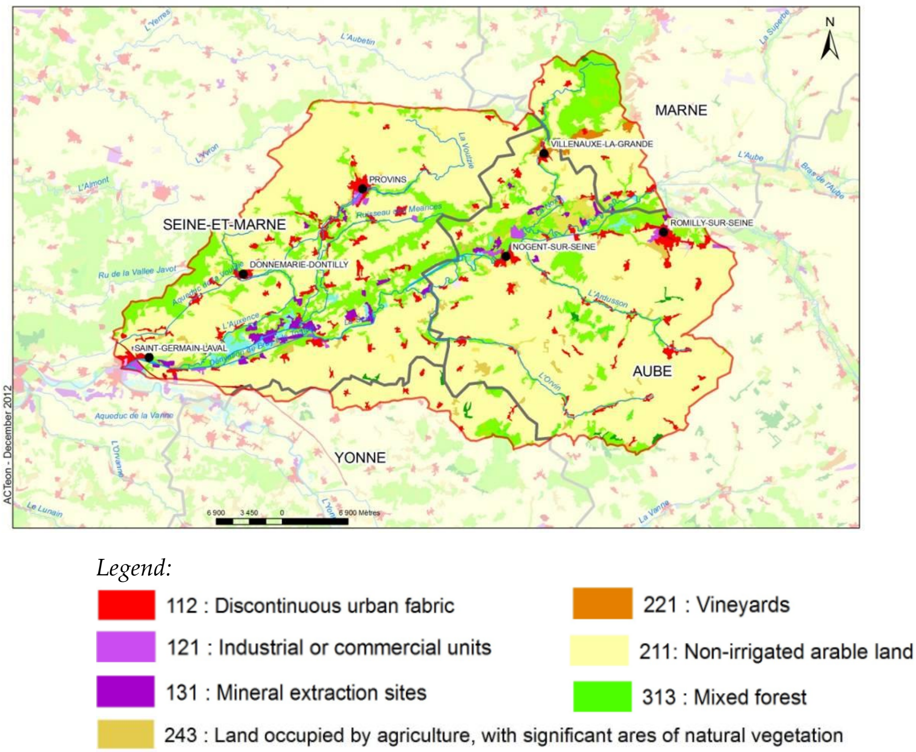


Figure 2-1. Land use in the Bassée-Voulzie river basin

Source: *Authors, based on Corine Land Cover*

The area's population is around 100 000 inhabitants[5] and has slightly increased since 1970 (INSEE, 2009), while urban areas currently covers about 6 % of the total surface area. The town and the villages have limited surface and spread on the entire basin. Only eight towns on the *Bassée-Voulzie* HU have more than 2000 inhabitants.

[5] The population of the municipalities concerned by the limits of the hydrographic unit is 130 000 inhabitants. But the surface covered by these municipalities is 2245 km², instead of 1700 km² for the hydrographic unit.

The area is quite flat, except rivers creating slight hollows. The hollow created by the *Bassée* (Seine River) is wider, going from the East to South-West of the *Bassée-Voulzie* HU. This area is mainly covered by wetlands from *Romilly-sur-Seine* to *Montereau-Fault-Yonne*.

The *Bassée-Voulzie* HU covers 9 water surface bodies and 6 groundwater bodies (SDAGE, 2010). There are 91 groundwater abstraction areas for drinking water supply.
The area covers the major part of the *Bassée* alluvium groundwater body. It only partially covers the other groundwater bodies, in particular the *Champigny* groundwater body whose surface is 5 163 km², and the *Senonais and Pays d'Othe* chalk which covers 4 333 km².

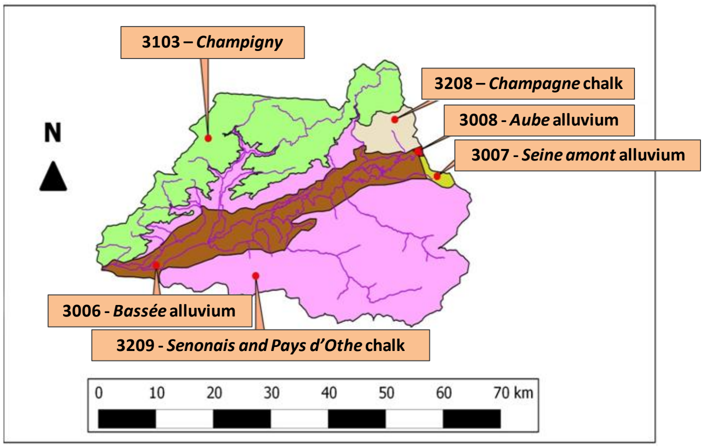
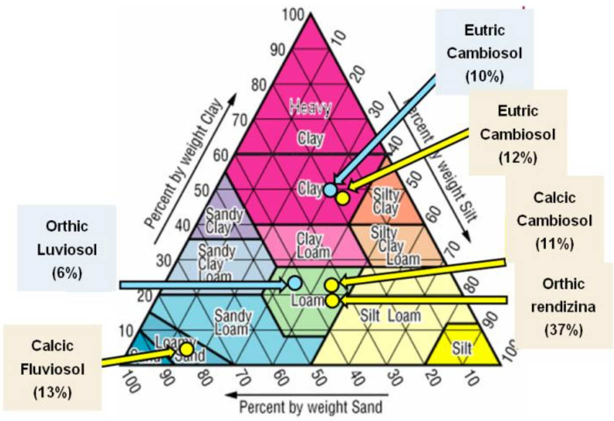


Figure 2-2. Water surface and groundwater bodies in the *Bassée-Voulzie* HU

Source: *Authors, based on the Seine-Normandy basin SDAGE, 2010.*



On the *Bassée-Voulzie* HU, the dominant soil is orthic rendizina (37%) with a fraction of silt of 44% (37% of sand), and orthic rendzin on the Ardusson catchment. Calcic cambiosol covers about 11% of the area and presents a similar proportion of sand, silt and clay.
Eutric cambisol represents about 22% of the soil type on the area. It is characterized by a fraction of clay of about 50%.

Figure 2-3. Type of soil in the Bassée-Voulzie HU

Source: *Authors, based on the European Soil Database*

2.2. Current challenges in the *Bassée-Voulzie* HU

Nitrate pollution in the Bassée-Voulzie HU and the supply of drinking water

Local municipalities of the *Bassée-Voulzie* HU and *Eau de Paris* are extremely dependant on water surface and groundwater quality and quantity:

- *Eau de Paris* draws, transports, treats and distributes an average of 500 000 to 600 000 m³ each day to Parisians coming from surface water for 50 % (pumped from the Seine and the Marne, upstream Paris) and underground water for 50 % (coming from five underground sources, the most distant one being located in Normandy). The *Voulzie* catchment area covers a quarter of the ground water used for its drinking water supply. But this catchment is supplied by the *Champigny* groundwater body in which nitrates concentration is estimated to be 54 mg/l[6] (Zakeossian, 2012). Other sources are also exploited by Eau de Paris on the *Bassée-Voulzie* Area (on the *Dragon* and the *Durteint* catchment area) but they are of less interest for Paris (as they represent smaller water production).

- A majority of the 158 towns of the territory has no substitute in case of pollution while at least 5 abstraction sites have already been abandoned in the north part of the hydrographic unit due to nitrate pollution (Safege, 2012).

On the *Bassée-Voulzie* HU, the objective of a good ecological status is to be achieved by 2015 for all water surface bodies except for the *Voulzie* river for which nitrate concentration is identified as a risk of not achieving the objective. The River Basin Management Plan (RBMP) of the *Seine-Normandy* river basin district gives specific recommendations on the *Bassée* groundwater body, whose quantity and quality must be preserved for future needs in drinking water, and on the *Champigny* groundwater body, whose quantity and quality must be restored (SDAGE, 2010). For both groundwater bodies, there is a risk of not achieving good status by 2015 because of high level of nitrates concentration. Besides, the lack of impermeable layer on the catchment makes groundwater bodies particularly vulnerable to pollution. See Viavattene (2013) for a detailed description of the main aquifers on the *Bassée-Voulzie* HU.

Flood regulation: a contribution to the reduction of risk for the cities downstream including Paris

In the Paris region, a major flood is characterized by its "low-frequency and its enormous gravity". In the case of extreme events[7], over four million people might be affected to varying degrees. The cost of damages of such events has been estimated at EUR 17 billion, excluding damages to transportation and various networks and the long-terms impacts of the economic paralysis (*EPTB Seine Grand Lacs*, 2011). Floods are the result of long and regular rainfall saturating the soil and increasing runoff.

The regulation of floods is mainly relevant to a part of the area considered here: the Bassée floodplain area and more precisely the upstream section between *Romilly-sur-Seine* and *Nogent-sur-Seine*[8]. This section remains relatively preserved and has kept a natural functioning in terms of river dynamism and flood retention. It contributes to reduce the flood peak. The efficiency of the flood regulation in this section is comparable to one of the reservoirs (dams) built upstream the

[6] The maximum concentration of nitrates in water resources required by the Nitrate Directive is 50 mg/l.
[7] Such as a 100-year flood comparable to the one occured in 1910.
[8] These municipalities correspond to Eurostat Local Administrative Units LAU2_NAT-CODE 10323 and 10268 respectively.

Seine or the Yonne rivers (Bouscasse *et al.*, 2012) and is relevant for ten-year floods (whose flows are around 150 m³/s) and for more frequent floods.

2.3. Agriculture: a prominent place in the local landscape and environment

Description of the agriculture on the Bassée-Voulzie HU

The *Bassée-Voulzie* HU is covered by about 154 000 ha of utilised agricultural land and concentrates 1 537 farms (General Agricultural Census, 2010) if we considered all towns located wholly or partly on the *Bassée-Voulzie* HU. Considering only towns with at least 50% of their surface within the limits of the *Bassée-Voulzie* HU (and representing more than 95% of the total surface of the HU), the utilised agricultural land fall down to 119 000 hectares distributed among 1 112 farms (see annex 1).

The main crops in the basin are cereals (wheat, barley and rainfed maize) and oilseed (rapeseed mainly). Cereals represent 60% of the utilised agricultural area and oilseed 16% as shown on the Figure 2-4. There are also industrial crops, mainly sugar beet. Those crops are well adapted to the silt soil of the area.

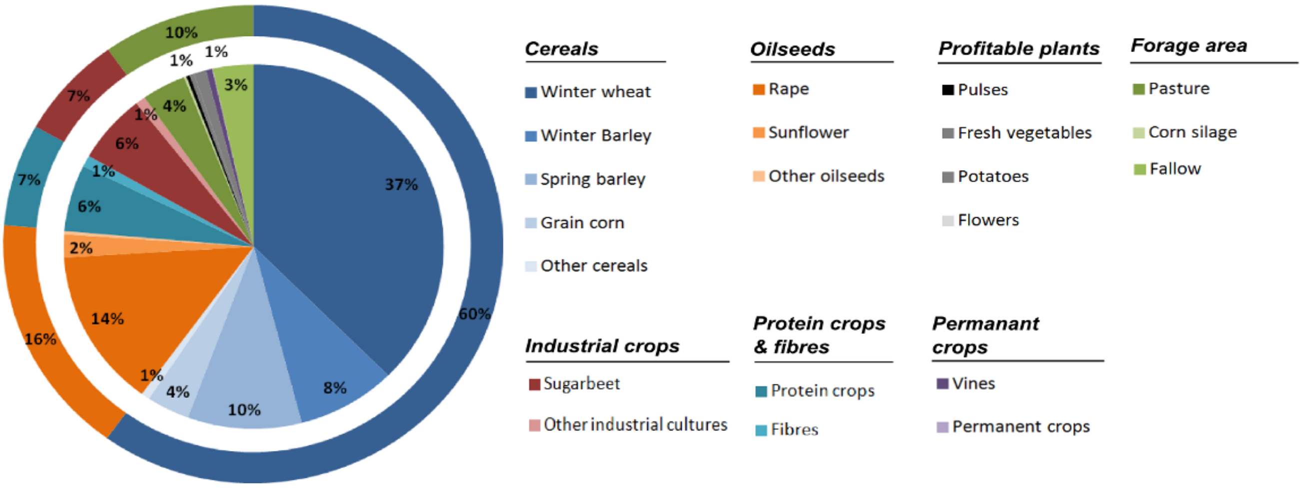


Figure 2-4. Main crops in the Bassée-Voulzie HU

Source: Authors, based on the General Agricultural Census (2010)

Agricultural land use decreased by 2% between 2000 and 2010. During the same period, the number of farms also decreased by approximately 15% (GAC, 2000 & 2010). Cereal surfaces were quite stable during the same period whereas oilseed surfaces strongly increased (+43%) while protein crops (-36%), fibres (-40%), industrial crops (-15%), forage area (-15%) and fallow (-25%) decreased significantly.

Based on the French General Agricultural Census[9], 6 types of farms were defined on the *Bassée-Voulzie* area according to their main production. The general agricultural census is based on the national classification of technical and economic orientations of farms. This typology is refined for our study to i) represent the diversity of the *Bassée-Voulzie* area, ii) fit to the main environmental issues assessed and iii) be as coherent as possible to the farm group classification considered in the economic model AROPAj developed at the *Seine-Normandy* basin level (see chapter 5 for more information). Thus, a few technical and economic orientations classes may be gathered within one farm type and some other are split (for instance, cereal farmers).

Finally, the types of farms defined are the following (see Figure 2-5):

- (T1) cereal farmers producing potatoes and/or vegetables and/or beet (286 farms and 19 146 hectares);
- (T2) cereal farmers not producing potatoes nor vegetables but beet (401 farms and 49 481 hectares);
- (T3) cereal farmers not producing potatoes nor vegetables nor beet (98 farms and 42 298 hectares);
- (T4) farmers producing permanent crops[10] (20 farms and 86 hectares);
- (T5) crop-livestock farmers (96 farms and 6 682 hectares);
- (T6) wine-growers (221 farms and 1 667 hectares).

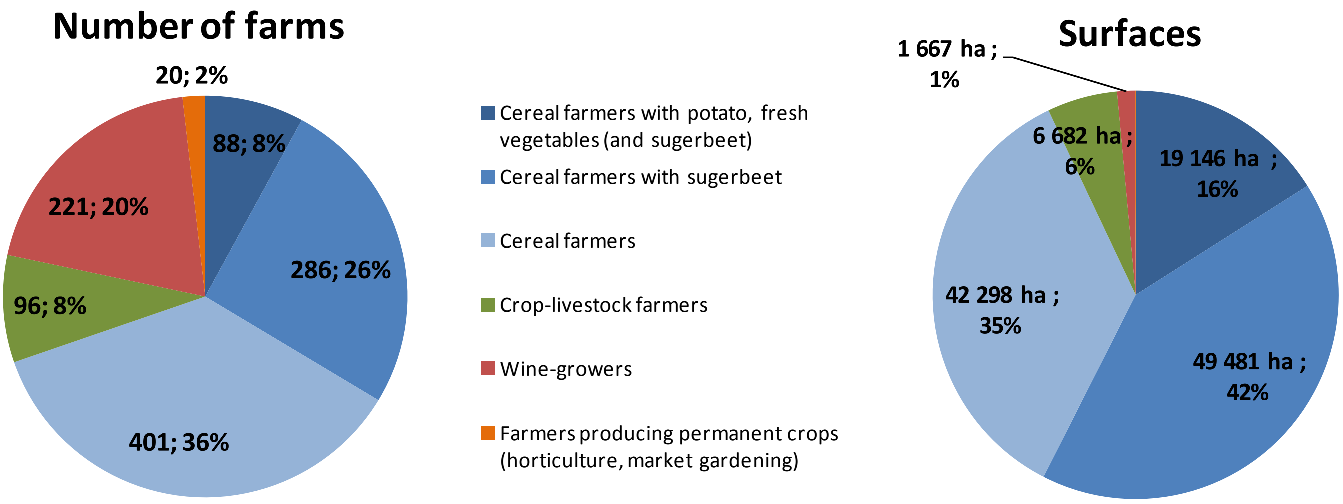


Figure 2-5. Distribution of the number of farms and agricultural surfaces per farm type

Source: Authors, based on the General Agricultural Census (2010)

The Figure 2-6 represents the distribution of crop per farm type. Type 1 and 2 are very similar and the cumulative surface of potato, fresh vegetables and sugar beet for the farm type 1 represents the same share in the crop allocation than sugar beet for the farm type 2. Nevertheless, the three cereal farm types are characterised by their proper logic and constraints.

[9] The last national census was conducted in 2010.

[10] Plus horticulture and market gardening.

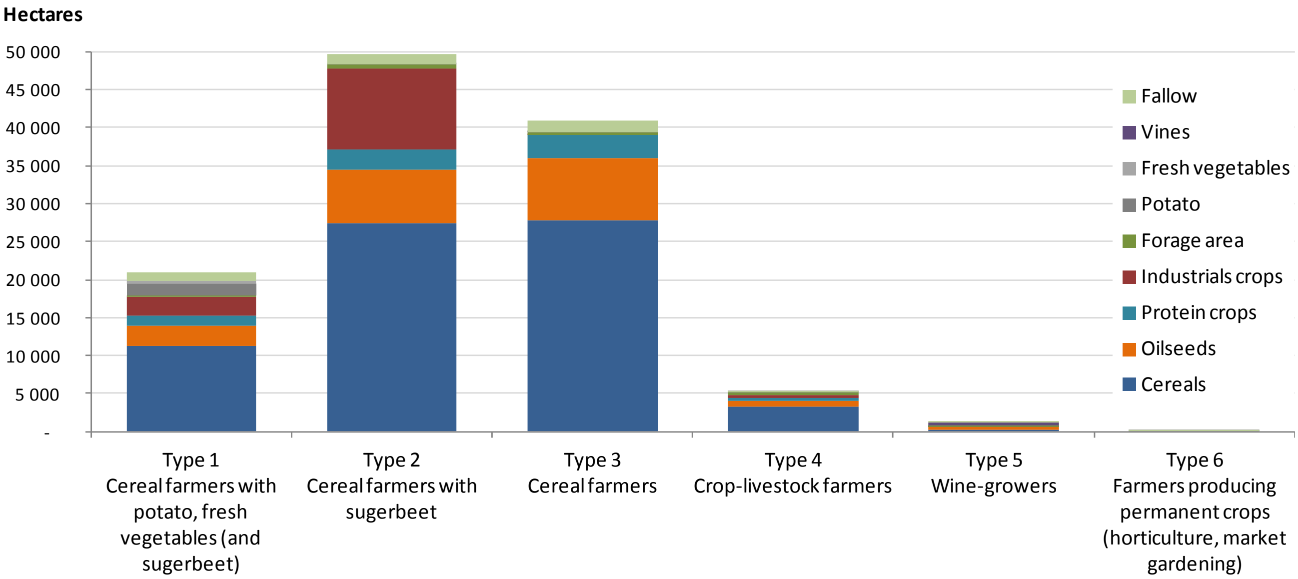


Figure 2-6. Distribution of crop surfaces per farm type

Source: Authors, based on the General Agricultural Census (2010)

Distribution of farm types within the Bassée-Voulzie HU

The *Bassée-Voulzie* HU has been divided into six coherent areas in terms of agriculture and potential environmental services produced (see figure 2.8). A number of criteria have been considered for the delineation of sub-area, such as: administrative entities (departments, municipalities), land use, limits of surface and ground water bodies, French small agricultural areas[11] and Natura 2000 perimeters.

At the end, sub-areas were defined based on the small agricultural areas (SAA) as these take into consideration most of the criteria, including information on soil and climate. They are also relatively coherent with the limits of the surface and groundwater bodies.

The six sub-areas are the following:

Name of the zone	Name of SAA gathered	Intersect the *Bassée-Voulzie* HU
Z1 "La Bassée"	"La Bassée"	90%
	"Basse Yonne"	1%
Z2 "Brie Champenoise"	"Brie Champenoise"	Not calculated

[11] The French small agricultural areas were originally defined in 1946 to establish coherent areas in terms of farming. However, these limits might have evolved due to the technological change and economic processes of specialisation. The small agricultural areas are coherent with the limits of the municipalities and have been defined as the combination of the agricultural regions with the French departments.

	"Brie Centrale"	5%
Z3 "Champagne crayeuse"	"Champagne crayeuse"	Not calculated
Z4 "Montois"	"Montois"	96%
	"Brie humide"	7%
Z5 "Vallées"	"Vallée du Nogentais"	100%
	"Vallée de la Champagne crayeuse"	6%
Z6 "Nogentais"	"Nogentais"	100%

The Figure 2-7 represents the distribution of farm types per sub-area. Surprisingly, crop livestock farmers are not well represented in the central part of the *Bassée-Voulzie* HU that corresponds to the Bassée floodplain, and are more located in the north of the territory (Z2, Z4 and Z6). On the contrary, 95% of the south (Z1, Z3 and Z5) is occupied by cereal farmers.

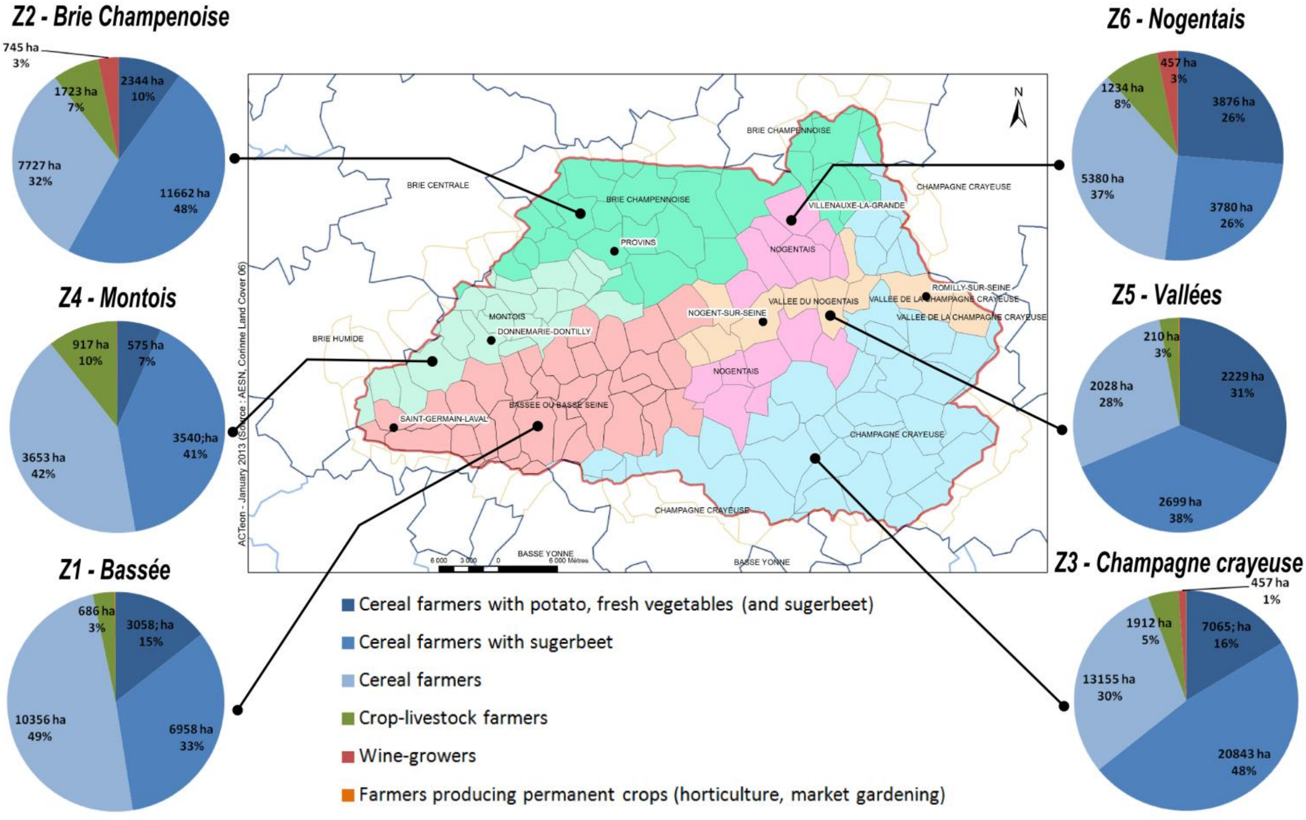


Figure 2-7. Theoretical approach to define coherent geographical unit

Source: Authors, based on the General Agricultural Census (2010)

3. Policy design

3.1. Overview of existing Economic Policy Instruments

Concerning nitrate pollution, agriculture and water treatment plants are considered to be the main sources of nitrogen pollution based on the CGDD report (2011). Agriculture contributes to 89% of the total nitrogen pollution at national level (around 416 000 tons coming from chemical fertilizers, 300 000 coming from organic fertilizers and 90 000 tons coming from water treatment plants). The last Programme of Measures of the Seine-Normandy Water Agency dedicated EUR 44 million to the improvement of water treatment for a few plants (below 10 000 population equivalent) in line with the Urban Waste Water Directive (1991). Thus, this source of nitrogen will not be an issue anymore on the HU from 2013 onwards.

Nitrate pollution from agricultural activities has been the focus of a large diversity of instruments, being regulatory, economic or contractual.

- Since 1985, Denmark has implemented a number of actions plans to reduce nitrate leaching. Instead of designating specific nitrates zones, all action plans apply for the entire territory. The Danish Action Plans for the Aquatic Environment (APAEs) precede the implementation of the Nitrates Directive, as the first plan was adopted in 1987. Among actions set, farmers must annually declare nitrogen accounting which enables to set an individual (non-tradable) quota, based on a standard for fertiliser needs differentiated by crops, soil type and climatic factors. The OECD however highlights the high administrative cost of implementation and monitoring of this measure (OECD, 2008). It also points out that the implementation of a tax on nitrogen fertilizers could be facilitated due to the existing administrative framework related to the phosphorus tax. These elements raise the question of "who pays" for a good water quality. It will be discussed in Chapter 7 "Making it happen".

- In France, the French Grenelle Environment Forum (2007) reiterated the need to induce changes in agricultural practices. However in 2012 the European Commission took France to the Courte of Justice following a reasoned opinion in 2011 regarding the lack of actions implemented within the framework of the national transposition of the Nitrates Directive (91/676/EEC). Water quality data have shown that some areas of France that were not designates as Nitrate Vulnerable Zones (NVZ) are in fact vulnerable to nitrates pollution and the Nitrates Action Programme is considered insufficient (see box 1).

Box 1. The outcry from farmers against the new national Nitrates Action Programme

France has undertaken in 2012 a review of areas designated as NVZ. All municipalities in which nitrate concentration exceeds 50 mg/l are now specified as NVZ, which represents 19 223 municipalities (823 more than in 2012[12]). At the scale of the Bassée-Voulzie HU, the entire area was already designated as NVZ[13].

Besides, the national Action Programme (AP) was reviewed and will be applied in 2013. This AP will strengthen actions to reduce nitrates pollution, such as an increase in the required capacity for storing manure and a restriction of the period during which the application of nitrogen fertilizers is allowed.

A majority of farmers currently protest against the AP, fearing dreadful consequences on the livestock activity and call for a moratorium. The high costs of investments required complying with the AP and the lack of continuity with the previous AP are criticized. The government is currently preparing a consultation with farmers' representatives. The future of the impacts of these new measures thus remains uncertain and will mainly depend on the negotiation with farmers.

- At the local level, measures that have been implemented have not given expected results in terms of water quality improvements:

- In the beginning of the 1990s, voluntary improved fertilisation experiments (i.e. *Fertimieux* programmes) have been conducted in the area of study; farmers received a subsidy per hectare when the level of nitrates remained low at the end of the crop season. After ten years of implementation, *Fertimieux* was criticized on the grounds of efficiency (Barraqué *et al.*, 2005). Nitrate concentrations in the *Voulzie* catchment area have been stabilized but there are still beyond the regulatory standard.

- In 2006, a study showed that the Seine-et-Marne department was behind in defining and implementing the "Declaration of Public Interest" DIP in comparison to other French department. Only 18% of its water abstraction sites were covered (Barraqué *et al.*, 2005).

- Since 2007, agri-environmental measures aiming to reduce pesticides have been contracted with some farmers across the distant perimeter protection of the Voulzie catchment area, in addition to the DIP procedure. The involvement of farmers in these measures was supported by information campaigns and technical support. These instruments are based on 5-years contracts and allow only compensation for any losses of income. Between 2007 and 2012, 36 farmers have been engaged in agri-environmental measures, which represent 40% of the *Voulzie* catchment area and 57% of existing farmers in this area (the objective was to achieve 60% of the eligible agricultural surface covered at the departmental scale in 2012). In 2012, all farmers have renewed their contracts but only one new contract has been signed which raises the question of the potential for this type of measure to involve a larger part of farmers. Agri-environmental measures concerning the reduction of nitrates have only recently been proposed (2012). This

[12] This review includes 1400 new municipalities that were not taken into account in the last designation of NVZ and 617 municipalities that were taken into account but are not identified as NVZ anymore thanks to actions for reducing nitrates pollution

[13] http://www.driee.ile-de-france.developpement-durable.gouv.fr

instrument has been recently the more used instrument to fight against pollutions in catchment areas while it is often criticised for its lack of effectiveness and incentive. In addition to high costs of implementation, agri-environmental measures and *Fertimieux* programmes have led to a certain degree of stakeholder fatigue (Barraqué et al., 2005). Moreover, the efficiency of these actions is based on voluntary contracts which imply communication and support.

- The *Seine-Normandy* Water Agency (and more recently a local environmental association) also developed a land acquisition policy since 1970 on the *Bassée* floodplain area considering its importance for potential future drinking water use. As transactions are made in an over-the-counter market, the process is relatively slow (between 15 and 50 hectares per year) and finally concerns less than 800 hectares (AESN, 2009b) of the 10 500 ha of existing farmlands that this area covers[14] (Bouscasse *et al.*, 2012).

- From the curative treatment side, a project concerning 50 municipalities is being considered as part of the Seine-et Marne Water Departmental Plan to reduce their vulnerability to diffuse pollution (interconnection of drinking water abstraction sites).

Concerning the management of flood risks, the *EPTB Seine Grands Lacs* is in charge of i) maintaining minimum flows in the Seine River and its tributaries and ii) fighting against the risk of flooding in the Seine river basin. To fulfil its mission, it operates four dams capable of storing more than 800 million m^3 of water.

A new project is being considered in the downstream area of *La Bassée* by the *EPTB Seine Grands Lacs*, close to the confluence between the *Yonne* and the *Seine* rivers, to increase flood protection for people living in the cities downstream. This project aims at pumping excess water during flood periods and storing it until the threat is passed. For an investment of EUR 495 million and operational costs of EUR 5.7 million per year, the project would lead to a decrease of the water level of 25 cm in Paris and 30 cm in *Montereau-Fault-Yonne*. The annual avoided damage is estimated at EUR 70 million for a total volume of 55 millions of m^3 of stored water in flood storage area. Even if it is not the aim of this project, it would compensate partially the loss of natural retention occurred in the past decades by the equipment of the sector downstream *La Bassée* (located between *Bray-sur-Seine* and *Montereau-Fault-Yonne)* to allow large tonnage transportation by ship on the Seine River. This heavily modified section does not allow flood retention anymore, except during floods with a flow exceeding 400 m^3/s (50-years floods).

The project aims at developing two types of flood storage area, conventional ones and ecological ones. The first type consists in maintaining current farming activities and compensating for the losses when used as flood storage area (every 5 years). The second more in line with our assessment consists in restoring wetland ecosystems within these flood storage areas by flooding them intentionally every year. However, the project has not been accepted yet and the public debate held at the end of 2011 and beginning of 2012 only validated the development of a pilot project.

These technical solutions to address flood issues have generally led to good results. However synergies could be found to increase flood control by optimising land cover to reduce runoff and

[14] Farmlands represent one third of the total *Bassée* floodplain surface.

increase storage. Between *Bray-sur-Seine* and *Romilly-sur-Seine* the natural characteristics of the flood plain are partially preserved, yet still at risk. The capacity of maintaining and restoring wetlands may be beneficial for the flood mitigation on the Seine river catchment.

Developing flood storage areas on private land has increased the potential flood damages to its associated activities. The "*L212-12 code de l'environnement sur la servitude de sur-inondation*" law is a legal instrument allowing the State and Local Authorities to impose rules and limitations on the private property rights in designed areas. The L212-12 article allows the creation of flood storage areas in rural area for extra volume of water for the benefits of downstream flood risk areas. This article also allows maintaining or restoring wetlands if designated as strategic areas for water management in a SAGE (*Schema d'Amenagement et de Gestion des Eau*); such institution does not exist yet on the *Bassée-Voulzie* HU (L.212-5.1).

The land owner can claim for compensations, compensation being at the charge of the State or the local authorities. The level of compensations is based on a negotiation between the two parties if not fixed by a judge. The compensation calculation method varies from one case to another. The authority is also tight to purchase within ten years. The owner can also ask for the purchase of other lands if their use is affected. Local Authorities may use their own budget to fund flood storage areas. Yet the article *L211-7 du code de l'environnement* allows Local Authority and contractors to set up a fee for benefiting of environmental services. An alternative is for the Water Agency (Article L213-9-2) to set up a fee. Current use of such approach has been limited to cover the costs of hard infrastructure such as dams. Few examples exist as it is difficult legally to define the areas and the levels of benefits of the services associated with flood mitigation.

When L.212-5-1 does not apply, changing current land uses to ecosystems in natural flood plain areas would be more suitable using more conventional approaches such as involving the SAFER (*Sociétés d'aménagement foncier et d'établissement rural - Articles L 143-1 et L 143-2 du code rural* provides right of pre-emption on current market) or developing voluntary agreements.

Indeed, a new tax has been developed and validated this year: the beneficiaries of the service of low water level support provided by the four dams will contribute financially to cover part of the operation costs of these infrastructures. Initially the tax was designed to cover both services of hydrological flows regulation including flood control. But, the implementation of a tax concerning the flood control service was consider to complex and has been postponed. The question of servitudes has also been deepened.

3.2. Proposed Innovative Economic Policy instruments

In 2005, experts contributing to the Millennium Ecosystem Assessment underlined that the degradation of ecosystems and associated ecosystem services has reached an alarming rate. Considering not only one environmental issue but ecosystems as a whole and its contribution to human well being then become one of the guidelines of most of public policies. From the economic perspective, payment for environmental services schemes has thus seen a widely growing interest in the last decade. As such instrument is not well developed in France, and more widely in Europe, an ex-ante assessment is a good opportunity for understanding its pros and cons.

Considering the main environmental issues of the Seine-Normandy river basin and how difficult it is to deal with diffuse pollution, a focus on the nitrogen issue was promoted by the main stakeholders. While taxation on nitrogen has already been assessed, its combination with positive incentives was suggested by recent research (Bourgeois, 2012). What could be the benefits of using a carrot and stick approach.

The nitrate tax: a focus on diffuse pollution

As an alternative to existing instruments, we propose to assess the impacts of a tax that will be set on all fertilizers containing nitrogen. The tax will thus be paid by fertilizer users. We expect that the tax has an incentive effect on the amount of nitrogen fertilizers used, by encouraging farmers to change their agricultural practices.

The comparative analysis conducted by UVEG on different types of taxes to reduce nitrogen pollution has highlighted the advantages and disadvantages of each type of tax regarding environmental efficiency and the ease of implementation (Molinos Senante, 2013c).
Three types of taxes were compared:

- A tax on nitrogen fertilisers, that we propose to assess, which is thus indirectly linked to the concentration of nitrates in water surface and groundwater,
- Taxes directly targeting nitrogen pollution :
    - A tax on nitrogen surplus at the individual level, based on analyses on farmer's soils to evaluate the amount of fertilisers released in water.
    - An "ambient" tax on nitrogen surplus based on analyses on aquifers that is subject to nitrogen pollution coming from several farms. The principle is a same tax for all producers when the observed concentration is greater than the target set in advance by the agency in charge of regulating.

UVEG highlights the difficulties on setting the level of a tax on nitrogen fertilisers, reflecting the indirect relationship between the damage done by the excessive use of fertilizers and the concentration of nitrogen in water. However, the main disadvantage of a tax on nitrogen surplus (which targets the pollution itself) is the difficulty for measuring and evaluating nitrogen surplus.

UVEG has also analysed the different types of taxes actually implemented in Europe to control nitrogen pollution. Four Member States have implemented a tax on nitrogen fertilisers: Austria, Finland, Sweden, Norway – while the Netherlands have set a tax on nitrogen surplus. It has been illustrated that the low price elasticity for fertilisers reduced the effectiveness of the taxes. The implementation of the N surplus tax on Netherlands involved a significant improvement of the environmental conditions. However, the transaction costs to administrate the revenues and to check the N balance in the farms were one of the main cons of the system.

Thus, a tax on nitrogen fertilisers would be a sub-optimal tool compared to a tax on nitrogen surplus; however it enables an easier implementation.

Other limits to the implementation of such a tax may already be highlighted. This instrument requires a payment from the first kilogram of nitrogen fertilizer purchased. Farmers that are efficient in the use of nitrogen fertilizer will also pay the tax. The assessment at the *Bassée-Voulzie* HU, a small-scale study, enables to gather information on farmer needs, constraints and strategies for a detailed assessment of social impacts of such instrument. Environmental impacts are assessed through modelling nitrate concentration in water surface and groundwater. Furthermore, the ex-ante assessment of PES (ACTeon, 2012) on the same study area enables to share analytical tools and to benefit from interviewing the same farmers, sharing a common economic model.

Nitrates tax can paradoxically lead to increased pollution, since a tax on nitrogen fertilizers is indirectly linked to its environmental effect (Bourgeois, 2012; Jayet, 2012). Therefore the amount of nitrogen released in water may increase while the use of nitrogen fertilizers decreases. *A priori*, a tax implementation leads to crops production that need less nitrogen but which may nevertheless be more polluter in terms of amount of nitrogen that is not absorbed by the plant. A tax on nitrogen fertilizer differentiated by crops would overcome the effects of land-use reallocation induced by the tax; however in practice this option is not applicable due to high control costs that would be necessary (Bourgeois, 2012; Jayet, 2012). One solution suggested by Bourgeois (2012) is to combine the tax with a subsidy on perennial crops. Coupling these two instruments is cost-effective compared to the implementation of a nitrates tax alone and can lead to some levels of abatement which are difficult to reach if the policy is only based on a nitrates tax.

To go further in the assessment of the impacts of a nitrates tax, we propose to analyse the impacts of a nitrates tax combined with PES as an alternative mix policy to the implementation of a nitrates tax alone. Sharing the same scale of study and economic and agro-hydrological models with the ex-ante assessment of PES will facilitate the assessment of the implementation of this mix policy. Moreover, it will give a real added-value to this case study, as the impacts of a single instrument will be compared with those resulting from the combination of the two instruments.

Could payment for environmental services contribute to tackle these issues?

When considering PES schemes, two questions are often raised: first, what is a PES schemes and how different an EPI is from agri-environmental programmes in which farmers are identified as the producers of services. Both of these questions are difficult to answer, especially because there is no clear definition for PES (see Anzaldua *et al*. 2013 and Bodini *et al*. 2013 for more information).

Authors frequently refer to the concise definition of Wunder (2005), who defined Payment for Environmental Services (PES) through five criteria as "(i) voluntary transaction where (ii) a well-defined environmental service (or a land use likely to secure that service) (iii) is being "bought" by a service buyer (iv) from a service provider". The fifth criterion defining a PES scheme refers to conditionality where the service provider secures service provision, this PES scheme needs to be truly contingent upon the service being continuously provided.

Muradian *et al.* (2010) extended this definition considering it would otherwise lead to the exclusion of many kind of payments. The role of Ecosystem Services as public good and the economic concept of internalizing externalities within PES were thus considered as central features of PES schemes. Muradian *et al.* (2010) insist on the fact that PES schemes aim at changing individual or collective behaviour that otherwise would lead to excessive deterioration of ecosystems and natural resources. And they defined PES as "a transfer of resource between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources".

While the distinction between PES schemes and agri-environmental measures (AEM) is questionable, three main characteristics of PES schemes can be highlighted to complete the definition of Muradian *et al.* (2010):

- The **type of buyers** considered: buyers of the environmental service can either be the actual users / beneficiaries of the environmental service (PES schemes are then defined as "user-financed" programs in the literature), buyers that act on behalf of the users of the environmental service (PES schemes are then defined as "government-financed" programs) or both together. Actual PES schemes in France can only be found in private-public cooperation and fall into the first category. Two examples refer to Natural Mineral Water Company: the most famous one is the case of Vittel, owned by Néstlé (Perrot-Maitre, 2006; Depres, 2008), but the case of the Evian Natural Mineral Water (owned by Danone Waters) has also been considered as a successful PES scheme (Defrance, 2011). Compared to AEM, the participation of private institutions can increase performance;

- The **mechanism used to define the level of payment**: while payments in AEM programs are constrained to the compensation of additional costs or the loss of income associated to the change of agricultural practices, the level of the payment for PES schemes is defined considering the two sides of the equation, both the farmer losses and the benefits of the buyer(s) leading eventually to higher payments (see Fig. 2.1.);

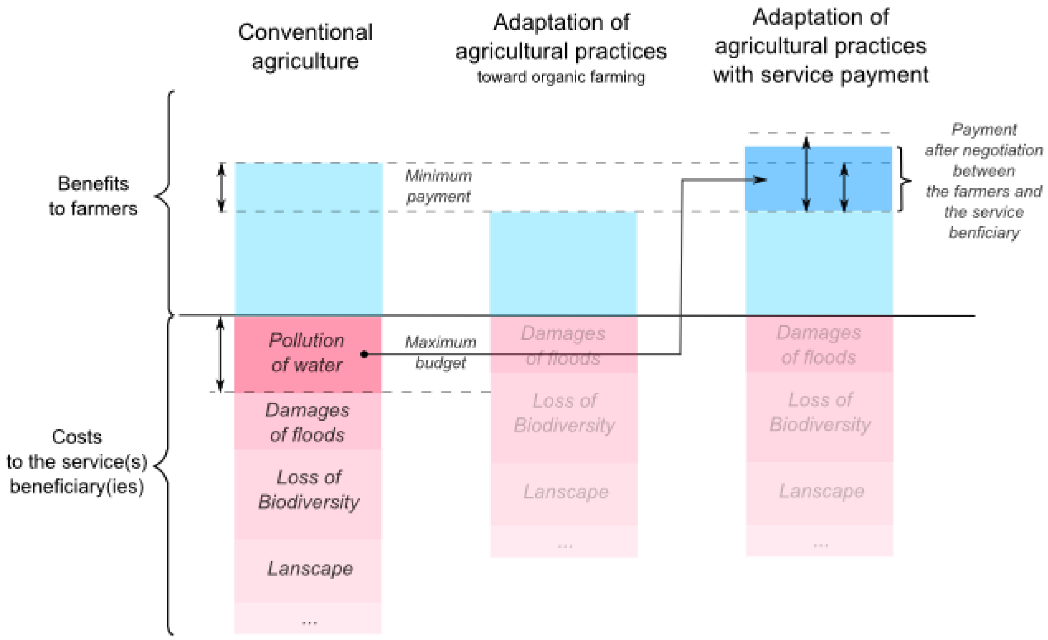


Figure 3-1 – The logic of payment for one environmental service

Source: Authors, adapted from Engel et al., (2008).

The issue of **flexibility**: PES schemes can be adapted to local conditions and stakeholders through a negotiation process. The type of environmental services considered, the duration of the payment, the nature of the payment, as well as the monitoring system can be discussed by the buyers and the providers. Flexibility contributes to the diversity of PES schemes around the world and to the difficulties in proposing one clear and common definition for this economic instrument.

Considering theses characteristics, two options were considered for the design of PES schemes:

- A PES scheme aiming at replacing agricultural land by wetlands. The main argument in favour of that option is that this process would lead to a clear substitution of negative externalities produced by intensive farming by positive externalities produced by wetlands. In addition, Bouscasse *et al.* (2011) already assessed the economic value associated to ecosystem services provided by wetlands on the *Bassée* floodplain. However, this mechanism would have been feasible only on a very restrictive area;

- A positive incentive reflecting the benefits associated to a change from current agricultural practices to more environmentally friendly practices. As mentioned by Bodini *et al.* (2013), farmers are not identified as polluters in that option even if current agricultural practices are overall associated with environmental costs (nitrate pollution), but rather as potential environmental services providers.

We focus on the second approach as results are supposed to be more interesting for the extrapolation process. Indeed, the assessment is done at very local scale, but the change from intensive agricultural practices for cereal farmers to practices coherent with the provision of various ecosystem services is relevant for the whole *Seine-Normandy* basin.

Considering the diversity of environmental issues to be tackled on the *Bassée-Voulzie* HU, various PES schemes could have been assessed taking into account one or more environmental services. For instance:

- The provision of good quality water for the consumption of Paris through groundwater (and the water abstraction sites of the *Voulzie*), *Eau de Paris* being the beneficiary (in the name of the residents of the city of Paris);
- The provision of good quality water for the consumption of towns located in the *Bassée-Voulzie* HU through groundwater;
- The regulation of floods, the residents of Paris (and other towns potentially exposed to flood events) being the beneficiaries;

The change of land-use and the change of agricultural practices produced by the positive incentive may lead to the simultaneous provision of multiple services. Bundling[15] might contribute to reduce transaction costs and improve the implementability of the scheme by helping local towns to access technical and financial resources (Barraqué *et al.*, 2005). Indeed, one barrier to the implementation of PES schemes in the field of good quality water provision highlighted by Barraqué *et al.*, (2005) is that diffuse pollution affects primarily local towns which do not have access to the financial and human resources required by this kind of process. Integrating these local towns into a broader multi-services PES schemes could contribute to the emergence of this promising EPI in the field of water management.

Defrance (2011) identified the gathering of beneficiaries into an "association of beneficiaries" as one key success factor in PES schemes as the presence of an intermediary allows reducing transaction costs. A gathering of producers of environmental services (farmers) is also considered in the design of the PES scheme. Consequences in terms of transaction cost, institutional set-up and policy implementability of such design is discussed in chapter 7. Alternative options are also considered such as using existing institution (water agencies) to collect money and distribute payments.

For diffuse pollution, it is possible to measure nitrogen losses (measures at the plot scale for each crop of each farm) as a proxy for nitrate concentration in groundwater. **Taking 2010 as a reference, the payment is defined based on the reduction of nitrogen losses:** for each kilogram of nitrogen that is not released in the environment compared to its reference, the farmer will receive a unit payment. Optimal payment is defined as the payment leading to an actual reduction of water treatment costs. It is set based on the results of a hydrological model (see chapter 5). Alternative systems of payment could have been considered. For instance, paying only the most efficient

[15] The concept of "bundling" is defined in the literature as grouping several environmental services produced to receive a single stream of compensation for the whole set. If all environmental services produced are not included in the transaction, an issue of free-riding appears: beneficiaries might benefit from the production of the services free of charge. See Anzuala *et al.* (2013) for a detailed literature review on multiple services.

farmers in terms of nitrogen use or defining a common reference on the whole area (thus farmers with current low level of nitrogen loss would have been paid without changing their practices).

For flood control, the level of payment would also be defined based on actual change in terms of environmental service provision.

The carrot and the stick

As suggested by Bourgeois (2012), combining a tax with a subsidy on perennial crops could be cost-effective compared to the implementation of a nitrate tax alone and can lead to some levels of abatement which are difficult to reach if the policy is only based on a nitrate tax. PES scheme (and eventually multi-services PES schemes) could then be considered as a specific subsidy. While the basis of the two instruments are different (local vs. national), sharing the same scale of study for economic and agro-hydrological models with the ex-ante assessment of nitrate tax eases the assessment of the implementation of this mix policy. Moreover, it will give a real added-value to this case study, as the impacts of a single instrument will be compared with those resulting from the combination of the two instruments.

4. Baseline scenario and key assumptions

The impacts of a change in agricultural practices due to the implementation of a PES scheme and/or a nitrate tax must be assessed over at least 20 years, so that the effects on runoff and on nitrogen released in groundwater could be simulated. The maximum time horizon will be 100 years, however it should be noted that uncertainty increases with time.

4.1. Main key drivers to be considered in the baseline scenario for the two issues

Climate change

Climate change is identified as one of the main key drivers that will have an impact on future environmental challenges of the area and on land uses (types of crops and adaptation of practices to reduce risks for agriculture).

Climate change will in particular impact the basin hydrology and the amount of nitrogen released in water resources. In Ducharne *et al.* (2004), the impact assessment of climate change on the hydrology of the Seine-Normandy basin shows that climate change will lead to an increase in mineralization of nitrogen in soil, which contributes to an increase in crop yield and to a decrease in a risk of production loss. The increase in crops yield is estimated to be between 14% and 25% by 2100 on average, at the scale of the Seine-Normandy river basin district. The increased mineralization also leads to an increased flux of nitrates from soil to groundwater. Based on STICS and MODCOU models, the increased flux is estimated to be between 0% and 30% by 2100, compared to the current state. Under ARPEGE NEW A2, it is estimated that 65% of the basin groundwater will exceed the standard for drinking water (50 mg/l).

Following the analysis of the *Explore 2070* project, rainfall could decrease by 5 % by 2070 on the area due to climate change. River flow could be reduce by 27 %, but the level of water in the aquifer of *La Bassée* should not decrease too much (few tens of centimetres). So the functioning of the *Bassée* floodplain could be modified by 2070 but its vulnerability to climate change is considered as moderate only. Ecosystem services that are considered to be the most impacted on the *Bassée* floodplain are: agriculture (irrigation could be required in certain areas), water purification and the augmentation of the low-flow of rivers during dry period (MEDDE, 2012).

Measures from the future Common Agriculture Policy (CAP) reform

The second main key driver identified is the evolution of the objectives and measures of the CAP within the next years. The literature review conducted by UVEG on the history of the CAP highlights the progressive evolution in CAP objectives towards support for a sustainable agriculture (Molinos Senante *et al.*, 2013a). Since 1992, CAP measures have progressively moved from a production support to a policy inciting the development of a viable and competitive activity compatible with rural development and the protection of the environment. The first CAP reform has introduced financial incentives that are “decoupled” from production. Moreover these aids have been granted on condition that they comply with a number of mandatory standards for the environment.

The CAP has evolved over time having been adapted in order to integrate environmental aspects: i) ensuring a sustainable farming by avoiding environmentally harmful agricultural activity and ii) providing incentives for environmentally beneficial public goods and services. UVEG shows that almost all Member States have reduced their surplus of nitrogen between 1990 and 2000. The EU-15 level of nitrogen balance was 16% lower in 2000 than the 1990 estimate. This increase may be explained by two major mechanisms: cross-compliance based on the Nitrate Directive and voluntary environmental-friendly activities through contracting agri-environmental measures.

The European Commission's proposals of the future CAP reform seem to pursue the aim of inducing a change in agricultural practices, pushing farmers to better taking into account environmental issues in their decisions. This will be done by maintaining the two pillars of the CAP (agriculture and rural development), continuing the first pillar greening, a simplification of agri-environmental measures and rural development policy, and a support to livestock and local sales. The CAP reform, as UVEG has pointed out in the literature review, CAP will move from a policy focusing on the three issues of the sustainable development (economic, environmental and social issues) to a policy that must contribute to achieve the objectives of the Europe 2020 strategy by fostering a sustainable, smart and inclusive growth.

As part of the EC proposals for the future CAP reform, a "green" payment (which will represent 30% of the direct payments) is proposed in return for compliance of environmentally friendly measures (maintaining permanent grassland, producing at least three crops on arable lands,...) and organic farmers will automatically receive this payment. Moreover tools for crisis management are proposed to be enhanced, which should reduce interannual variations of farmers' income subject to weather variations. In addition, the budget for agricultural research and innovation is expected to enable more research on production efficiency.

The future CAP reform will surely have an impact on the profitability and the comparative advantage of different production systems. However the levels of change that will be induced remain uncertain since the proposals have not been adopted yet.

Input and output prices

The evolution of crop and fertilizer prices is also a key factor to be considered in the impact assessment of the PES scheme and the N-tax. Analyses have been conducted by UVEG on the past trends of the main crop and input prices at the global, European and French levels (Molinos Senante *et al.*, 2013b).

In France, cereal prices have been highly volatile over the 1970-2012 period including three specific periods of strong price fluctuations (around 1985, 2007 and 2012). Since the progressive decoupling of EU agricultural support from production beginning in 2003, French crop prices are aligned with world prices which depend on various factors - weather conditions, financial speculation, the development of biofuels, etc.

Regarding nitrogen fertilizer prices, their increase is constant in France since the 1970s. UVEG explains this trend in particular by the increase of the fuel price which is highly correlated with the price of nitrogen fertilisers. Other drivers certainly play a role in the evolution of fertiliser prices, such as the price of raw materials and demographic trends. Fertilizers prices are nevertheless also subject to financial speculation on cereal prices (Ministère de l'Agriculture, 2010).

Annex III presents the past evolution of crop prices, fuel and fertiliser prices in France from 1970 to 2012.

Additional drivers are also identified, as the improvement of agricultural techniques which have an effect on a crop yield thus on the gross margin associated to the crop, and the enlargement of the European Union which will likely impact on the land use and the agricultural practices in a context of improving competitiveness, social expectations on an agriculture more environmentally friendly.

4.2. Specific key drivers to be considered in the baseline scenario for diffuse pollution

Local actions for preserving water resource quality

Water needs in the Ile-de-France region have decreased by about 16% between 2000 and 2010 (AESN, 2012b). Production facilities are more than sufficient to ensure global demand. However at the local level, the Champigny groundwater has been overexploited in the past years. A specific management and limited extractions (140 000 m^3/day) are implemented in order to reduce impacts on anthropic activities and aquatic environment and the impacts resulting from climate change will probably strengthen measures of restriction. Actions from *Eau de Paris* in collaboration with AQUI'Brie to promote the reduction of nitrates and pesticides around the Voulzie catchment area are likely to continue (Zakeossian, 2012). The first Water Departmental Plan created in 2007 for a 5 year period in *Seine-et-Marne* and its renewal for the next 5 years show the willingness of the local authority to make stakeholders work together on the objective of recovering the good status of surface waters and groundwater.

A Water Development and Management Scheme[16] is planned to be implemented on the *Bassée-Voulzie* HU within the next years (AESN, 2005). Actions have already been designed by the Seine-Normandy Water Agency as part of its local programme of actions. For about EUR 46 million, actions are planned to remove or reduce pollution (nitrates and pesticides) on strategic catchments by implementing subsidies to encourage the conversion into organic farming and by controlling untreated areas. Other actions are planned to be implemented such as those for reducing point source pollution by improving the capacity of water treatment plants and limiting the use of

[16] In French SAGE (*Schéma d'Aménagement et de Gestion des Eaux*). This planning document specifies the main orientations for water management planned by the SDAGE at the level of a hydrographic unit.

pesticides by municipalities for example (about EUR 62,5 million) and actions to preserve and restore watercourses (about EUR 41 million). This initiative should contribute to the preservation of the water resource within the next decades.

4.3. Specific key drivers to be considered in the baseline scenario for flood regulation

Two main drivers have been identified in relation to the flood regulation issue.

In a short term, two projects may modify the natural hydrological functioning of *La Bassée* and the ecosystem services it provides: the modification of the Seine River between *Bray-sur-Seine* and *Nogent-sur-Seine* to improve ship transport (*Voies Navigables de France*) and the project of flood protection (*EPTB Seine Grands Lacs*).

Mining activities for the extraction of alluvial gravel may increase significantly to respond to the increasing needs of Paris (+15% in 2030) and *La Bassée* represents one of the main producers of this building material in the Region. Thus the Seine River at *La Bassée* may change significantly in the next years, with potential impacts on flood regulation.

4.4. Conclusion: defining the baseline scenario

Baseline scenario for diffuse pollution

The EC's proposals regarding the **CAP reform** seems to pursue the aim of inducing a change toward environmentally-friendly agricultural practices. Besides, **local actions** set to preserve the quality of water resources on the Bassée-Voulzie HU are consistence with a sustainable agriculture scenario for the next decades. In this scenario, agriculture introduces more environmentally friendly practices (reduction of fertilisation and increasing use of intermediate cultures) without changing the type of crops.

Such a scenario has already been simulated (Ducharne *et al.*, 2004) leading to a reduction of pressures on groundwater. In addition, Ducharne *et al.* (2004) also simulated the potential impacts of **climate change** in combination with the sustainable agriculture scenario. It is shown that the impacts of a sustainable agriculture on nitrogen concentration in groundwater are opposed and of the same order of magnitude as those under a climate change scenario. A scenario combining climate change with a sustainable agriculture cancel out each other's effects on nitrates pollution, leading to a **stabilization of current trends.**

This assumption must however be mitigated given the high dependence of **cereal and fertilizer prices** on various factors which leads to an uncertainty on the changes in farmers practices (in particular the evolution of the consumption of nitrogen fertilisers) and crop allocation. The fluctuating evolution of cereal prices and the constant increase in input prices suggest that agricultural practices will go towards a more rational use of fertilisers. But we may also suppose that a higher level of cereal price leads to a higher consumption of fertilizers, since it is more interesting for farmers to ensure high cereal yields. The impact assessment of EPIs therefore needs to include a sensitivity analysis in particular on cereal and fertilizer prices, in order to estimate the extent to which the EPI is effective or not.

Baseline scenario for flood regulation

In the short term, projects aiming to modify the natural hydrological functioning of *La Bassée* and the extension of mining activity will certainly have a negative effect on the environmental service for flood regulation that it provides. In the long term climate change will have a negative (but moderate) impact on the functioning of the Bassée floodplain. Given the uncertainty of the effects regarding measures from the future CAP reform on land-use allocation and the evolution of crop prices, we propose to set a baseline scenario consistent with the degradation of the service of natural flood regulation in the *Bassée* floodplain.

Table 4.1 summarises the expected effects of the main key drivers regarding the two issues.

Table 4.1. Expected effects of the main key drivers identified on the quality of water resources and on flood regulation in the Bassée-Voulzie HU. In green: positive expected effects; in red: negative expected effects, in grey: uncertain effects

	Expected impacts on the quality of water resources in the *Bassée-Voulzie* HU	Expected impacts on flood regulation in the *Bassée-Voulzie HU*
Measures from the future CAP reform	The EC's proposals of the future CAP reform seem to pursue the aim of inducing a change in agricultural practices, pushing farmers to better taking into account environmental issues in their decisions. However the levels of change that will be induced remain uncertain since the proposals have not been adopted yet.	The EC's proposals of the future CAP reform seem to pursue the aim of inducing a change in agricultural practices, pushing farmers to better taking into account environmental issues in their decisions. However the levels of change that will be induced remain uncertain since the proposals have not been adopted yet.
Climate change	Climate change will lead to an increased flux of nitrates from soil to groundwater. A scenario combining climate change with a sustainable agriculture cancel out each other's effects on nitrates pollution, leading to a stabilization of current trends.	The functioning of the *Bassée* floodplain could be modified by 2070 due to climate change but its vulnerability to climate change is considered as moderate.
Local actions	Actions from *Eau de Paris* in collaboration with AQUI'Brie, the Water Departmental Plan in *Seine-et-Marne*, and the future implementation of the SAGE in the *Bassée-Voulzie* HU contribute to preserve water quality in the area	In a short term, two projects may modify the natural hydrological functioning of *La Bassée* and the ecosystem services it provides. Moreover the Seine River at *La Bassée* may change significantly in the next years due to mining activity extension, with potential impacts on flood regulation.
Input and output prices	The high dependence of cereal and fertilizer prices on various factors leads to an uncertainty on the evolution of the consumption of nitrogen fertilizers.	Output and input price surely have an impact on the comparative advantage of different production system and on land-use allocation. However the high volatility of crop prices leads to an uncertainty on changes in land-use allocation.

5. Methodology and tools used

The chapter 5 discusses the methodologies and tools used for the assessment of the two EPIs proposed for the *Bassée-Voulzie* area, reminding first the Assessment Framework developed in WP2 of the EPI Water Project and presenting then both quantitative and qualitative techniques are used.

The results from this exercise are then discussed in two other chapters. Chapters 6 and 7 focus on the performance (out oriented) and include the quantification of the economic, environmental and distributional outcomes of the assessment framework, whereas the chapter 7 is conceptually oriented and includes the other criteria of the assessment framework, which are discussed qualitatively.

5.1. Using the EPI-Water assessment framework

The WP2 of the EPI Water Project leads to the specification of the Assessment Framework (AF) used both in the ex-post assessment of EPIs (WP3) and the ex-ante assessment (WP4).

Seven assessment criteria were selected: four outcome-oriented criteria describe EPI performance, costs and induced effects (the environmental and economic outcomes, the distributional effects and the transaction costs from negotiating and enforcing policies) while three other contextual criteria describe the conditions influencing EPI outcomes (the institutional conditions, the process of implementing EPI and the uncertainty surrounding the process and the results). See Zetland *et al.* (2011) for the detailed description of the assessment framework.

Chapter 6 and 7 present the qualitative and quantitative results for each of these criteria in order to ensure a broad assessment of both the tax on nitrogen fertilisers and the payment for environmental services scheme.

5.2. How to address the socio-economic and environmental outcomes of the EPIs?

Socio-economic and environmental outcomes are assessed through a combination of agro-economic and hydrological models as illustrated in the Figure 5-1.

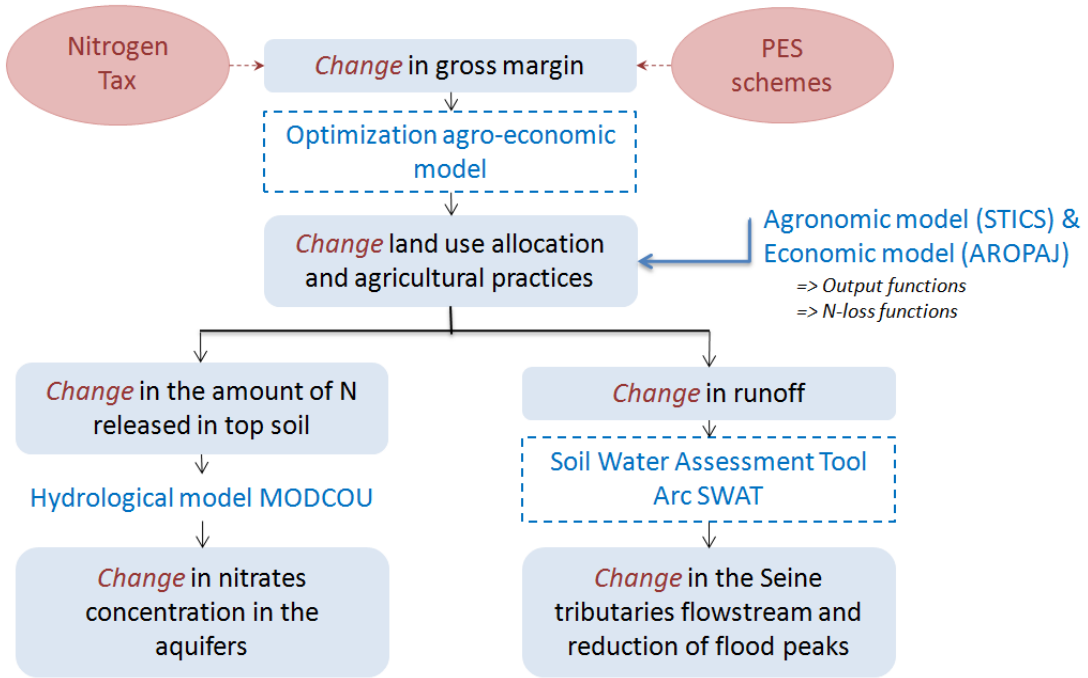


Figure 5-1. Theoretical process for the assessment of the socio-economic and environmental outcomes.

Source : Authors, 2013

An economic optimization model simulates the potential land-use reallocation generated by the implementation of the PES scheme and/or a tax on fertilisers by modelling the gross margin associated to each crop. Farmers, as rational economic agents, are expected to react to the signals (level of payment and tax, respectively) by changing the crop allocation, their production levels and the level of inputs used. Associated to this agro-economic model, the nitrogen loss function developed by INRA (as combination of an agronomic model STICS with an economic model AROPAj) allows for each crop to define the amount of nitrogen released in water.

Then as a next step, two hydrological models are used to convert land use reallocation and a change in agricultural practices into changes in environmental services provided:

- The hydrological model MODCOU and its combination with the agronomic model STICS and the economic model AROPAj are detailed in the section 5.2.2. It estimates nitrate transfer of top soil toward groundwater at the Seine river basin level. Initially developed by the Geosciences Centre from Mines ParisTech[17] (Ledoux, 1980), simulations were run by Cyril Bourgeois (Sisyphe Joint Research Centre) at the scale of the *Bassée-Voulzie* HU, for the purpose of the EPI-Water project;

- The public Soil Water Assessment Tool ArcSWAT has been selected to assess the potential impact of land use changes on the water balance (Viavattene, 2013). ArcSWAT can simulate

[17] Located in Fontainebleau (France), the Géosciences Centre is a Research and Education Center shared between MINES Paris Tech and ARMINES - http://www.geosciences.mines-paristech.fr/fr

water surface and groundwater quality and quantity at the water catchment scale. Simulations were run by Christophe Viavattene (Middlesex University) on three sub-basins of the *Bassée-Voulzie* HU to assess whether land use reallocation could significantly change the runoff, the stream flow of the Seine tributaries and finally could reduce flood peaks.

5.2.1. Simulating socio-economic outcomes using an optimization agro-economic model

The optimisation model was developed by ACTeon and Jean-François Amen[18] at the scale of the *Bassée-Voulzie* HU taking into account local specificities. It models farmers' behaviour and helps understanding performance-based outcomes of both the tax on fertilisers and the PES schemes. Indeed, the simulations run at the farm level provide a signal to the farmer's income for different farm types (economic outcomes and distributional effects) and crops allocation. By combining each crop to its nitrogen loss function, the agro-economic model helps measuring diffuse pollution at the scale of the *Bassée-Voulzie* HU and sub-areas (environmental outcome).

The agro-economic model developed is a linear-programming model describing the annual supply choices of representative farmers, called "farm types". In linear-programme modelling, and *a fortiori* in all mathematical programming models, there is one expression called the "objective function" that should be maximised or minimised and a series of constraints, both described by linear mathematical expressions. Mathematical programming model are widely used for analysing agriculture as it provides the advantage of combining the manifold and interlinked nature of agriculture (see Bodini *et al.*, 2013 for more information on model used for the assessment of EPI such as tax and subsidy in the agricultural field).

In the model, farmers are considered as rational economic agents thus they optimise their gross margin under technical and economic constraints. In response to EPIs simulations (both positive incentive through the simulation of a PES scheme and negative incentive through the tax on nitrogen fertilisers), farmers are expected to change their choice of crop allocation and their agricultural practices, through the amount of fertilisers used.

The model structure: a combination of multiple economic optimisation models

The EPIs are introduced into the optimisation function of each crop gross margin of each type of farm of each area as follow:

For the tax on nitrogen fertilisers:
Max Σ (Crop Gross Margin)
= Max Σ (revenue – operation costs)
= Max Σ [revenue – (quantity of nitrogen fertilizer*(price + **TAX**) + other operation costs)

[18] Agro-economist specialized in agricultural modelling.

For the PES scheme:
Max Σ (Crop Gross margin) + PES
= Max Σ (revenue – operation costs) + PES
= Max [(crop yield * price + subsidies) – operation costs)] + PES

For each crop of each farm type of each area, a new gross margin is calculated including the EPI. The change in the balances of crop gross margins leads to a change in crop allocation. The new crop allocation that is chosen is the one that maximizes the sum of the gross margins at the scale of the farm.

In practice, as the model is designed for six farm types and six subareas, the final agro-economic model is a combination of 36 sub-models. Each of them can be calibrated with specific data adapted to the local farm types and leads to an optimisation of local gross margins at a farm type level. The results of the sub-models are then aggregated to fit with agricultural statistics[19] at the scale of the HU (number of farms and surface of crops per type and area).

Model inputs

The crops considered in the economic modelling are maize (rainfed and irrigated), bread wheat, sugar beet, potato, rape, barley (winter and spring), silage corn, sorghum, soy (rainfed and irrigated), sunflower, protein pea, alfalfa, hemp, melon and meadow. For most of these crops, three activities are integrated to allow varying agricultural practices in terms of fertilisation (and thus yield).

Describing these activities requires collecting local data considering potential differences between farm types and location (sub-areas are defined based on small agricultural areas taking into account the type of soil). As mentioned by Balana *et al.* (2011), there is a risk of failing to capture the inherent heterogeneity of farms by using "stylized" farm in the modelling. Yet, the agro-economic model should provide relevant results while using local and precise farm data.

Two types of information are considered in the linear programming model: information on activities and constraints. As regards to activities, the main data used are:

- Data on crop surface per farm type and town (aggregated at sub-area level) based on the French General Agricultural Census (2010);
- Data on outputs, mainly the price and yield per crop type. Regional and departmental data were collected from various sources, among which rural economic centres in charge of producing reference values, and refined based on the 25 years experience of an agro-economist engineer.

[19] General Agricultural Census, 2010

- Data on inputs: price and amount of inputs used per crop type. In addition to previously quoted sources of information, data collected by INRA from 1970 to 2000 at the level of the small agricultural areas on crop rotation, fertilisation, yield, seeding date and tillage were used[20].

- Information on subsidy per crop[21]: thanks to recent Common Agricultural Policy, most subsidies are decoupled. However, farm operating statements and results reported in the CER data based indicated that a few crops still benefited from subsidies. For instance, protein peas are associated with a EUR 174 per hectare subsidy, representing about 17% of the total operating revenue.

In order to calculate the gross margin per crop, these data were compared to local data collected through the field survey. Sixteen farmers were interviewed in the *Bassée-Voulzie* area in January and June 2013. Surveys gave information on the financial situation of farmers associated to the main farm types, drivers that conduct farmers to choose their current agricultural practices considering among others the type of soil and the production constraints that determine the amount of nitrogen fertilizers applied on crops.

Agricultural and economic constraints are used to calibrate the model to reflect as much as possible the current behaviour of farmers. The set of constraints includes i) crop rotation and agronomic constraints ii) and restrictions concerning industrial crop surfaces mainly.
Regarding agronomic constraints, an example is given with irrigable surfaces in the *Bassée-Voulzie* area: potato and fresh vegetables are often irrigated. Yet, irrigable surfaces are limited and competition with maize for instance is integrated in the model.
Besides, a few crops are constraints by the industrial sector. For instance, the surface of sugar beet is determined by industrial firms that allocates quota to farmers depending on the quality of their plots mainly (type of soil).
Another specific constraint is integrated in the agro-economic model: in 2010, winter barley has been introduced by farmers in crop rotation while its gross margin was quite low. Due to bad meteorological conditions, farmers had not enough time to plant intended surfaces of cereals. Thus they used winter barley to complete their rotation as there is time lag in its seeding date. Bread wheat, spring and winter barley surface were thus interlocked in the model.

In order to simulate nitrogen loss per crop (and per type of farm and zone), data collected on the field and the amount of nitrogen fertiliser applied for the year 2010 are complemented by two types of functions which were provided by the Sisyphe Joint Research Centre which contributes to the PIREN-Seine programme. These two functions enable to assess the environmental outcome associated to the implementation of the two EPIs.

[20] We would like to thank Catherine Mignolet and Celine Schott (INRA Mirecourt) for sharing the information.
[21] Information on territorial Agri-environmental measures is not directly included in the modelling as it concerns only a small percentage of total number of farms on the area (around 3%).

Yield function per crop: an additional input developed by INRA

Yield functions establish the link between the amount of nitrogen applied and the crop yield, according to a set of parameters. Output functions were previously developed in the context of the PIREN-Seine research programme when coupling the economic model AROPAj with the agronomic crop model STICS (Bourgeois, 2012 based on Brisson et al., 1998 and 2003). N-yield points were then replaced by function of nitrogen dependent on physical and economic factors for crops in each farm group considered in the AROPAj model[22].

The production function is based on information at the regional scale and designed with a method adaptable to any European region (Godard et al., 2008). They described the choice of the mathematical function, that is:

$Y = Y_{max} - (Y_{max} - Y_{min}) * exp^{-tN}$

where Y is crop yield, N is nitrogen fertilizer amount and t stand for the rate of increase.

The production function assumes that farmers optimize the use of nitrogen fertilizer in order to maximize the gross margin. The chosen level of the amount of fertiliser is thus defined by the economic optimum and not the maximum yield, that is to say the amount of nitrogen above which marginal gain from an increase in crop yield is lower than the cost of the corresponding additional amount of nitrogen.

A set of functions were thus developed at Regional level for each crop considering a few agricultural characteristics (the variety of the crop, the seedling season, the previous crop and irrigation). For each French Region of the Seine-Normandy basin, between 30 and 60 functions per crop and per farm group were considered.

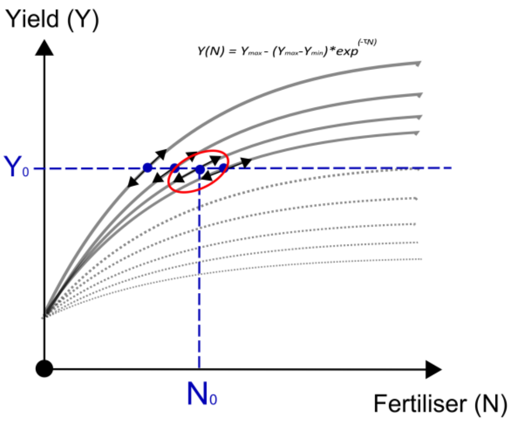


Figure 5-2.Tthe method of constructing nitrogen response curve for each crop of each

For each crop and farm group, the most suitable function was selected among the range of N potential nitrogen response curves following a three step process described by Godard *et al.*, 2008.

First, a range of N potential nitrogen response curves are generated based on the agronomic model STICS. Then, the curves reaching observed yield are selected. And finally, the one response curve selected is one for which the curve slope is the closest from the price ratio (nitrogen price over selling price of the

[22] The economic model AROPAj is defined based on three criteria available in the Farm Accountancy Data Network (FADN): the technical and economic orientations, the economic dimension classification and the altitude.

farm type from the combination of the STICS and the AROPAj models, based on Godard et al. 2008	crop).

The *Bassée-Voulzie* HU lies on three French Regions and encompasses 22 AROPAj farm groups[23]. Among the set of functions provided by the Sisyphe JRC, we chose, for each crop for each type of farm of the *Bassée-Voulzie* agro-economic model, the function that reflects the better the gross margin (GM) actually observed on the field assuming that farmers are rational economic agents.

The production function was used in the *Bassée-Voulzie* agro-economic modelling for the following crops: maize, bread wheat, sugar beet, potato, rape, barley, soy and sunflower. The total surface of these crops represents 93% of the total agricultural surface of the *Bassée-Voulzie* area.

The nitrogen loss function: an important input for the Bassée-Voulzie agro-economic modelling developed in the context of the PIREN-Seine research programme

As described by Bourgeois (2012), the STICS crops model provides us one nitrogen loss function for each crop considering the type of soil as well as climatic conditions and application date. Nitrogen loss functions establish the link between the amount of nitrogen applied to a crop and its associated loss of nitrogen at the top soil level for each main crop of the Seine basin (maize, bread wheat, sugar beet, potato, rape, barley, soy and sunflower). These functions will help estimating the nitrate contamination of the aquifer, based on nitrate lixiviation flux (Brisson *et al.*, 1998).

Nitrogen loss is represented by a linear function: aN +b, where N represents the amount of nitrogen used. For more information on these functions, see Bourgeois, 2012. See annex II for the description of nitrogen loss function per crop.

Using yield and nitrogen loss functions to assess the economic and environmental outcomes of EPIs through the agro-economic model

Observed data are used in the model for both crop yields and the amount of nitrogen applied per crop. Thus, they do match with theoretical functions provided by the Sisyphe JRC. However differences are quite important for a few crops. See chapter 7, section on uncertainties, for more information.

That said, these functions are useful for estimating the impact of a tax on fertiliser on farmers' choices in terms of agricultural practices. The amount of the tax on nitrogen is added to the current price of nitrogen fertiliser. Therefore the new optimised crop gross margin is the one that optimises the amount of nitrogen fertiliser applied according to the new fertiliser price (see Figure 5-3).

[23] Farm Group 1 to 12 and 40 to 49. See Jayet *et al.*, 2009 for more information.

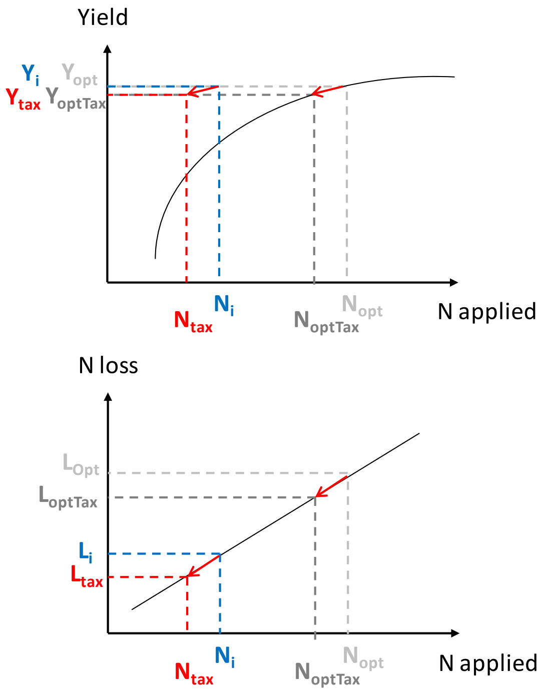


Figure 5-3. Combining theoretical yield and nitrogen functions with observed data in the Bassée-Voulzie agro-economic model

The new crop yield is estimated using the optimized yield function. It is assumed that the selected function represents as much as possible the potential evolution of crop yield according to the nitrogen applied.

The percentage change between the initial amount of nitrogen applied (N_i) and the new amount of nitrogen applied (N_{tax}) is used to calculate the new yield following the implementation of the N-tax:

$$Y_{tax} = \frac{|Ni - Ntax|}{Ni} = \frac{|Nopt - NoptTax|}{Nopt} Y_i + [1 + (Y_{opttax} - Y_{opt}) / Y_{opt}]$$

The linear function establishing the link between the amount of nitrogen applied on the crop and the amount of nitrogen loss enables to estimate the new amount of nitrogen loss (L_{tax}), assuming that

$$L_{tax} = \frac{|Ni - Ntax|}{Ni} = \frac{|Nopt - NoptTax|}{Nopt} L_i + [1 + (L_{opttax} - L_{opt}) / L_{opt}]$$

Changes in crop allocation are simulated for both the scenarios of implementing a nitrate tax and a PES scheme. The model simulates the new crop allocation which optimises the total gross margin, sum of the optimized crop gross margins, and according to the production constraints.

How the nitrate tax is simulated into the agro-economic model?

The nitrate tax may lead to three cumulative effects, as described in Bourgeois (2012):

- A reduction of pollution due to a reduction of cropland area by an increase of perennial crop or meadows. It is referred as the "total land effect";
- A change in nitrogen loss due to crop reallocation. It is called the "land-use reallocation effect". The model stimulates the new crop allocation which optimises the total gross margin, as the sum of the optimized crop gross margins considering the agronomic and economic constraints. The reallocation could lead to an increase or a decrease of nitrogen losses depending on the new crop nitrogen loss function;
- And finally, a change in agricultural practices in terms of nitrogen used. This "input prices effect" concerns the decrease of pollution due to a reduction of fertilizers use. The model stimulates the new optimised gross margin of each crop consuming nitrogen fertiliser using

the yield function, including the tax. The gross margin of these crops decreases when the level of the tax increases.

How payment is simulated into the agro-economic model for PES schemes?

In the model, farmers receive an additional payment when they reduce their nitrogen loss considering the current situation as a reference. For each kilogram of nitrogen avoided, they receive a unit payment. Let us take a simple example. We consider one farm with ten hectares of agricultural land and three crops defined by their gross margin and nitrogen loss:

- Bread wheat (cereals) is associated to a gross margin of EUR 860 per hectare and a nitrogen loss of 13,2 kg of N per hectare;

- rapes (oilseeds) is associated to a gross margin of EUR 843 per hectare and a nitrogen loss of 59 kg of N per hectare;

- peas (protein crop) are associated to a gross margin of EUR 611 per hectare and a nitrogen loss of 2 kg of N per hectare;

In order to simplify the example, we consider two hypothetical constraints: wheat ant rapes cannot represent more than a third of the total agricultural surface. The current situation without payment is thus defined by a total gross margin of EUR 7 711 per farm and a loss of 247 kg of nitrogen. Considering a payment for the reduction of nitrogen loss, the farmer will probably think about planting more peas to reduce its global loss of nitrogen:

- Replacing one hectare of wheat by one hectare of peas will be associated with a payment of EUR 40 if we consider a unit payment of EUR 3, and EUR 53 for a unit payment of EUR 4. In both cases, the new gross margin of peas are lower than the gross margin of wheat ;

- Replacing one hectare of rape by one hectare of peas will be associated with a payment of EUR 176 if we consider a unit payment of EUR 3, and EUR 235 for a unit payment of EUR 4. In the second case the new margin of peas considering the payment (EUR 846 per hectare) is higher than the one of rape.

Thus, the farmer will plant one more hectare of peas (in place of rape). The new situation is then defined by a total gross margin of EUR 7 714 (EUR 7 479 plus a payment of EUR 235) and a nitrogen loss of 190 kg, that is a better situation both from economic and environmental aspects. We also note that the change of crop distribution is associated to a precise amount of payment, located in that example between EUR 3 and EUR 4.

In order to simulate changes in the amount of nitrogen applied on crops for PES schemes, crops consuming nitrogen fertilisers were included in the model with three potential yields per hectare (see Table 5.1). Indeed, the payment does not affect directly operating charges or products and crops with alternative agricultural practices have to be created artificially.

Table 5.1. Yields par type of crop simulated in the model[24]

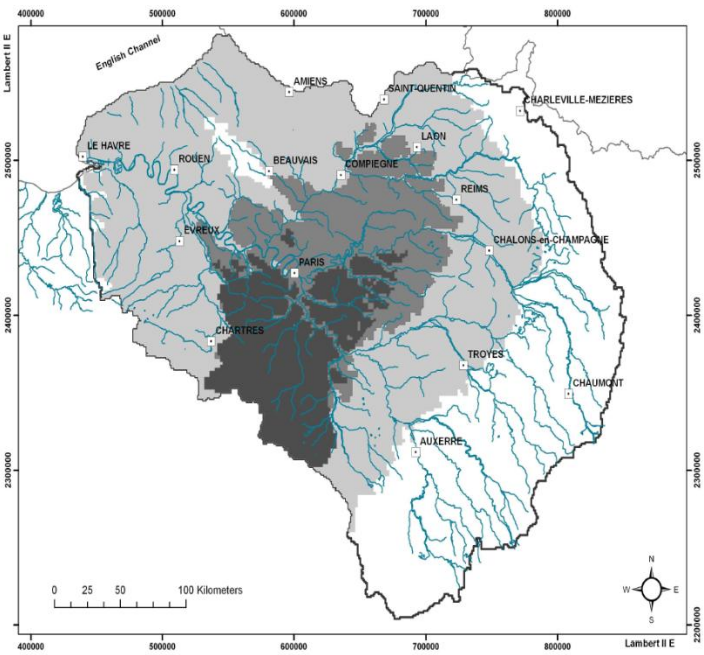
	Bread wheat	Spring Barley	Winter barley	Grain Maize	Rape	Sunflower	Sugar beet	Potato
Current yield (T/ha)	8,0	6,6	7,6	8,8	3,5	3,2	91	55
Current quantity of N-input (kg N/ha)	220	150	121,5	195	210	46	145	160
Alternative yield (2)	7,0	5,8	6,6	7,8	3,0	2,8	86	50
N input (2)	153	122	94	101	104	19	95	103
Alternative yield (3)	6,0	5,0	5,6	6,8	2,5	2,4	81	45
N input (3)	110	99	73	64	32	3	72	64

Source: Authors, based on the yield functions provided by the Sisyphe JRC

5.2.2. Simulating environmental outcomes of EPIs for the diffuse quality issue using the MODCOU hydrological model

The MODCOU hydrological model, developed in the eighties by the Geosciences Centre from Mines ParisTech, allows estimating nitrate transfer of top soil toward groundwater at the Seine river basin level. It converts the amount of nitrate released into a concentration of nitrates in water surface and ground water. It computes the daily water balance using climatic data, the water flow to and in the river network as well as the flow to, in and between aquifer layers (Bourgeois, 2012).

The MODCOU model can simulate water flow for the three main aquifers of the Seine basin (see Figure 5-4): the Oligocene, the Eocene and the Chalk aquifer with a spatial resolution varying from 1 to 8 km.



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24 When we refer to a crop without any additional information, then we consider the crop with reference yield. Otherwise, it is referred as "crop (-XT/ha)".

Figure 5-4. *The Seine basin and the main three overlayed aquifer layers, from top to bottom: the Oligocene (dark grey), the Eocene (grey) and the Chalk (light grey)*

Source: Bourgeois, 2012

The coupling of the economic model AROPAj with the hydrological model MODCOU is described in Bourgeois (2012). Activities and farm groups are specialized with the same precision as the MODCOU spatial unit through spatial econometrics model developed by Chakir (2009).

The environmental outcome of the EPI is thus calculated thanks to this model. The baseline scenario was not simulated combining directly the *Bassée-Voulzie* agro-economic model to the hydrological model MODCOU. Instead, the agro-economic model allows calculating a percentage of nitrogen loss reduction for the six bus-areas of the *Bassée-Voulzie* HU. These reductions are applied to a previously defined baseline scenario simulated by the coupling of AROPAj and MODCOU. The baseline scenario thus corresponds to a "business as usual" scenario, considering that agricultural practices observed until 2010 are repeated (input and output prices are not changed and there is no technological change).

The three aquifers considered by MODCOU are intersected to the *Bassée-Voulzie* HU limits. The same process is done at the scale of the six sub-areas (see Figure 5-5).

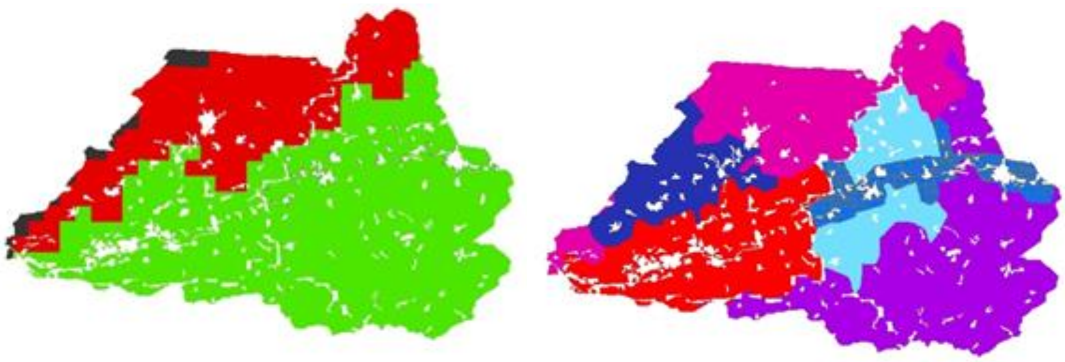

Figure 5-5. Definition of the three main aquifers at the scale of the *Bassée-Voulzie* HU (on the left hand) and limits of the six sub area in the hydrological model MODCOU (on the right hand).

Source: Bourgeois, 2012

The Chalk aquifer is represented by 433 spatial units in the hydrological model MODCOU[25], while the Eocene represents 116 spatial units and the Oligocene is constrained to 29 spatial units only. The latter is thus not well defined at the scale of the *Bassée-Voulzie* HU. Sub-areas are represented by 1 to 151 spatial units in the MODCOU model depending on the aquifer considered. Thus, results will only be discussed at the scale of the chalk and the Eocene aquifers.

[25] The groundwater body associated to the Bassée Floodplain (*Alluvions de la Bassée* - 3006) is thus integrated into the Chalk aquifer.

When a MODCOU spatial unit straddle two subareas, the nitrates flux are calculated considered the following mathematical formula:

$N_{incoming\ flux}$ (i) = N_{mean} (i) * Σ [pourcent_zone(j) * S(i) ∩ S(j)] / S(i),

where N(i) represents the nitrate flux on the MODCOU spatial unit (i), S(i) represents the surface of the MODCOU spatial unit (i) and S(j) represents the surface of the subarea (j).

At the end, the optimal amount of payment could then be determined considering the avoided cost of treatment incurred by a decrease in nitrate concentration (simulation of the point of view of the service beneficiary). For the provisioning of good quality water, the function is non-linear: when the concentration of nitrate in water does not exceed 50 $mg.l^{-1}$, the cost of treatment might be zero; it is then constant until another threshold around 80 $mg.l^{-1}$; finally, the cost of treatment could be the cost of finding a new abstraction site while the amount of pollutants is too high to be treated.

5.2.3. Simulating environmental outcomes of Payment for Environmental Services schemes for flood regulation using the SWAT hydrological model

ArcSWAT (Soil Water Assessment Tool) is a public American model simulating surface and groundwater water quality and quantity at the water catchment scale. It is used by Middlesex University to assess potential changes in the water balance (evapotranspiration, runoff, infiltration and storage) following the implementation of a payment for environmental services scheme on the *Bassee-Voulzie* HU. The hypothesis being tested is concerned with whether a change in land use allocation could change runoff at the scale of a sub-basin, then change the streamflow of the Seine tributaries and finally reduce flood peaks of the Seine river.

Ideally, these results could lead to the calculation of the benefits of flood regulation. Benefits can be calculated considering several methods: the avoided cost, replacement cost and substitute cost methods (Bouscasse *et al.*, 2012).

Only two gage stations with relevant information on measured water river flow were identified as available. Therefore the study was limited to two sub-catchments: The Voulzie river and the Ardusson river (see figure below and Viavattene, 2013 for more information)[26].

- The Voulzie gage station is located downstream of Jutigny. The catchment size is 280 km^2 and the average river flow is 1.6 m^3/s;
- The Ardusson gage station is situated at Saint-Aubin. The catchment size is 159 km^2 and the average river flow 0.6 m^3/s.

[26] Daily flow data (m^3/s) were collected from the national French hydrologic bank "hydro banque"(http://hydro.eaufrance.fr)

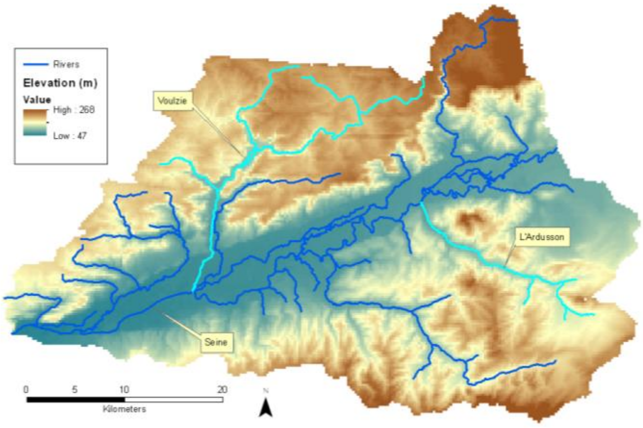

Figure 5-6. The location of the two tributaries of the *Bassée-Voulzie* HU considered in the hydrological modelling

Source: Viavattene (2013)

In order to run the model, information on altitude, land use, type of soil and climate conditions were required. This information is detailed in Viavattene (2013). Two aquifers were simulated with SWAT (the shallow and deeper aquifers), while the hydrological context of the *Bassée-Voulzie* area is quite complex: both aquifers are karstic and the shallow aquifers do not contribute entirely to the considered catchment.

5.3. A qualitative analysis of the context-oriented assessment criteria

While performance oriented outcomes and most of the uncertainty assessment criteria are tackled through the modelling, assessment of other criteria (transaction costs, institution, policy implementability and to a lesser extend the distributional issues) require a complementary approach.

5.3.1. A series of collective meeting with stakeholders to address the contextual criteria for assessing the EPI

Such processes are at their most productive when all parties have the opportunity to develop and reflect their ideas as indeed further details of analysis emerge and relationships are fostered. As such, we intend to carry out a series of meetings which provide a forum for the instruments to be discussed and for the research team to capture information, and then refine and correct our representation of the issues identified through discussion with local actors and technical experts.

In addition to the three meeting with the advisory group[27] aiming at presenting and discussing the methodology and results of the assessment, a few meetings were organized with key stakeholders:

- A workshop organized in January 2013 gathered local institutions (members of the local Chambers of Agriculture and local water managers and authorities) in order to collect information and discuss on (i) the key drivers contributing to making the environmental challenges worse or better, (ii) the conditions and obstacles to the implementation of a PES scheme and a tax on the area.

[27] The three meetings were held in Paris (April 19th 2012, January 16th 2013 and July 12th 2013).

- Meeting with the French Ministry of Environment (July 16th 2012). The objective was to build synergies on PES initiatives in terms of transaction costs analysis. The issue of transaction costs has been identified as one of the priorities of the French Ministry of Environment (CGDD) during the first advisory group meeting. A second meeting was then organised with a few experts of the ministry to define more precisely how the EPI-Water project and the WP4 ex-ante analysis could contribute to their initiatives and vice-versa. Three priorities were thus defined regarding i) transaction cost definition and the role of intermediation, ii) the issue of land acquisition and iii) the institutional and legal dimensions of payment for environmental schemes.

- Meeting with the Seine-Normandy Water Agency (*July 17th 2012*). The objective of this meeting was to identify local needs in terms of water management and existing initiatives including economic or regulatory instruments.

- Meetings with the French research project team of the PIREN-Seine. The focus of the meeting was to identify potentials synergies between EPI-Water project and research activities of the PIREN-Seine research team. One PIREN-Seine researcher contributes directly to both the PES and nitrates tax case-studies through his expertise in agronomic and hydrological modelling.

- Meetings with institutions related to organic farming[28].

In addition, a few interviews were organized from July 2012 to January 2013 with main stakeholders concerned by potential environmental services provided by farmers from the *Bassée-Voulzie*: the *EPTB Seine Grands Lacs* and *Eau de Paris*.

5.3.2. Interviews with farmers

In addition to these meetings, face-to-face interviews with farmers were organised. An initial series of interviews has been conducted with a dozen of farmers mid January 2013, completed by around ten farmers in June 2013. These interviews have highlighted that the major part of farmers use nitrogen fertilization in a quite efficient manner, doing nitrogen balances and ground analyses which help farmers to use the adequate amount of nitrogen fertilizer. A semi-structured qualitative approach has been adopted with the intention of contextualizing both the economic models in play by reviewing the possible different farming strategies typical in each area, and any differing institutional arrangements encountered by these actors. More precisely, information has been collected about: i) strategies adopted by farmers and ii) the constraints they are subjected to.

[28] AbbA (*Agriculture Biologique et Biodynamique de l'Aube*), FRAB (*Fédération Régionale des Agrobiologistes*), Chamber of agriculture of the Champagne Ardenne region, INAO (*Institut National de l'Origine et de la Qualité*), coopérative Vivescia, coopérative Cercabio, Capdéa (local industry specialized in the lucerne deshydratation).

5.3.3. A comparative analysis of institutional context between France and Denmark for the implementation of a tax on nitrogen fertiliser.

As part of the WP4 of the EPI-Water research project, an ex-ante impact assessment of a tax on nitrogen fertilisers was also conducted in the Odense River basin in Denmark. A comparative analysis of the dimensions of policy implementability between these two mirror cases aimed to identify the key institutional factors that determine the success of implementing a tax on nitrogen fertilisers as an instrument for reducing nitrogen loads in water resources.

The methodological approach proposed was to analyse the institutional background for water management in these two countries in order to answer to the following questions:

1. To what extent is the EPI expected to be a flexible instrument, which could be adapted to local particularities?
2. Is public participation likely to play an important role in the choice, design and implementation of the EPI? Which are expected to be the powerful stakeholder groups with dominant opinions?
3. What will be the most likely synergies between the EPI and sectorial policies and how can be taken advantage of? On the contrary, what are likely to be the barriers linked to other policies that impeded the successful implementation of the EPI?

The following key elements helped to analyse the pre-conditions of implementing such a tax given two different national institutional contexts:

- The social perception of the value of water resources and the tradition for water management in these two societies.
- The current national regulatory framework for water management which includes water legislation introduced within or without the framework of the Water Framework Directive.
- The decision-making process for water management which includes the identification of institutions that are implied at the local and national levels as well as their relative roles and responsibilities in water management, the institutional framework in which they operate (mandate to work on pollution, enforcement powers and practices, regulations and coherence with other policies…). This also included the analysis of the role of public participation and the involvement of each stakeholder for the decision-making process, as well as their interplay.

These elements enabled to discuss the importance of social acceptability as well as the role of stakeholders and the socio-economic context as key factors for the design and the implementation of a nitrate tax at the national level.

6. Performance (outcome oriented)

6.1. Baseline scenario

Main indicators for the agro-economic model

This first part presents the main indicators considered for the baseline scenario in the modelling. The Figure 6-1 shows the associated nitrogen loss and gross margin calibrated for the year 2010 for each of the main crop simulated in the model. It has to be highlighted that not all crops are represented here: for instance, irrigated maize is integrated in the model but is not affected by EPI; Forage crops are also integrated but are not presented here (their gross margin are not representatives as livestock activities are not simulated in the model).

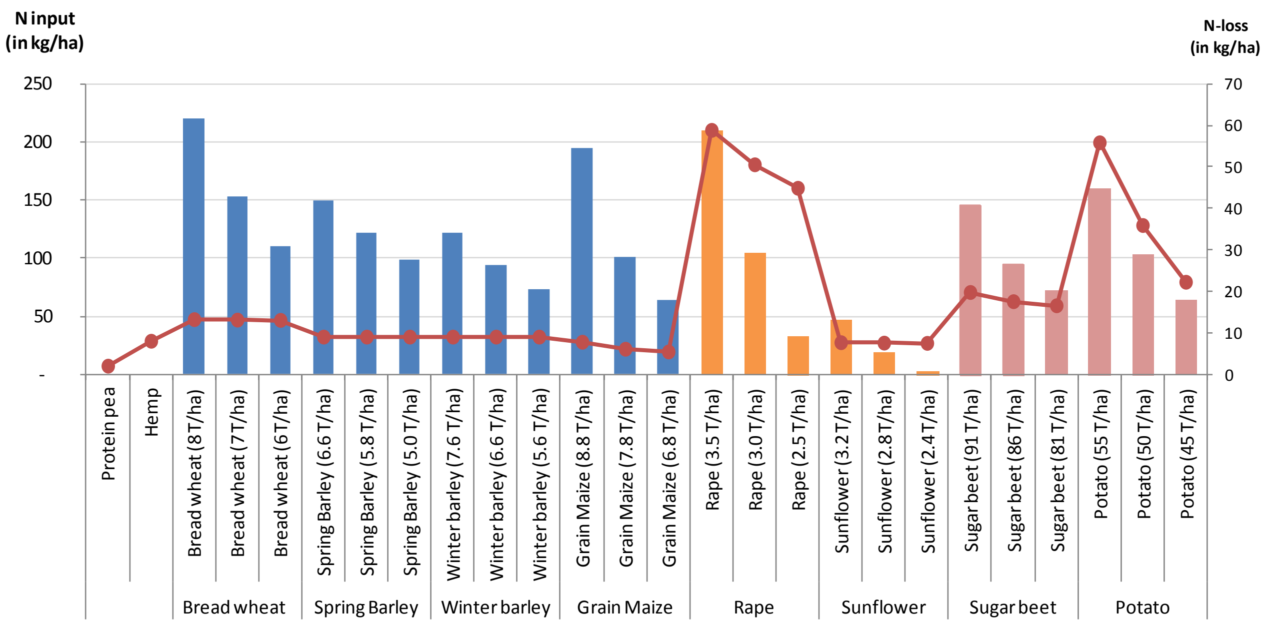

Figure 6-1. Nitrogen used and nitrogen loss per crop in the baseline scenario

Source : Authors

In the baseline scenario, nitrogen losses are the lowest for protein pea and hemp. The crops that are the most polluting are rape (about 59 kg/ha) and potato (56 kg/ha). The data provided by the Sysiphe Joint Research Centre based on agronomic (STICS) and economic (AROPAj) models allocates relatively low nitrogen loss to cereals in general, with values ranging from 5 to 13 kg per hectare.

Oilseed crops are thus responsible for more than 53% of the nitrogen loss in the *Bassée-Voulzie* area, and cereals contribute to 37% of the 2 583 tons of nitrogen loss. Thus, farm types 1 to 3 contribute to more than 94% (18%, 42% and 34%, respectively) of the nitrogen losses on the area and should then be the focus of the EPI. Protein crops only represent 0.1% of the nitrogen loss given they only represent less than 1% of the total agricultural land in the baseline scenario.

Yields and gross margin are directly related to the quantity of N-input that the farmer put on the crop. Thus gross margin decreases for each crop for which we consider lower quantity of N-input (see Figure 6-2). Protein pea has a gross margin lower than most of the other crops, except for winter barley and sunflower.

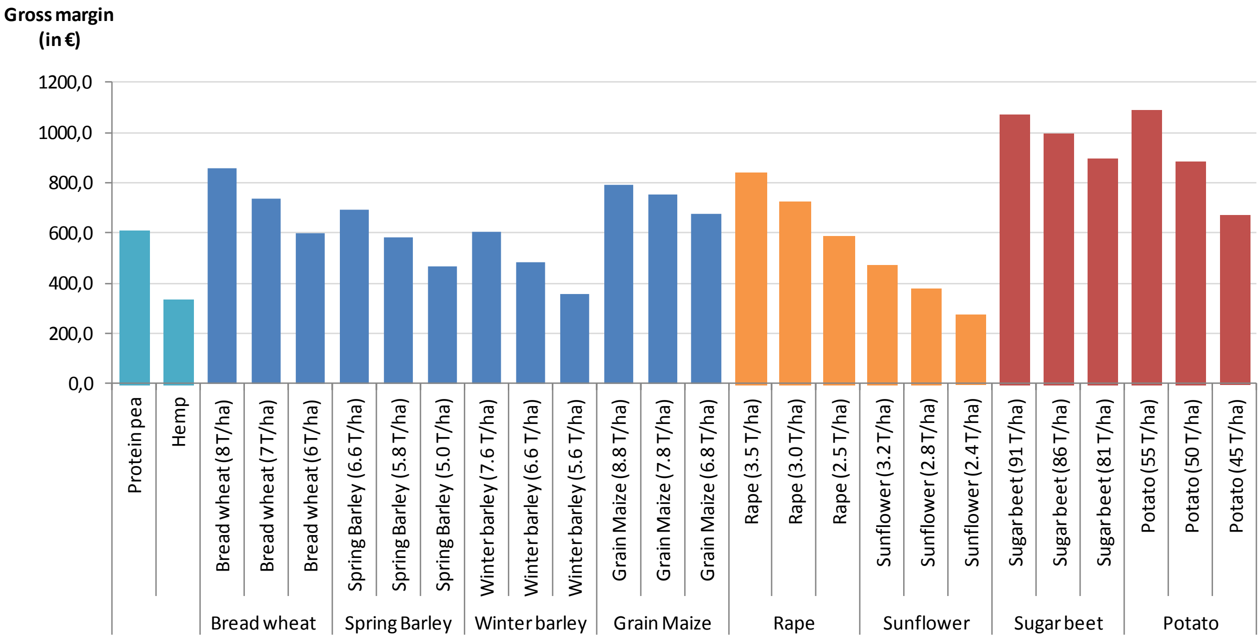

Figure 6-2. Crop gross margin in the baseline scenario

Source: Authors

At a farm type scale, figures are quite similar for gross margin and nitrogen loss. Cereals represent almost 58% of the total gross margin, while oilseed crops represent 18% and wines 16%. The economic weight of farm type 1 to 3 is "only" 80% of the total gross margin (respectively 15%, 36% and 29%). Their gross margin per hectare is ranged from EUR 770 and EUR 870 while the gross margin per hectare is EUR 610 for crop-livestock farmers (farm type 4), EUR 1350 for farmers producing permanent crops (farm type 6) and EUR 11 000 for wine-growers. The gross margin of farm type 6 is probably underestimated: only one activity was integrated in the model for this type (which represents less than 2% of the farms on the area) while other activity with higher gross margin could have been integrated. The same observation can be made for farm type 4 (livestock activities are not considered).

Main indicators for the hydrological model

On the *Bassée-Voulzie* area, concentration of nitrates in the two most important aquifers is expected to gradually increase for the next 60 years. The hydrological model simulates an increase by 0.35 mg/l per year for the Chalk aquifer and 0.40 mg/l for the Eocene aquifer. Thus the value of 50 mg/l should be reached by 2040 for nitrates in the Chalk aquifer and by 2060 in the Eocene aquifer (see Figure 6-3).

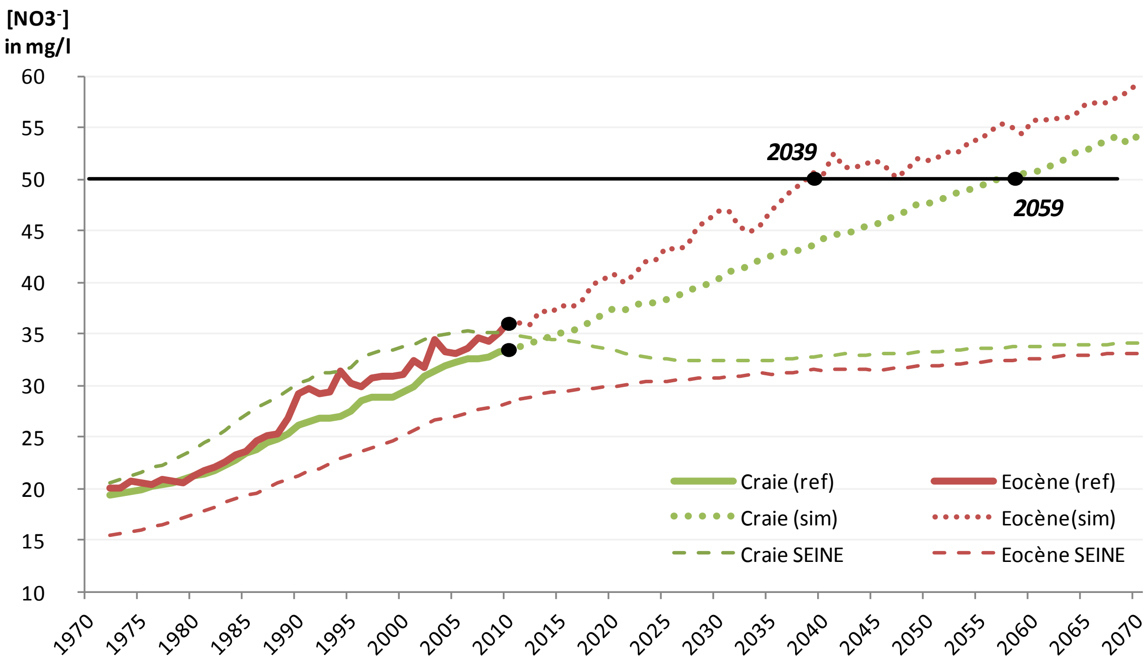

Figure 6-3. Nitrate concentration trends for the Chalk and Eocene aquifers under the Bassée-Voulzie and the Seine river basins

Source: Authors, based on the results of simulations run by the Sisyphe Joint Research Centre

However, nitrate concentrations tend to stabilize (under 35 mg/l) in these aquifers when the Seine basin is considered as a whole. Between 1990 and 2010 (based on the STICS agronomic model), the nitrogen loss observed decreased significantly at that scale while it continues increasing at the scale of the *Bassée-Voulzie* HU.

Simulations run at the scale of sub-area showing differences between the north (Z1, Z2 and Z4) and the south (Z3, Z5 and Z6) of the *Bassée-Voulzie* area (see Figure 6-4 for the chalk aquifer). This is coherent with the structure of the geological disposal where aquifers tend to be deeper when moving northwards. A buffering effect could thus explain the separation of the curves.

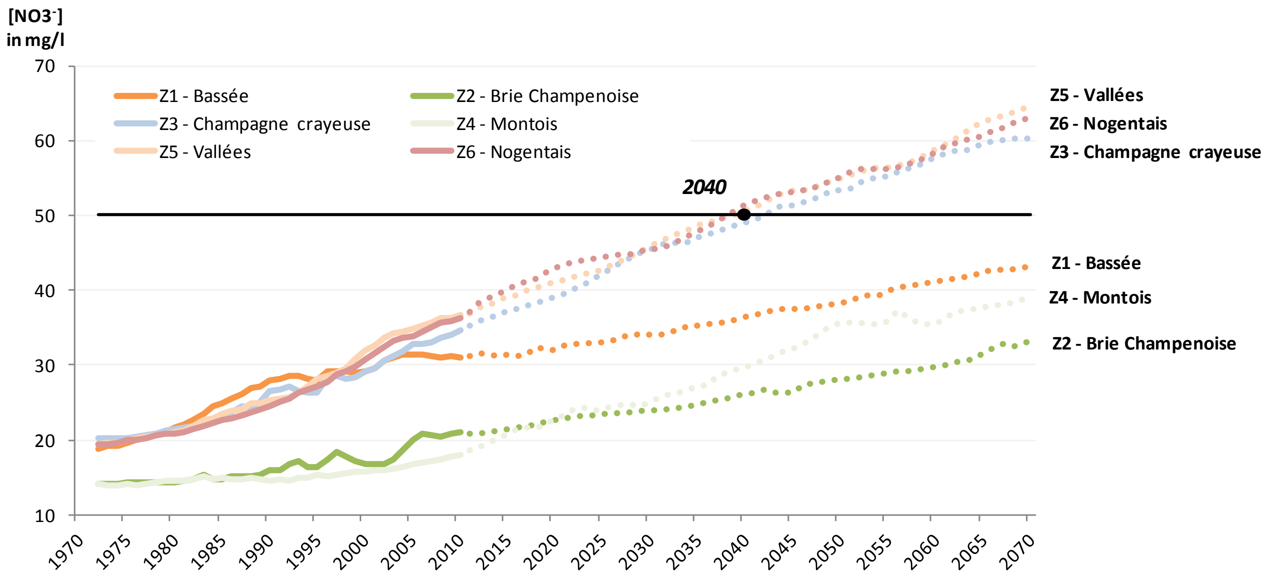

Figure 6-4. Concentration of nitrate simulated in the Chalk aquifer for the six sub-area of the Bassée-Voulzie HU

Source: Authors, based on the results of simulations run by the Sisyphe Joint Research Centre

6.2. Evaluation of the impacts of a nitrate tax

Taxes on nitrogen fertilisers are defined as an increase in the price of nitrogen fertilisers. The current price is set at EUR 0.65 per kg (2010). For information purposes, the price of nitrogen fertiliser was EUR 0.88 per kg in 2013. Thus a 10% tax means that an additional EUR 0.065 per kg of nitrogen used is added, leading to a total price of nitrogen fertiliser at EUR 0.71 per kg for 2010. Following the same logical calculation, a 100% tax means doubling the price of nitrogen of fertiliser (EUR 1.29 per kg) and a 200% tax means multiplying by three the price of nitrogen fertiliser (EUR 1.94 per kg).

The following chapters present the environmental and economic outcomes as well as distributional effects for six levels of tax (10%, 20%; 30%, 50%, 100% and 200%).

Tax impacts on the change in nitrogen loss at the scale of the Bassée-Voulzie area: a first step through the evaluation of the environmental outcome of a N-Tax

At the scale of the *Bassée-Voulzie* area, the implementation of a tax leads to a reduction of the amount of nitrogen released at the sub-root level. The model simulates a linear trend of reducing nitrogen losses for taxes from 10% to 50%. A 100% tax and a 200% tax lead to relatively higher reduction of losses. The response of the total gross margin at this scale to the implementation of an N-tax is similar to the one of the nitrogen loss. It appears that a reduction of pressure in terms of diffuse pollution is associated to a reduction of revenues for farmers, i.e. an increase of charges due to the tax and a reduction of profits due to the change of crops and/or a reduction of yield.

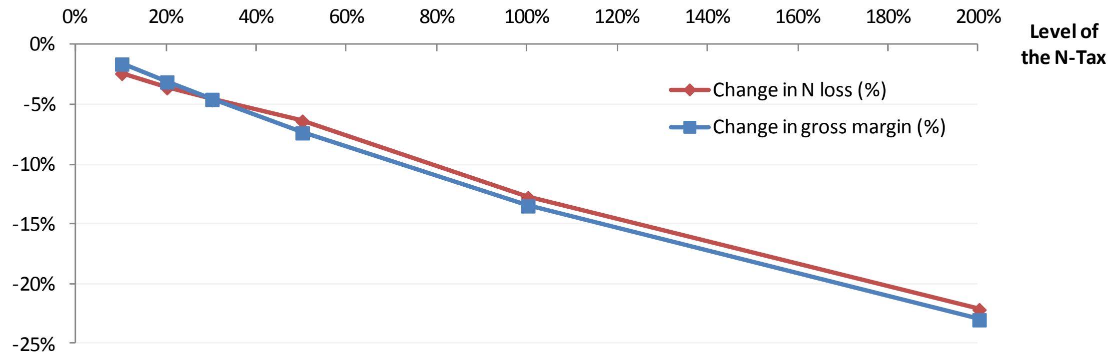

Figure 6-5. Change in nitrogen loss and gross margin at the scale of the Bassée-Voulzie HU depending on the level of the tax (%)

Source: Authors

Changes in nitrogen loss per crop: how can we explain the reduction of nitrogen losses?

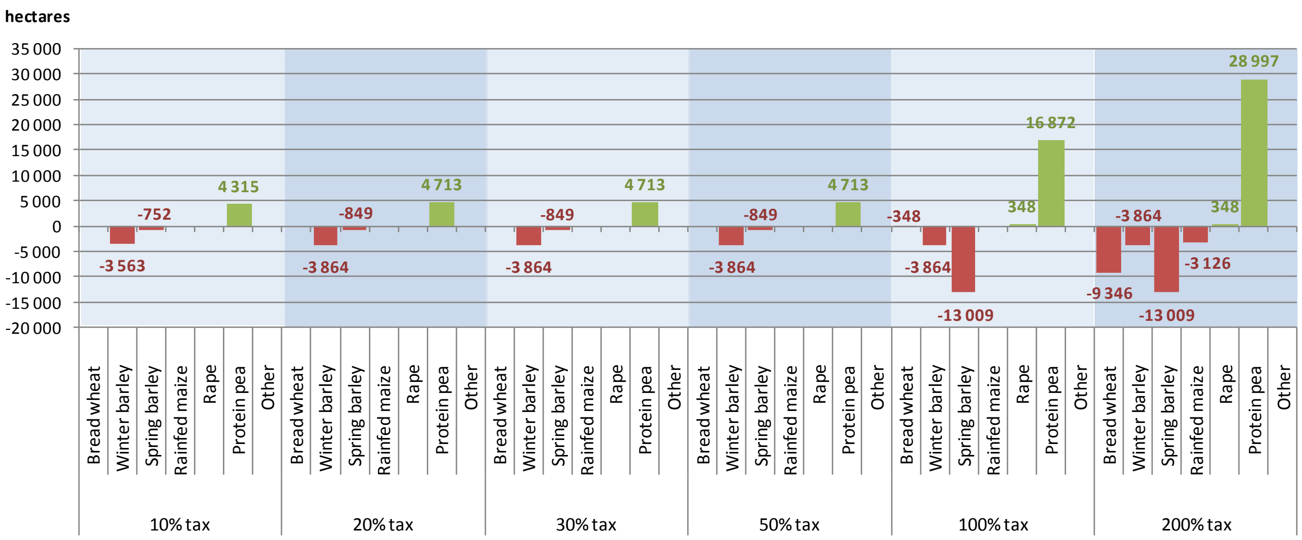

Figure 6-6. Change in crop allocation depending on the amount of the tax

Source: Authors

Three main changes are observed when we look closer at trade-off between crops. First, the model simulates a crop reallocation in favour of the protein pea which consumes no nitrogen fertilisers. The surface of protein pea proposed by the model is closed to 4 700 hectares for increases of the price of N-fertilisers up to 50%. The surface of protein pea then increases up to 29 000 hectares for an N-tax of 200%. The latter threshold is close to the maximum surface of protein pea allowed by the constraint of the agro-economic model, which is a quarter of the total agricultural surface. Considering that nitrogen losses for protein pea are lower than those for other crops, the implementation of the N-Tax leads to a reduction of nitrogen loss on the *Bassée-Voulzie* area.

The Figure 6-7 shows the changes in the crop gross margin for the main crops of the *Bassée-Voulzie* area[29]. It helps explaining the first change: the production of protein pea does not need nitrogen fertilisers, thus the nitrate tax does not affect the gross margin of this crop (represented on the figure by the green area). The gross margin remains the same regardless the level of the tax, while other gross margins decrease.

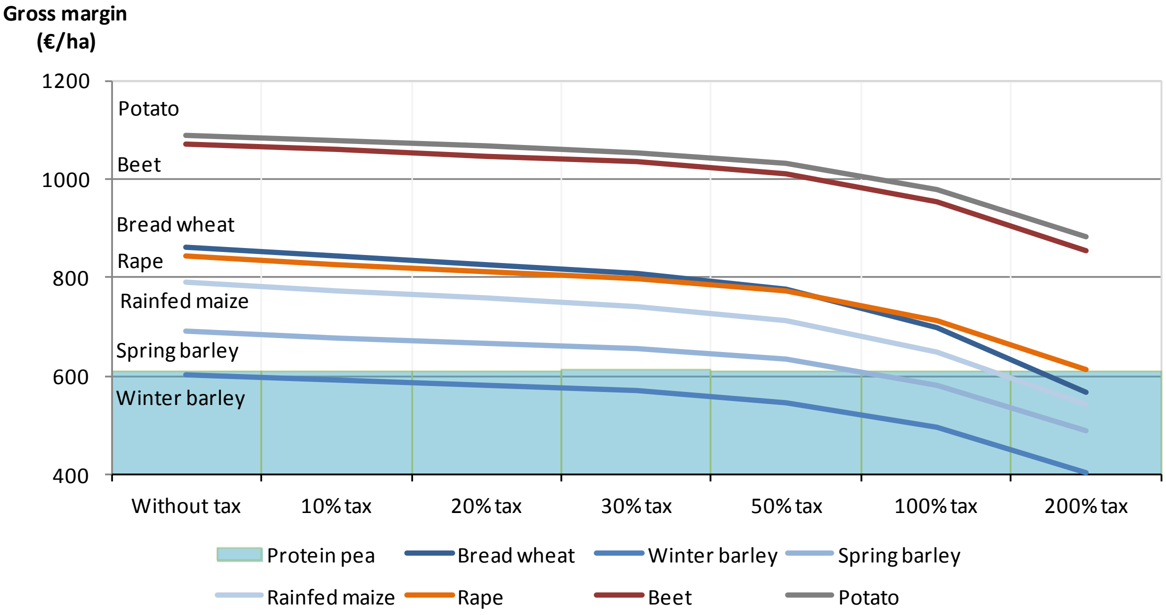

Figure 6-7. Change in crop gross margin depending on the level of the N-tax

Source: Authors

The second change observed on Figure 6-6 is a progressive decrease of cereals' surfaces. Cereals are clearly put at a disadvantage when the N-Tax is implemented. The main reason for this change could be explained by analysing the gross margin of crops and its change due to the tax on fertilizers (see Figure 6-7). Initial gross margins are lower than those of potato and beet and they are relatively close to the gross margin of protein pea. This figure explains the important reduction of spring barley surfaces when the price of fertilizers is doubled and the reduction of surfaces for rainfed maize and bread wheat when the price of fertilizers is tripled (the gross margins of the wheat and of the maize become lower than the gross margin of the protein pea).

However, winter barley should not be put forward by the model in the situation without tax if we consider only the gross margins optimisation ($GM_{Winter\ Barley} < GM_{Protein\ Pea}$). In fact, the constraint linking the surface of spring barley to the surfaces of winter barley and bread wheat forces the model to propose a few hectares of winter barley (with a relatively low gross margin) to allow producing more spring barley (with a relatively high gross margin). The constraint is relieved when a N-Tax is implemented, explaining a reduction of both winter and spring barley surfaces for taxes on fertilizers up to 50%.

[29] The total surface allocated to the crops presented in the figure represents 94% of the total simulated surface.

In addition, the model simulates a decrease in the gross margin of all crops consuming nitrogen fertilisers, as a result of the new optimization of their gross margin including the tax effect. But the decreases are more or less important depending on i) the initial quantity of input needed by the crop and ii) the slope of the nitrogen/yield curve. For instance, the yield of bread wheat increases faster than the yield of rapeseed for each additional unit of nitrogen fertiliser. Thus, yield and gross margin are relatively more sensitive to a reduction of nitrogen fertiliser for bread wheat than rapeseed.

Finally, the third change observed is a trade-off between bread wheat and rape when the price of nitrogen fertilisers is at least doubled. The change has already been explained by comparing the gross margin evolution. But, it is interesting to observe the paradoxical effect of an input tax on pollution that has already been described by Bourgeois (2012): this specific land use reallocation lead to an increase of pollution in terms of nitrates as rapeseed requires less nitrogen as input but releases more nitrogen in the soil than bread wheat. This tax is thus not efficient for this specific trade-off, but it is compensated at the level of the *Bassée-Voulzie* (and at the level of sub-area) by the global land use reallocation.

Change in gross margin per crop: an indicator for the evaluation of the distributional effect of the tax

The reduction of the total gross margin on the Bassée Voulzie area increases with the augmentation of the level of the tax, from a reduction of around 2% of the total gross margin for an increase of the price of nitrogen fertilisers of 10% to a reduction of almost 23% of the total gross margin for a tax set at 200% of the initial price of nitrogen fertilisers.

However, the economic impact of the N-tax is not homogeneous among farm types, as the tax focuses on crops requiring nitrogen fertilisers such as cereals or oilseed crops. The three first farm types (T1 to T3) suffer more important gross margin reduction than presented at an aggregated scale. Conversely, wine-growers (T5) are relatively preserved from the negative economic impact of the tax as its main crop is not (or almost not) dependent on nitrogen fertilisation.

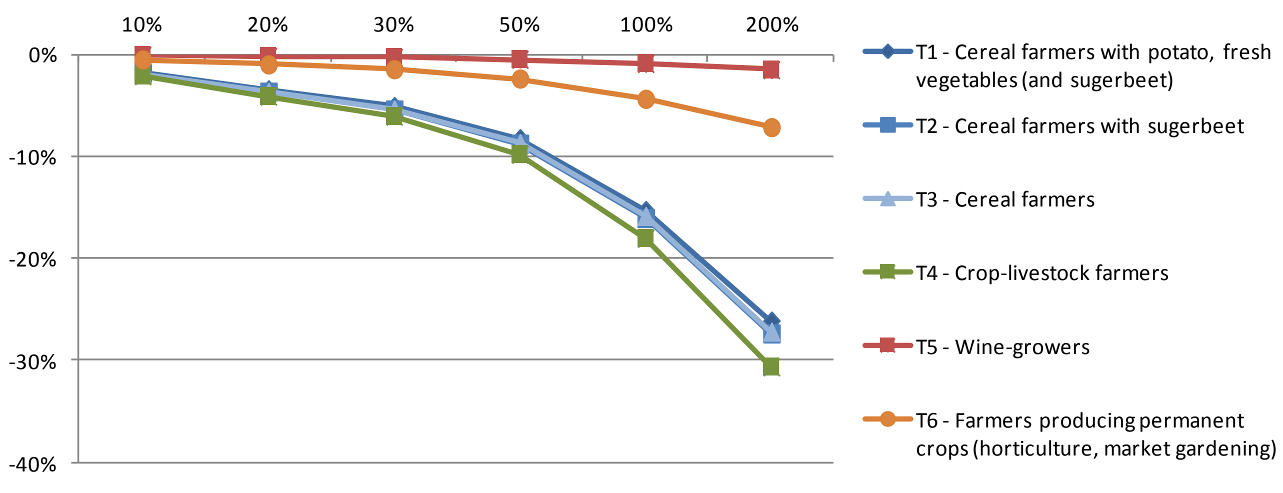

Figure 6-8. Change in the total gross margin depending on the type of farm and the level of tax
Source: Authors

However, the model is not well designed to deduce real reduction of revenues for farmers who belong to the type 4 and 6. Indeed, livestock is not integrated into the agro-economic model while it represents an important part of revenues for the farm type 4. And farm type 6 represents less than 2% of the farms on the *Bassée-Voulzie* area and has not been defined with detailed in the model.

6.3. Evaluation of the impacts of a PES scheme

Considering from one side the average nitrogen loss per farm and from the other side the average nitrogen loss per hectare of crop, maximum payment per farm and per hectare have been calculated.

This preliminary calculation allowed defining the range of payment that could be considered in the model: payments from EUR 0.5 per kg of nitrogen to EUR 50 per kg of nitrogen. This range of payment represents payments from EUR 10 to EUR 1 040 per hectare and EUR 1 125 to EUR 112 000 per farm (that is from less than 1% to more than 260% of the initial gross margin of farms, depending on farm type). These values can be considered as maximum values, as farmers are not expected to reach zero nitrogen loss.

The following chapters will present the environmental and economic outcomes as well as distributional effects for nine levels of payments (from EUR 0.5 to EUR 25 per kg of nitrogen loss avoided).

Evaluation of the impacts of a PES scheme on the change in nitrogen loss at the scale of the Bassée-Voulzie area

At the scale of the *Bassée-Voulzie* area, the implementation of a payment for each kilogram of nitrogen loss avoided leads to a non linear reduction of the amount of nitrogen released at the sub-root level. **While the reduction of nitrogen loss is very low for a payment up to 4 €/kg of nitrogen, there is a significant reduction of nitrogen loss (more than 50%) for payments at 5 €/ kg of nitrogen and more** (see Figure 6-9).

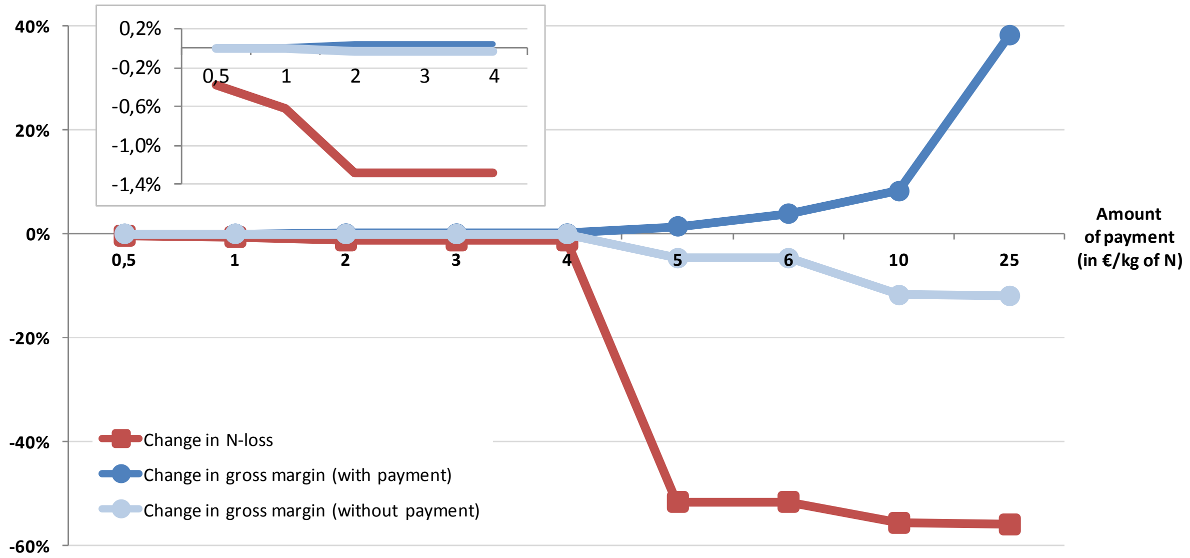

Figure 6-9. Change in nitrogen loss and gross margin (with and without the surplus of the payment) at the scale of the Bassée-Voulzie HU depending on the level of payment

Source: Authors

This reduction of nitrogen loss is associated to a reasonable reduction of gross margin at the scale of the *Bassée-Voulzie* area (less than 5% of the initial gross margin for payments at 5 or 6 €/kg of nitrogen and around 12% for payments of more than 6 €/kg of nitrogen) if we do not include the revenue generated by the payment. When considering both the gross margin of crops and the payment, farmers then have higher revenues compared to the baseline scenario. The total gross margin is thus increased by 1.4% for a payment of 5 €/ kg of nitrogen, 8% for a payment of 10 €/ kg of nitrogen and more than 38% for a payment of 25 €/ kg of nitrogen.

Changes in nitrogen loss per crop: how can we explain the reduction of nitrogen losses?

To better understand environmental and economic outcomes associated to the payments simulated with the agro-economic model, we need to look closer at the crop gross margin and at land use reallocation (see Figure 6-10).

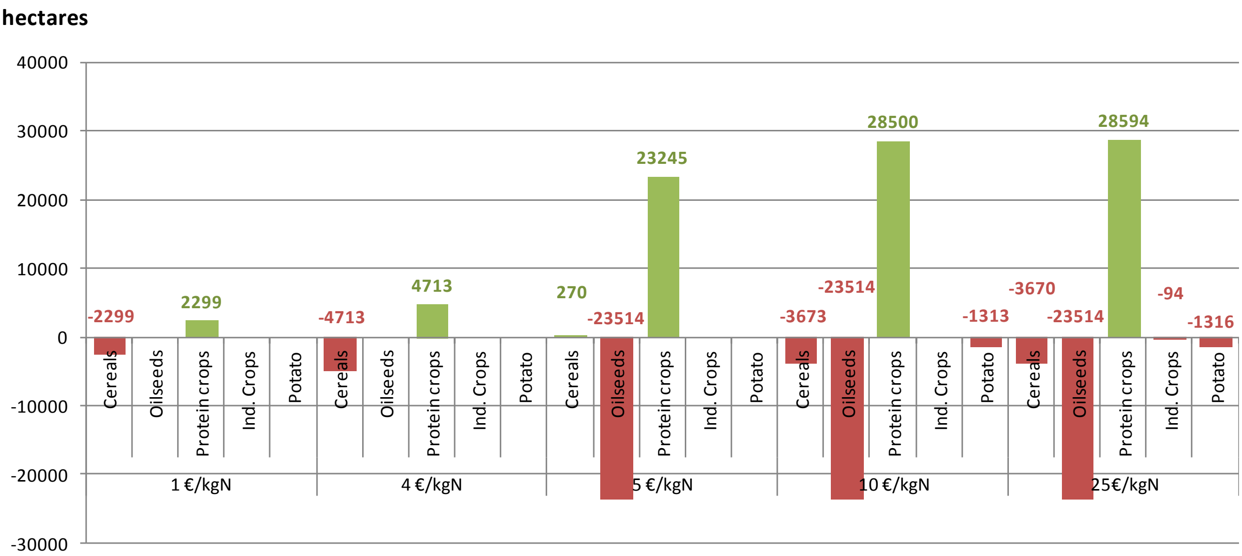

Figure 6-10. Change in crop allocation (hectares) depending on the amount of payment

Source: Authors

In fact, we need to compare the gross margin of crops with and without the payment. Let's consider two crops with respective gross margin GM_1 and GM_2 ($GM_1 > GM_2$) and nitrogen loss associated Nl_1 and Nl_2 ($Nl_1 > Nl_2$). If we consider a payment P_0, then comparing crop 1 and 2 is equivalent to:

$$GM_1 <> GM_2 + (Nl_1 - Nl_2)*P_0$$

$$= \quad GM_1 - Nl_1 * P_0 <> GM_2 - Nl_2 * P_0$$

Thus introducing a payment for each unit of nitrogen that is not released in the soil (payment that could be consider as a heterogeneous subsidy considering that each crop is associated to a nitrogen loss function) is equivalent in our model to the introduction of a taxation per hectare adapted to each crop depending on its associated N-loss. The Figure 6-11 represents the change of gross margin for the main crops depending on the amount of payment.

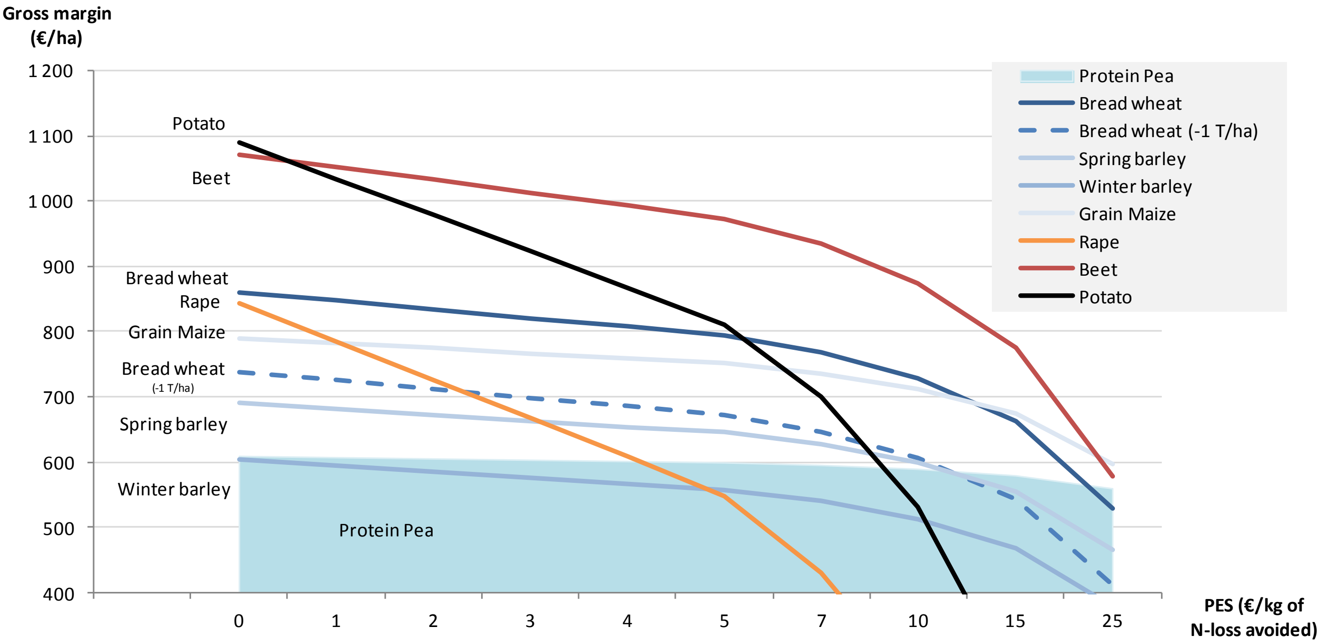

Figure 6-11. Change in crop gross margin depending on the amount of payment

Source: Authors

Considering that the main change simulated in terms of land use reallocation is the augmentation of surfaces of protein peas, we take that crop as a reference in the analysis of gross margin. We first observed that the gross margin of protein pea is relatively low (EUR 611 per hectare) and slightly decreasing when the amount of payment is increased (due to the limited N-loss associated to this crop, fixed in the model at 2 kg per hectare).

For payments lower than 4 €/kg of nitrogen, changes are very limited. A few hectares of cereals (winter and spring barley) are converted into protein pea leading to an insignificant reduction of nitrogen losses. For a payment of 4 €/kg of nitrogen, farmers will lose around EUR 3 million of gross margin for cereals and compensate it with a EUR 2.8 million benefit. The total payment only represents EUR 85 000 on the area, that is EUR 18 per hectare converted and around EUR 83 per farm in average.

When the threshold of 4 €/kg if nitrogen is exceeded, the gross margin of rape drops below the level of the pea gross margin. More than 23 000 hectares (almost 20% of the total agricultural surface on the area) of rapeseed are converted into protein pea, leading to a drastic reduction of nitrogen losses (a gap of 51 kg of N-loss per hectare between the two crops). A few hectares of barley are suggested by the model depending on the subarea due to complex trade-off between rapeseed, winter and spring barley. Farmers compensate their losses in terms of revenue due the replacement of oilseed crops (EUR -19 million) by protein crops (EUR 14 million) with the payment, which is around EUR 7 million on the total area. The total payment represents a subsidy of EUR 300 per hectare converted and around EUR 6 200 per farm in average. The payment represents about 6% of the total revenue of farmers.

For payments higher than 10 €/kg of nitrogen, the surface of protein peas increases to a maximum threshold of about 28 500 hectares. The model suggests an ideal but realistic crop reallocation considering the gross margin and N-loss of different crops and the agronomic and technical constraints (such as crop rotation and labour constraints).

Indeed, **a significant reallocation of crops in favour of protein pea is realistic**. Comparable changes have already been observed in other regions of France within few years due to the CAP incentives. In 1993, subsidies were introduced for protein pea leading to a huge increase of surfaces especially in the south of France. And the inverse change occurred a few years later (in 2010) due to decoupled direct payments. The agronomic constraint integrated into the model allows respecting good agricultural practices that aim at avoiding diseases (which represents a real issue for protein pea). In terms of labour constraints, the production of protein pea is not an issue as plantation and harvesting periods are outside the critical period imposed by cereals (April and May).

Furthermore, the absorption capacity of the agricultural sector should be acceptable thanks to industrial opportunity with animal feeding. Considering the agricultural sector's relative rigidity, changes should be considered within a two or three-year period while the model only considers one-year periods. Finally, changes suggested by the model could be considered as the upper bound of the solution set.

In addition to conventional crop reallocation from rapeseed to protein pea, a payment of 10 €/kg of nitrogen would lead to a reduction of cereal surfaces (winter and spring barley) and a reduction of yield for bread wheat. Farmers will thus prefer to reduce the fertilization on bread wheat to reduce their diffuse pollution targeting lower yields (-1ton per hectare). For the same amount of payments, potatoes are also replaced by protein pea, the new gross margin including the payment falling below the level of protein pea.

The significant losses in terms of revenues (EUR 1.5 million for potato, EUR 9 million for cereals and EUR 19 million for rapeseeds) are not compensated by the gross margin of protein pea (EUR +17 million for a total), leading to a 12% loss for farmers compared to the current situation. However, the EUR 22.5 million payments widely compensate actual losses. The amount of payment significantly increases due to additional surfaces included in the scheme and the high level of unit payment. This amount represents a payment of almost EUR 800 per hectare converted and EUR 20 000 per farm in average. The payment represents more than 18% of the total revenue of farmers.

A payment of EUR 25 per kg of nitrogen will not allow additional land use reallocation, except changes between beetroot and protein pea. However, the EUR 56 million payment represents a payment of almost EUR 2000 per hectare converted and EUR 51 000 per farm in average. The payment represents more than 36% of the total revenue of farmers. The high level of unit payment explains the significant change in terms of revenues for farmers (+38% compared to the current situation) while the reduction of nitrogen losses is quite stable compared to a situation with a EUR 10 per kg of N payment.

As a conclusion, the use of the model allows understanding the stepped response curve to payments. Two thresholds at least have to be considered and well understood: the level of payment allowing a change from polluting crops to environmentally friendly crops such as protein pea (and potentially various thresholds if more than one environmentally friendly crop is at stake); and **a second threshold beyond which deadweight effect becomes a serious issue.**

Such thresholds depend on the type of crop and their respective gross margin but also – and mainly – on relative nitrogen losses for crops. Indeed, changing the amount of losses for one crop will affect the amount of payment that is required to observe changes of land use. For instance, moving from a N-loss of 2 kg per hectare for protein peas to no nitrogen loss will move the breaking point from a payment of EUR 4 per kg of nitrogen to a payment of EUR 3 per kg of nitrogen. **A precise knowledge on nitrogen loss curves for each crop is thus essential.**

Change in gross margin per type of farm: an indicator for the evaluation of the distributional effect of the PES

The same type of analysis that is performed for a N-Tax can be performed for PES.

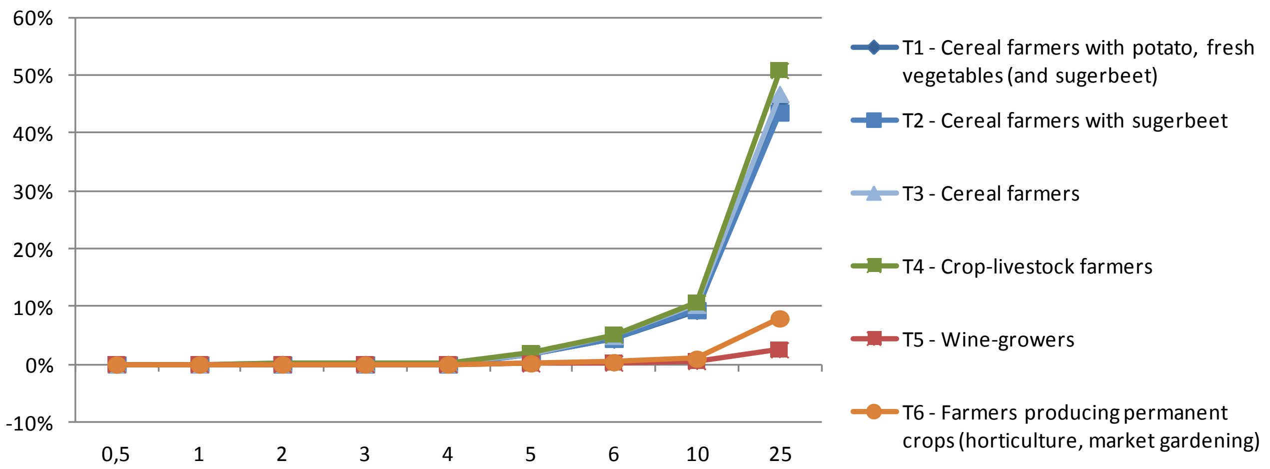

Figure 6-12. % Change in the total gross margin depending on the type of farm and the amount of PES (€/kg)

Source: Authors

We observe that cereals farmers (T1, T2 and T3) are facing the same type of changes in terms of gross margin. These changes are acceptable from a social point of view for payments lower than EUR 10 per kg of nitrogen. Indeed farmers can improve their financial situation while i) there is a significant reduction of pressure on surface and groundwater (Figure 6-9) and ii) deadweight effect is limited (a surplus of gross margin of less than 10%) (Figure 6-12).

Thus the ideal solution will be located in the interval EUR [4; 10] per kg of nitrogen in order to maximise nitrogen loss reduction and minimise deadweight effect.

Uncertainty is too high for the three other farm types due to the model specifications to assess their actual change of revenue.

Evaluation of the impacts of a PES scheme on runoff

Taking into account i) that the calibration of the SWAT model could have been improved and ii) that the expected effect of a land use change in runoff would not be spectacular, a important change of land use was first simulated: 20% of the arable lands were hypothetically converted into forests for both catchments (*La Voulzie* and *l'Ardusson*) without specific location. No significant change was observed in terms of infiltration or runoff.

This result could be explained by the characteristics of the area:

- Aquifers are karstic with the presence of sinkholes and pots. These aquifers are thus complex and difficult to assess;
- Porosity and infiltration is quite high and dominating the water balance;
- Water abstraction is consequent and have an impact on the Voulzie river flow, while *Eau de Paris* pump water upstream of *Bray-sur-Seine* and discharge in the Voulzie to compensate these losses;
- Finally, the two pilot catchment considered might not be large enough. Indeed, the *Voulzie* and the *Ardusson* represents less than 3% of the Seine river flow.

Another explanation (linked to the first point) could be associated to the quality of the simulation: input data as well the model calibration could be refined to describe with more details the role of land use on runoff.

Finally, it was not possible to measure the effect of a marginal land use change on runoff, neither its contribution to the regulation of floods. Thus the idea of combining payments for various environmental services appears difficult in terms of implementation.

6.4. Combining N-Tax and PES scheme to address diffuse pollution

In addition, the feasibility of coupling a PES scheme with a tax on nitrogen fertilisers was also assessed. As suggested by Bourgeois (2012), combining a tax with a subsidy-like economic instrument could be cost-effective compared to the implementation of a nitrate tax alone and can lead to some levels of abatement which are difficult to reach if the policy is only based on one economic instrument. Bourgeois (2010) considers a subsidy on perennial crops whereas we have focused on a payment associated to the reduction of nitrogen loss at the scale of the farm.

Comparative analysis of the three instruments

The Figure 6-13 presents economic and environmental outcomes for a series of combination of tax (20%, 50%, 100% and 200%) and payment (2, 3, 4 and 10 €/kg of nitrogen loss avoided).

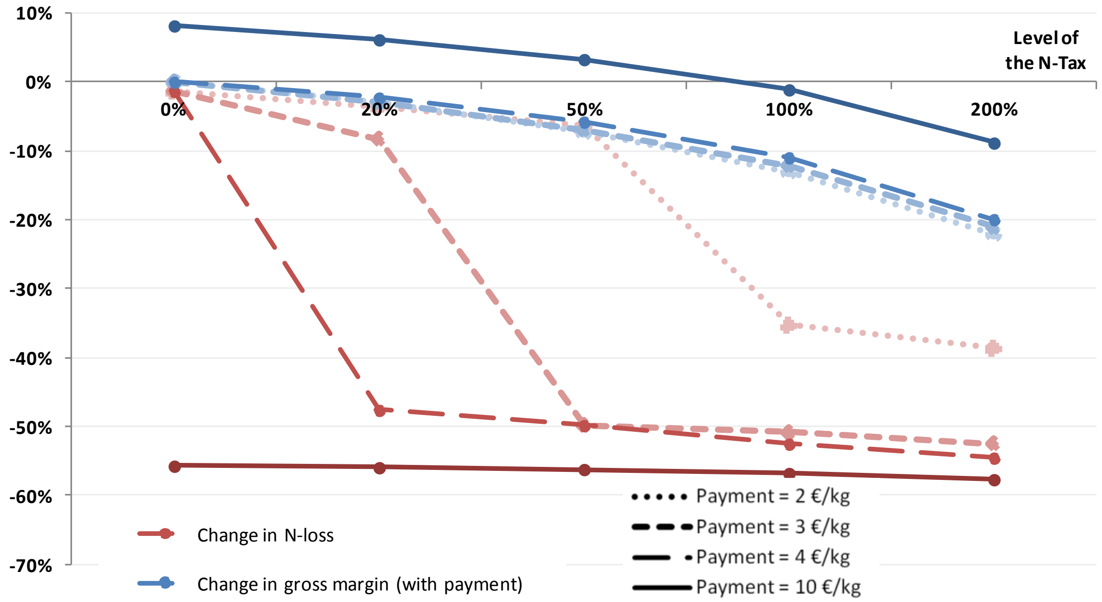

Figure 6-13. Environmental (in red) and economic (in blue) outcomes of various combination of N-Tax and PES

Source: Authors

The gross margin (in blue) ranges from +10% to -20% and is mainly influenced by the level of tax (gross margin of farmers decreases when the N-Tax increases). The amount of payment may contribute to improve the economic situation of farmers when considering large amount of payment (gross margin increases by more or less +10% for a 10 € payment). The combination of tax and payment lead to reduction of the positive and negative impacts of each of the EPI considered separately.

In terms of nitrogen loss reduction, the combination of the two EPI is also interesting. Payment for environmental services allows reducing the nitrogen loss significantly (-50%) for payment higher than 4 €/kg of nitrogen loss avoided. Combining it with a tax allows achieving a similar objective in terms of nitrogen loss reduction while reducing the amount of payment: nitrogen loss can be reduced by almost 50% with a payment of 3 € when the tax on nitrogen fertilizer is fixed at 50%; when the price of nitrogen fertilizer is doubled, then a payment of 2 € leads to a reduction of pressure by 35%.

The Figure 6-14 gives another perspective for the comparison of the three instruments (a tax on fertilizer, a payment for environmental services and the combination of the two economic instruments).

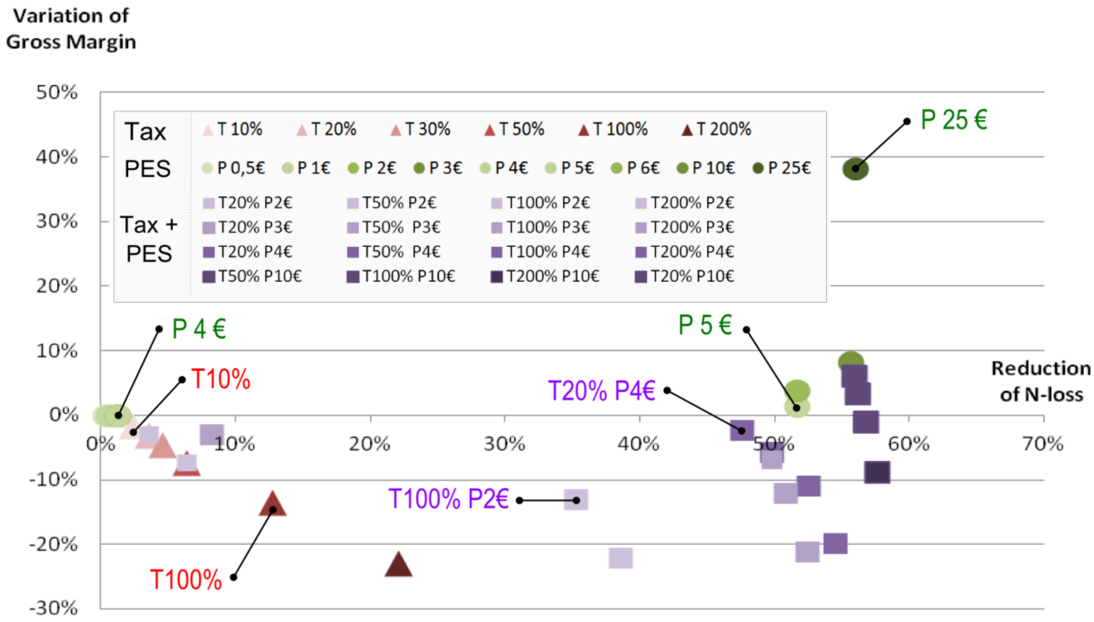

Figure 6-14. Comparing environmental and economic outcomes of the three EPI

Source: Authors

Change in nitrates concentration in the Bassée-Voulzie aquifers: the role of the MODCOU hydrological model

A limited number of simulations was made using the MODCOU hydrological model, representing a range of potential reduction of nitrogen losses (from -5% to -65%). The Figure 6-15 shows the environmental outcome of the implementation of the three EPIs (the N-Tax, PEs and the combination) on the two main aquifers of the *Bassée-Voulzie* area, compared to the baseline scenario (the green and red solid lines).

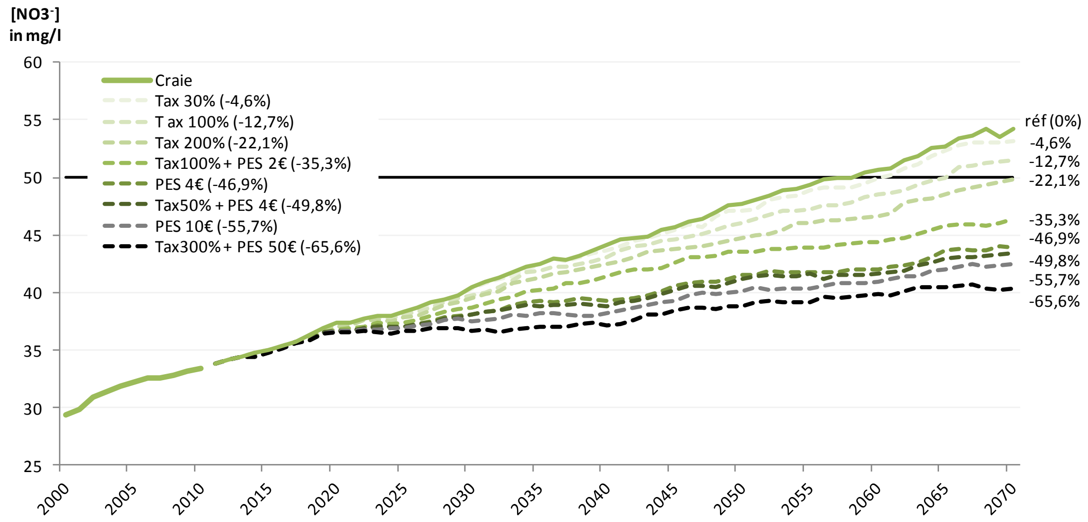

Figure 6-15. Environmental outcome simulated by the MODCOU hydrological model on the Chalk aquifer[30]

Source: Authors, based on the results of simulations run by the Sisyphe Joint Research Centre

The first result observed in the *Chalk* aquifer system is a significant time lag between action and results, estimated at about 15 years. For each scenario, the concentration of nitrates in the aquifer does not change at all compared to the "business as usual" for 10 years and starts varying significantly with the "business as usual" scenario in 2020.

The value of 50 mg of nitrate per litre (the norm for groundwater and drinking water) is exceeded in 2060 for the *Chalk* aquifer in the "business as usual" scenario. A reduction of nitrogen loss in the soil of -22% will slightly change the slope of the concentration curve and delays the date when the threshold concentration will be exceeded by 10 years. None of the simulation run allowed reversing the growing trend of nitrate concentration in the aquifer: the best case scenario only, the concentration is reduced to 40 mg/l in 2070 and appears to be stabilized. But, this scenario corresponds to a reduction of nitrogen loss by 65% obtained by the combination of a 300% tax and nitrogen fertilisers and an unrealistic payment of 50 € per kg of nitrogen loss avoided.

However intermediate scenarios already achieve good results by delaying the pollution threshold. A doubling of the price of fertiliser combined to a 2 € payment would lead to a significant change of the slope of the concentration curve.

Similar observations can be made on the other aquifer of the *Bassée-Voulzie* area (see Figure 6-16), while greater efforts might be required to prevent exceeding the 50 mg/l threshold.

[30] In french : « *l'aquifère de la Craie* »

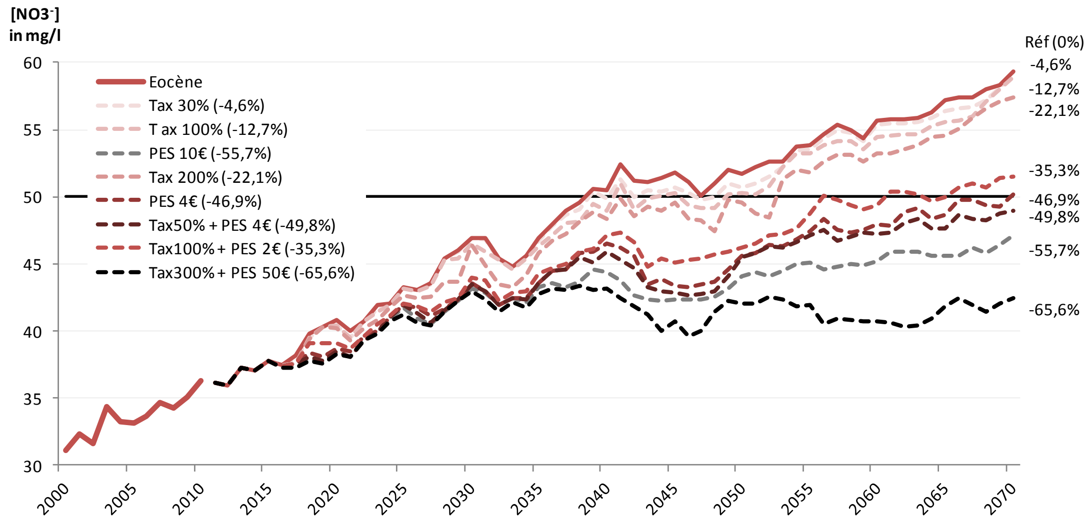

Figure 6-16. Environmental outcome simulated by the MODCOU hydrological model on the Eocene aquifer

Source: Authors, based on the results of simulations run by the Sisyphe Joint Research Centre

In the Eocene, time lag is about 10 years and the concentration of 50 mg/l of nitrates might be exceeded in 2040, 20 years earlier than in the Chalk aquifer. A nitrogen loss reduction below -25% may not change significantly the trend. As for the Chalk aquifer, none of the simulated EPI allowed to move back to the nitrates concentration observed in 2010 (around 37 mg/l). However, large reductions of nitrogen loss (from 35% to 55%) contribute to a significant gain in terms of water quality.

Cost-benefit analysis: from subsidy to payment from environmental services

Considering these results, the implementation of an EPI may contribute to avoid drinking water treatment on the *Bassée-Voulzie* area for a period ranged from 15 to more than 30 years. **Current local water consumption on the basin is about 7.1 million m³ per year. Avoiding water treatment will lead to a benefit ranging from EUR 2.8 million and EUR 4.3 million per year** (considering the more recent treatment cost calculated by CGDD, 2011, estimated between EUR 0.40 and EUR 0.61 per m³). This saving represents between EUR 17.1 and EUR 46.6 million over the periods considered, that is a discounted benefit ranged between EUR 1 and more than EUR 1.7 million per year.

Eau de Paris is not considered directly as a contributor given that groundwater coming from the *Voulzie* is not treated while nitrate concentration has already exceeded the 50 mg/l threshold due to a system of interconnections. **Nevertheless, drinking water treatment could cost between EUR 2.8 and EUR 6.1 million per year (considering a discounted cost over a 10, 20, 30 or 50-year period) to Parisians.**

In comparison, the implementation of a PES scheme with a unit payment of EUR 5 per kg of nitrogen-loss avoided should be enough to avoid drinking water treatment and would cost between EUR 4.5 and EUR 6.9 million to beneficiaries[31]. **Implementing this EPI alone would thus not be interesting from an economic point of view.**

However, combining the PES system with taxation may change the results. Indeed, the combination allows reducing the amount of payment required to change land use and agricultural practices also generating revenues from the tax. For instance:

- Combining the payment with a 20% N-Tax will allow achieving the same environmental outcome while reducing the payment to EUR 4 per kg of nitrogen-loss avoided. The cost of payment will be reduced to a range from EUR 3.2 to EUR 5.0 million per year. In addition, the tax will lead to a reduction of 1184 tons of nitrogen used[32] compared to the baseline scenario. Revenues associated to the tax are thus estimated between EUR 1.8 and EUR 2.5 million per year (the tax yields EUR 0.13 per kg of nitrogen used), considering a discounted cost from a 10 to 50-year period;

- Combining the payment with a 50% N-Tax will allow achieving the same environmental outcome while reducing the payment to EUR 3 per kg of nitrogen-loss avoided. The cost of payment will be reduced to a range from EUR 2.5 to EUR 3.9 million per year. In addition, the tax will lead to a reduction of 2634 tons of nitrogen used compared to the baseline scenario. Revenues associated to the tax are thus estimated between EUR 4.1 and 5.9 million per year (the tax yields EUR 0.32 per kg of nitrogen used), considering a discounted cost from a 10 to 50-year period;

- Combining the payment with a 100% N-Tax will allow achieving a reduction of nitrogen loss by 35% (compared to the 50% reduction of other scenarios) while reducing the payment to EUR 2 per kg of nitrogen-loss avoided. The cost of payment will be reduced to a range from EUR 1.1 to EUR 1.6 million per year. In addition, the tax will lead to a reduction of 4849 tons of nitrogen used compared to the baseline scenario. Revenues associated to the tax are thus estimated between EUR 7.3 and EUR 10.5 million per year (the tax yields EUR 0.65 per kg of nitrogen used), considering a discounted cost from a 10 to 50-year period;

The comparison of cost and benefits should also integrate transaction costs (the cost of intermediaries, negotiation and monitoring mainly) and the cost associated to the PES scheme. One of them, and may be the most important, is related to nitrogen residues analysis in the soil as the amount of payment could be defined based on that information for each farm. Considering a unit cost of EUR 40 per analysis, nitrogen residues analysis could cost between EUR 100 000 and EUR 450 000 per year on the *Bassée-Voulzie* area.

[31] The calculation of the discounted cost is done considering 10, 20, 30 or 50-year periods.

[32] 17 654 tones of nitrogen are used each year on the Bassée-Voulzie area in the baseline scenario.

7. Making it happen

7.1. Social acceptability

Nitrate tax

Taxes on nitrogen pollution from agricultural activities have been discussed three times within the French government (in 1998, 2004 and 2013) but have each time faced an outcry from farmers and fertiliser industries.

In 1998, a charge on nitrogen surplus was for the first time suggested by the then Minister of the Environment, Dominique Voynet then Yves Cochet, through a draft national law for the revision of the French water legislation. The charge was considered to be more incentive and effective than a tax on nitrogen fertilisers. It required an accounting of nitrogen inputs and outputs (fertilisers and manure) for each farm, which was qualified as a "Byzantine system". After four years, many versions and amendments, of heated debate the draft law was presented to the National Assembly in 2002 and abandoned after the change in the majority in the government, the French President Jacques Chirac having undertaken not to impose new taxes on farmers during the presidential elections.

In 2004, while a judgment of the European Court of Justice (ECJ) had ruled against France for failure to comply with the Directive 80/778/EEC on the quality of water intended for human consumption, the Minister of the Ecology Roselyne Bachelot and then Serge Lepeltier proposed again to implement a charge on nitrogen pollution. This time this charge would be paid on the first kilogramme of nitrogen fertiliser and feed for more simplicity compared to the previous proposed tax. Moreover, this charge would have been collected by Water Agencies to fund projects related to the protection of water quality. The rate would be determined based on the amount of nitrogen in fertilisers. This charge would have brought between EUR 30 and 60 million to Water Agencies, thus ten times more than the amount then collected from farmers. However, under strong pressure from fertiliser industries and from the majority agricultural union, the draft law was abandoned. "*Farmers are not able to bear an additional levy at a level that would weaken them*" (Hervé Gaymard, then Minister of Agriculture).

In April 2013, the State was condemned by the Court of Appeal of Rennes to pay compensation to the Department of the *Côtes d'Armor* (Brittany, France) for the treatment of green algae. In June 2013, France was condemned by the ECJ for failure in the implementation of the Nitrate Directive. While a new draft law for the implementation of a tax on nitrogen was again rejected, environmental associations denounce the curative policy adopted which lead to a diffuse pollution borne by taxpayers and water consumers.

Today, the French government is torn between protecting farming and industry while the economic crisis persists, and, on the other hand, to comply with European law and the need to preserve water resources. Nitrate pollution is a sensitive "political" issue, something that was also palpable during our study. Impacts on farmers' competitiveness were one of the main arguments put forward against the implementation of a nitrate tax.

To contrast this situation in France it is interesting to highlight that the principle of clean, untreated drinking water has taken hold among Danish politicians as well as the Danish general public. Regulation of agricultural emissions has been a main focus in successive large-scale action plans to protect drinking water. The institutional climate for green taxes has also been favourable as Denmark undertook a move towards a green tax reform in the 1990s, shifting the tax burden some from income taxes to environmental taxes.

PES scheme

Accepting a PES scheme seems simpler than a tax, since it rewards farmers for the service product. But this raises two questions.

The first question is who will receive the payment and who will not receive them. Indeed, the payment rewards an amount of nitrogen loss avoided, but it does not reward farmers that already produce non polluting crops. However on the *Bassée-Voulzie* area, protein crops represent a marginal part of the surface in the area (6% of the total agricultural surface) compared to the potential shift towards less polluting crops for a PES between 5 and 10 €/kg (around 20% of the total agricultural surface).
A PES on the amount of nitrogen loss avoided could lead to a risk of a perverse incentive: farmers highly consuming fertilisers will find easier to reduce the amount of inputs without impacting their performance and will receive the payment as well. But the measures implemented as part of the Nitrate Action Program in the *Bassée-Voulzie* area limit the amount of fertilisers used (170 kg/ha in a nitrate vulnerable zone). In addition, interviews conducted with farmers point at a sense of responsibility and rationalisation of the consumption of fertilisers.

The second issue is that of the willingness of water users to pay farmers to reduce pollution may be a challenging issue. Nevertheless, PES schemes can be adapted to local conditions and stakeholders through a negotiation process. The type of environmental services considered, the duration of the payment, the nature of the payment, as well as the monitoring system can be discussed by the buyers and the providers.

Combining a nitrate tax and a PES scheme

Despite the advantages highlighted in the analysis of a combined nitrate tax combined and PES scheme, its implementation may lead to acceptability issues, since those who pay the tax are not necessarily those who receive the payment. In fact, the tax is paid from the first kilogram of nitrogen fertiliser thus it impacts all farmers even those who do not necessarily benefit from the payment. Farmers who might benefit from the payment are in particular those who have the technical possibility of crop reallocation and adaptation to their practices.

In addition, the scale at which each of these instruments could be implemented lead to spatial inequity. The tax on nitrogen fertilisers can only be implemented at the national level to take into account the whole fertiliser market. The payment must be however implemented on an area where the service providers are clearly identified.

However, the coupling of the nitrate tax with the PES scheme enables to lower the level of the tax and the PES for the same environmental outcome on the *Bassée-Voulzie* area compared to the effects of each EPI considered separately, thus to the reduction of the negative economic impacts of the tax and the deadweight effects of the PES. Payment for environmental services allows reducing the nitrogen loss significantly (-50%) for payment higher than 4 €/kg of nitrogen loss avoided. Combining it with a tax allows achieving a similar objective in terms of nitrogen loss reduction while reducing the amount of payment: nitrogen loss can be reduced by almost 50% with a payment of 3 € when the tax on nitrogen fertilizer is fixed at 50%.

7.2. Institutional set-up

Nitrate tax

The implementation of the nitrate tax can benefit from the institutional system already in place for the charge on pesticides implemented since 2008 in order to encourage farmers to moderate their use. The charge was previously implemented in the framework of the General Tax on Polluting Activities. In order to give a greater transparency on the revenues collected, the tax was replaced by a charge on diffuse pollution collected by Water Agencies to finance programs that enable to achieve good water status as well as measures aiming at reducing the use of pesticides. In particular, these revenues provide financial support for local authorities, industry, farmers and organizations that carry out studies or actions in favour of water quality improvement. The charge is integrated in the price of the pesticide and the level of the charge depends on the level of toxicity of the product. Distributors are required to report the results of their sales to Water Agencies. In 2010, one of the Water Agencies, the *Artois-Picardie* Water Agency, has been designated for the management of the pooled revenues collected on behalf of all Water Agencies.

PES scheme

The implementation of a PES system has an interest in the sense that it integrates private stakeholders in the process. We can imagine various organisational options:

- A group of local municipalities and a delegation of the private stakeholders that benefit from the services and which would be in charge of contracts and payments. However the benefits are expected to materialise over a long period (40-60 years), thus the current contracts for delegation are not adapted. Besides the hydrographic unit may not be an adapted scale.

- An association gathering private stakeholders and local municipalities. The example of Evian (Defrance, 2011) enables assessing transaction costs of this type of organisation. Eau de Paris could be integrated in this kind of association but would contribute only for the *Voulzie* area.

7.3. Feasibility

Nitrate tax

The nitrate tax does not present a major challenge to be implemented regarding technical feasibility. The tax would be integrated in the price of the nitrogen fertiliser and would be calculated based on the amount of nitrogen contained in the fertiliser.

PES scheme

The implementation of a PES scheme requests to measure the reduction of nitrogen loss at the level of the farm. Considering a unit cost of EUR 40 per analysis, nitrogen residues analysis could cost between EUR 100 000 and EUR 450 000 per year on the *Bassée-Voulzie* area. Regarding legal feasibility, the framework defined by European rules and the Common Agricultural Policy allows financial support to farmers only for a compensation of additional costs or a loss of income that are not covered by the first pillar of the CAP. The payment for environmental services can only be done through agri-environmental measures-like mechanisms (Larroque, 2010).

7.4. Uncertainty

Uncertainties related to the flexibility of the EPI

Several factors lead to uncertainty regarding the actual farmer behaviour. It is uncertain whether farmers are driven by profit or more by professional ambitions to produce a good crop or by family practices which do not maximize their profits for instance. Hence they attempt to optimize their physical yield rather than their economic yield. This issue has in fact been raised by the local institutions of the Bassée-Voulzie during a meeting with stakeholders in January 2013. Moreover, the model developed does not integrate the time spent for agricultural activities. Farmers might not have the time and unless the decision is economically crucial, also not the incentive to pay attention to all decisions; so they may settle for an adequate solution rather than an optimal solution. Thus, it is quite possible that the EPI would be less effective than modelled. The global economic context might however lead to a better consideration of economic constraints even if, on the other side, the economic crisis seems to orient government priorities on improving competitiveness rather than on environmental protection.

Another source of uncertainty is the results from the negotiation phase during the design of the EPI. The past shows the strong influence of stakeholders on the implementation of a nitrate tax.

Sensitivity analysis: changing the price of inputs and outputs

The agro-economic model is calibrated based on crops surfaces, yields and prices of 2010 (date of the last available agricultural census data in France). However, prices and yields are highly volatile due to local climate condition and international context. For instance, between 2010 and 2013 the price of products has increased from 0% (potato) to 100% (alfalfa). Most cereals have seen their price increased by 30% (from 24% for bread wheat to 38% for winter barley). The price of rapeseed has increased by 30% while the price of protein pea increased by 46%.

The baseline scenario was simulated with the 2013 price set (prices of input and products) and new references for yields. The simulation gives a sense of the effect of potential changes at the macro-economic level. Compared to the 2010 situation, the surface of oilseed crops is doubled (the gross margin of sunflower becomes attractive) replacing hectares of cereals (bread wheat, rainfed maize, winter and spring barley). The land use reallocation leads to a reduction of nitrogen loss by 2% on the *Bassée-Voulzie* area (the nitrogen loss of sunflower is set at 8 kg per hectare compared to a nitrogen loss of 9 kg per hectare for barley). At the same time, gross margins have increased by 28% (the price of inputs has significantly increased).

Doubling the price of fertilizers (100% N-Tax) in the 2013 system does not lead to any land use reallocation, while it allows replacing cereals by protein crops in the 2010 system. Thus, the reduction of nitrogen loss is less efficient (-10% compared to -13%). In the 2013 system, the reduction of N-loss is only associated to a reduction of fertilizer use (adaptation of agricultural practices linked to a higher price of inputs). The crop allocation suggested as reference by the model in the 2013 system is less sensitive to a taxation. Indeed, gross margins of oilseed crops are relatively high and surfaces of cereals are lower than in the 2010 situation.

As shown in sections 6.2 and 6.3, protein crops (pea) are significantly impacted by the two EPIs. Changes in nitrogen loss reduction are thus largely dependent on that crop. A 10% increase of the price of protein pea (from EUR 178 per ton to EUR 196 per ton) leads to a reduction of nitrogen loss on the Bassée-Voulzie area of almost 5% (trade-off between barley and protein pea), equivalent to the reduction associated to a 30% N-tax. Such an increase of the price of protein pea is more than realistic. Indeed, the average price of protein pea over the five year period 2008-2012 was EUR 193 and the price was EUR 260 in 2013. The latter represents a 50% increase compared to the price of 2010. Such increase *ceteris paribus* would lead to a reduction of 24% of nitrogen losses, equivalent to a 200% N-Tax. Thus, a price system in favour of protein pea may have the same effect as a taxation on nitrogen to a certain extend and would lead to an increase of gross margin at the farm level.

Other uncertainties may arise from the evolution of other drivers that might affect the agriculture on the *Bassée-Voulzie* area. This is particularly the case of the effects of the CAP reform for which measures have yet to be adopted.

Uncertainties related to the agro-economic model developed

As any other model, the agro-economic model developed is based on assumptions (such as the consideration of homogeneous farms within each type of farm developed, assumptions on rotation constraints and agricultural practices, the calibration of the model on a single reference year, ...). However, this inevitably leads to biases on the effectiveness of the instrument. Similarly, yield functions and functions on nitrogen loss per crop were initially developed by PIREN at the scale of the Regions of the Seine-Normandy basin. So the choice of the curve does not correspond completely to the physical and farmers' characteristics of the *Bassée-Voulzie* area.

This dimension of uncertainty could be explored through the following tests to assess the robustness of the model:

- Changing the nitrogen losses associated to each crop (uncertainty associated to the data provided by "Sisyphe" in the context of the PIREN Seine programme) and ratios between cereals, oilseed crops and protein crop. Nitrogen loss functions were indeed defined per crop at a regional scale considering an average situation in terms of agricultural practices, soils and crop varieties. In addition, the selection process for the more representative function assumed a rational behaviour of farmers (they are supposed to maximise their revenues using the optimal quantity of input);

- Refining gross margin and quantity of input for Hemp to move closer to reality. Indeed, the characterisation of hemp was approximate in the model. The change might have marginal impact on the calibration process and the constraint of the model. Assessing the sensitivity of this crop in the model would help refining the results.

8. Conclusions and Policy Recommendations

The EC's proposals regarding the CAP reform seems to pursue the aim of inducing a change toward environmentally-friendly agricultural practices. Besides, local actions set to preserve the quality of water resources on the *Bassée-Voulzie* HU are consistent with a sustainable agriculture scenario for the next decades. However, other drivers, in particular the effects of climate change, the high volatility of crop and input prices lead to uncertainty on the changes in farmers' practices and crop allocation. The consideration of the main key drivers of nitrate pollution assumes a stabilisation of current trends.

The assessment of the tax on nitrogen fertilisers shows a relative proportional reduction of nitrogen loss with the level of the tax. A 30% tax leads to a reduction of 5% of nitrogen loss and a 200% tax leads to a reduction of less than 25% of nitrogen loss at the scale of the *Bassée-Voulzie* area. However this reduction is associated with a similar reduction of revenues for farmers, i.e. an increase of charges due to the tax and a reduction of profits due to the change of crops and/or a reduction of yield. This contribute to explain the strong outcry that caused a similar tax to farmers and fertiliser industries each time the French government tried to implemented it. Moreover the current economic context is not conducive to the implementation of such a tax, while improving of farmers' competitiveness is a challenging issue.

We propose to design a PES scheme as a positive incentive reflecting the benefits associated to a change from current agricultural practices to more environmentally friendly practices. The change of land-use and the change of agricultural practices produced by the positive incentive may lead to the simultaneous provision of multiple services. Gathering beneficiaries into an "association of beneficiaries" is one key success factor in PES schemes. Besides, compared to AEM, the participation of private institutions is expected to increase performance levels.

Taking 2010 as a reference, the payment is defined based on the reduction of nitrogen losses: for each kilogram of nitrogen that is not released in the environment compared to its reference, the farmer will receive a unit payment. The use of the model allows understanding the stepped response curve to payments. A payment of 5 €/kg and more allows a significant change from polluting crops to environmentally friendly crops such as protein pea. A payment of more than 10€/kg leads to a serious deadweight effect. Such thresholds depend on the type of crop and their respective gross margin but also on relative nitrogen losses for crops. A precise knowledge on nitrogen loss curves for each crop is thus essential.

A payment of 5 €/kg represents a subsidy of EUR 300 per hectare converted, and around EUR 6 200 per farm in average. The payment represents about 6% of the farmer total revenue. At the scale of the Bassée-Voulzie area, the payment represents a subsidy of around EUR 7 million per year.

The feasibility of coupling a PES scheme with a tax on nitrogen fertilisers was also assessed. As suggested by Bourgeois (2012), combining a tax with a subsidy-like economic instrument could be cost-effective compared to the implementation of a nitrate tax alone and can lead to some levels of abatement which are difficult to reach if the policy is only based on one economic instrument. Bourgeois (2010) considers a subsidy on perennial crops whereas we have focused on a payment associated to the reduction of nitrogen loss at the scale of the farm. PES allows reducing nitrogen loss significantly (-50%) for payment higher than 4 €/kg of nitrogen loss avoided. Combining it with a tax allows achieving a similar objective in terms of nitrogen loss reduction while reducing the amount of payment: nitrogen loss can be reduced by almost 50% with a payment of 3 € when the tax on nitrogen fertilizer is fixed at 50%. Regarding the economic impacts, the amount of payment may contribute to improve the economic situation of farmers. A payment of 5€/kg combined with a 50% tax leads to a total cost of payment of around EUR 3 million per year while around EUR 5 million per year are collected through the tax, at the scale of the *Bassée-Voulzie* area. At the scale of individual farms, this combination leads to a reduction of around 5% of the total gross margin. Thus the combination of these two instruments enables to lower the costs of each EPI considered separately for the same environmental outcome on the *Bassée-Voulzie* area easing their implementation.

The impact assessment of a PES scheme on runoff led to no significant conclusion on the effectiveness of this EPI. It was moreover not possible to measure the effect of a marginal land use change on runoff, neither its contribution to the regulation of floods. Moreover, the maintaining or the improvement of biodiversity was originally planned to be assessed as a third ecosystem service (annex IV). But practical issues did not allow us to assess the impacts of implementing a PES scheme on this environmental issue. Thus the idea of combining payments for various environmental services appeared difficult in terms of implementation. However a multi-services PES scheme remains a promising EPI that could contribute to enhance the environmentally friendly practices while reducing transaction costs.

One of the main issues to address is the social inequity that may induce the implementation of the combined EPIs, since the tax on nitrogen fertilisers can only be implemented at the national level to take into account the whole fertiliser market. The payment must be however implemented on an area where the service providers are clearly identified. An institutional set-up allowing the reallocation of funds collected through the nitrate tax to the contribution of the PES could be a solution to mitigate social inequity.

The legal feasibility of the PES is however still unclear. The legal institutional framework allows financial support to farmers only for a compensation of additional costs or a loss of income that are not covered by the first pillar of the CAP. The payment for environmental services can only be done through agri-environmental measures-like mechanisms (Larroque, 2010). Today PES schemes can only be found in France in private-public cooperation, such as the case of Vittel, owned by Néstlé (Perrot-Maitre, 2006; Depres, 2008), and the case of the Evian Natural Mineral Water (owned by Danone Waters) (Defrance, 2011).

The scale of the *Bassée-Voulzie* HU is not adapted to assess the level of the EPIs that allow for full compliance with the Nitrate Directive (nitrate concentration below 50 mg/l), since the two main aquifers in question are only partially covered by the study (i.e. Chalk and Eocene aquifers).

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Annex I: Limits of the study area, the Bassée Voulzie Hydrographic Unit

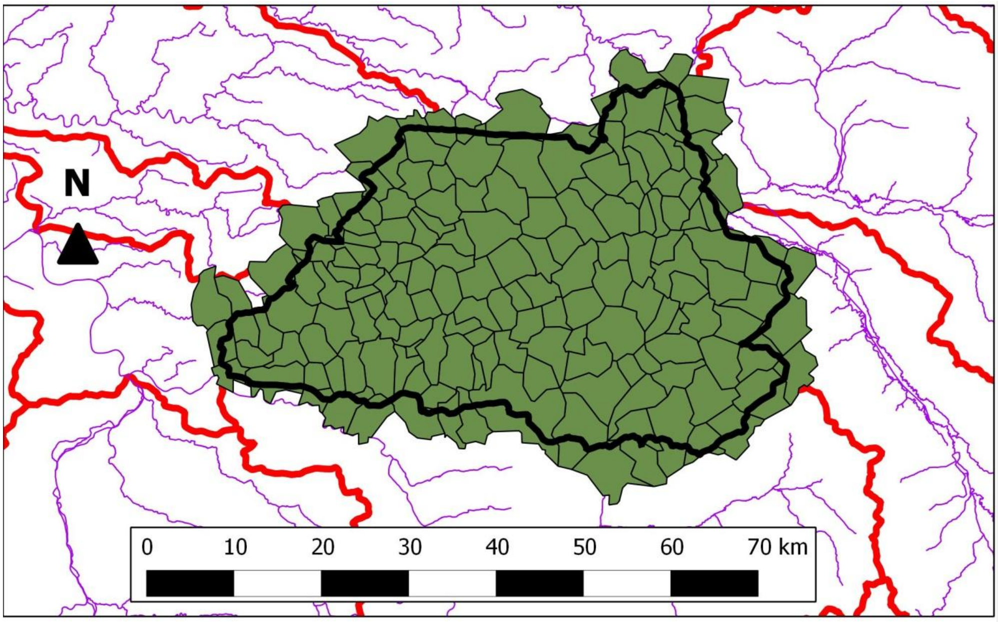


Figure I.1.Limits of the Bassée-Voulzie area, considering all towns

Source: Authors

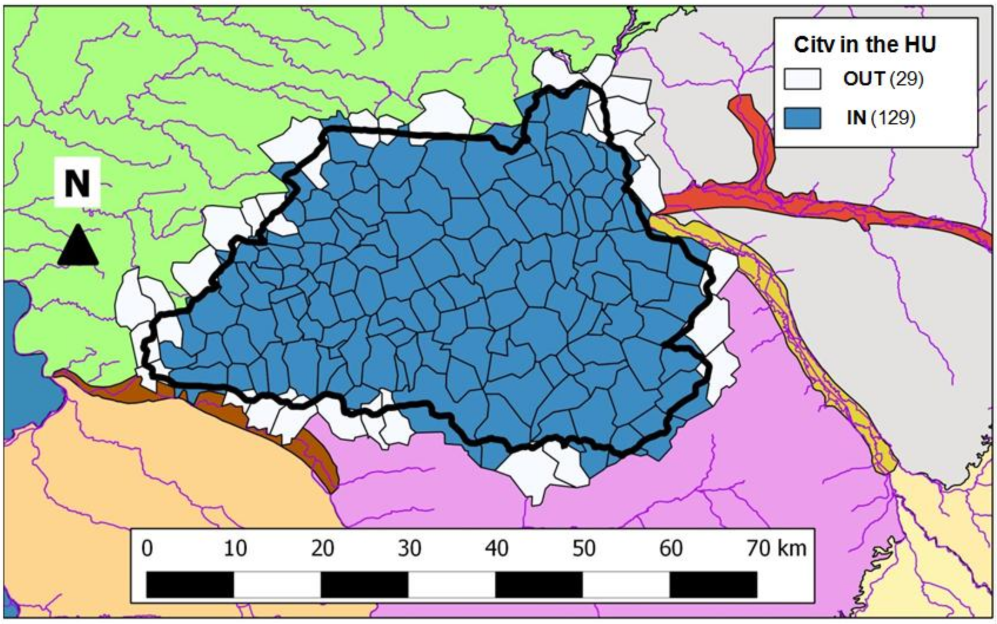
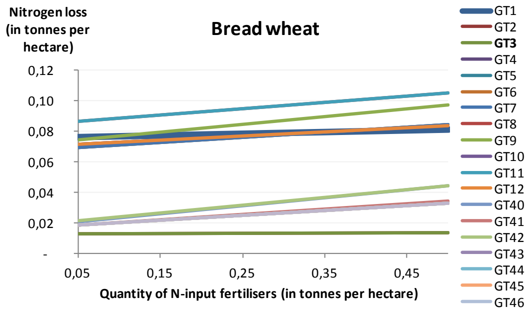


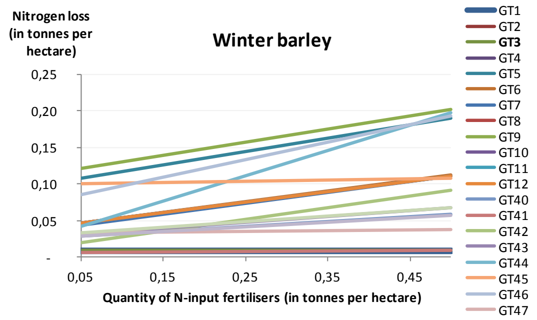
Figure I.2. Limits of the Bassée-Voulzie area, considering towns with more than 50% of their surface within the study area

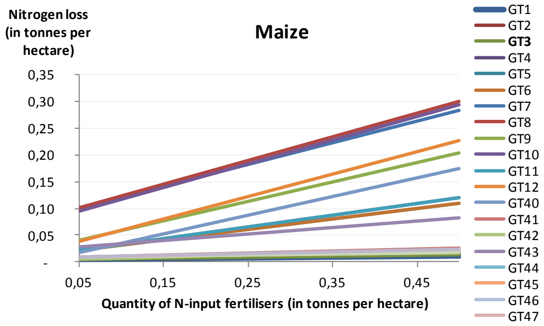
Source: Authors

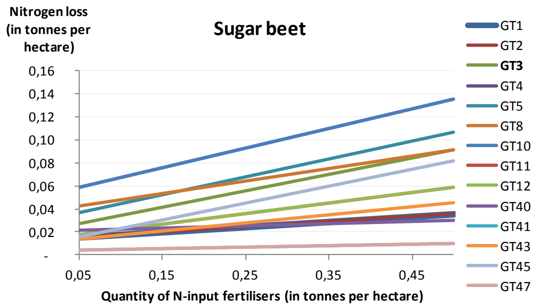
Annex II: Nitrogen loss functions

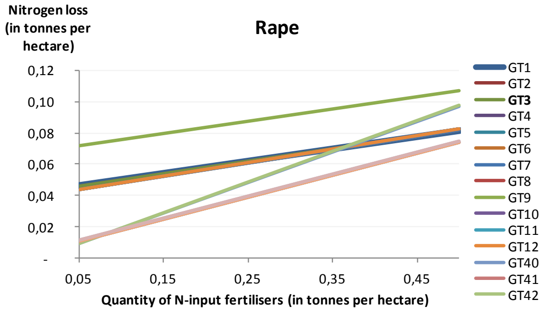
The following figures presents the nitrogen loss function for each crop integrated in the *Bassée-Voulzie* agro-economic model. They were provided by Cyril Bourgeois (Sisyphe JRC) based on his thesis. We would also like to thank Florence Habets (Sisyphe JRC, Mines-Paristech, Geosciences Center) for her contribution.

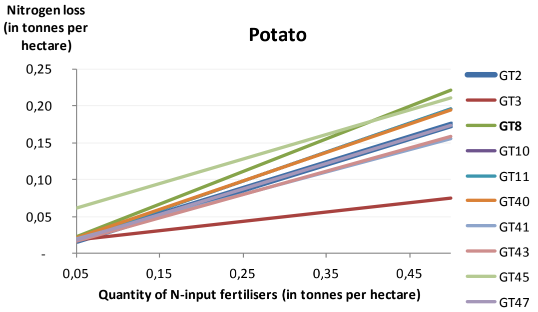


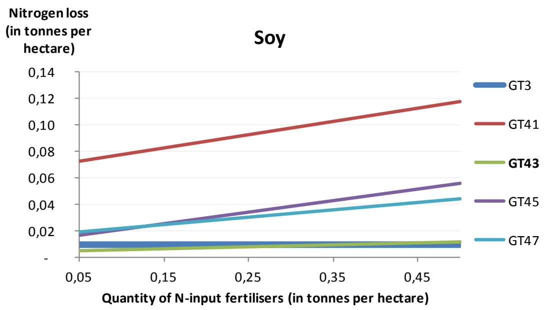


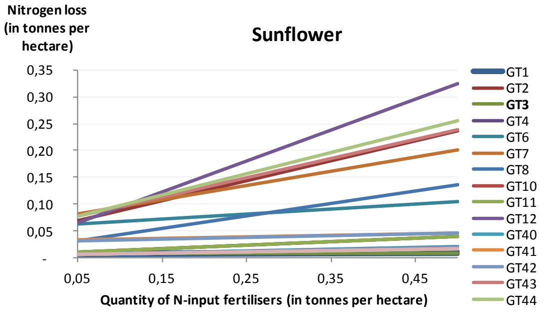












Annex III: Input and output price past evolutions in France

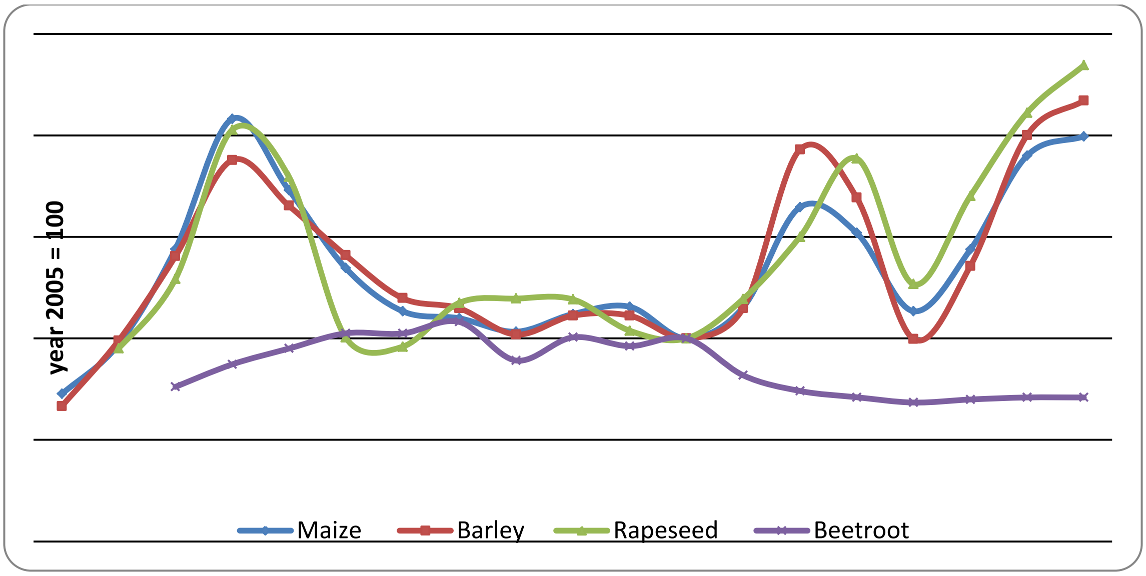


Figure III. 1. Evolution of crop prices in France from 1970 to 2012 using year 2005 as basis 100

Source: UVEG based on data from Agreste, INSEE

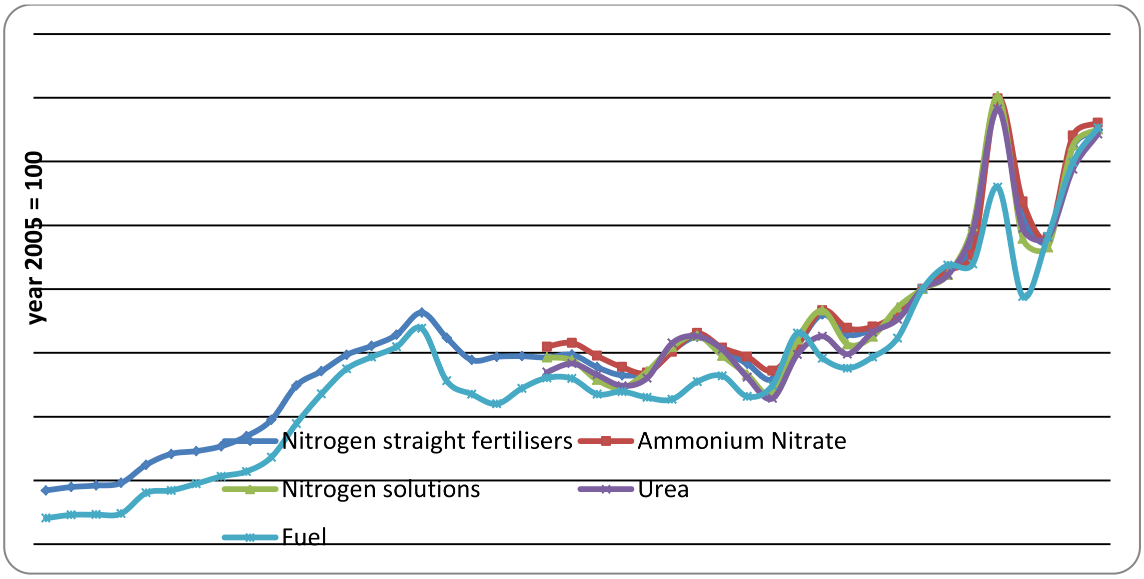


Figure III. 2. Evolution of fertilizers and fuel prices in France from 1970 to 2012 using year 2005 as basis 100

Source: UVEG based on data from Eurostat and Agreste, INSEE

Annex IV: Assessing biodiversity issue

A third ecosystem service was originally planned to be assessed: the maintaining or the improvement of biodiversity. Taking into account practical issues and the lake of knowledge on biodiversity (while the definition of that "service" is frequently discussed due to its complex interactions with other ecosystem services, the main constraint remains the measurement of a marginal change and its economic valuation), the assessment focused only on the other two environmental services (the provision of good water quality and flood control). The annex IV presents however some food for thought on this issue.

The biodiversity hotspot of the *Bassée-Voulzie* HU is located in the sector of *La Bassée*, especially in the upstream section that remains relatively preserved. Naturalistic work done since the early 1980s helped to highlight the ecological quality of the sector leading to demands for protection from the State services and local associations: *La Bassée* concentrates 41 Natural Zones of Interest for Ecology, Flora and Fauna (ZNIEFF), 4 Natura 2000 protected areas and 1 National Nature Reserve. This latter was created to preserve the remaining biodiversity against the development of ship transport and gravel extraction activities and the intensification of agriculture (Bouscasse *et al.,* 2012). The *Bassée-Voulzie* area also gathers 6 Biotop Protection Orders[33]. However global trends are not optimistic for the preservation of biodiversity as the main pressures are not disappearing neither decreasing.

Adapting agricultural practices could lead to some improvements and contribute to the green and blue belt to preserve ecological continuity. But existing instruments did not manage to reverse the current trend of degradation.

In 2005, the Common Agricultural Policy (PAC) reform lead to a new principle: payments to farmers were becoming dependent on the achievement and maintenance of baseline standards, among which the standards consistent with keeping land in "good agricultural and environmental conditions" including habitat conservation. But the environmental effect of this measure was limited because the constraint was applied *a minima* (Tobias *et al.,* 2011).

The *Conseil Général* of the Seine-et-Marne department is developing a dynamic conservation atlas of biodiversity but the work is still in progress. A local environmental association developed a similar tool for the *Bassée* floodplain area in order to raise awareness (at a local scale) of the biodiversity issues. Even if local elected representatives were interested. None of these initiatives are restrictive.

In addition, agri-environmental measures (AEM) focusing on biodiversity have recently been designed on two *Natura 2000* areas: this instrument will be available for a few farmers on the *Dragon* catchment (one of the three sources of *Eau de Paris* in this area) and later for farmers located in the *Bassée* floodplains. However this instrument concerns a few municipalities of the Bassée-

Voulzie HU and is generally criticised for its high level of transaction costs (administrative burden).

Finally, a project of creating a second National Natural Reserve has been discussed for years. This protection area would allow a high level of protection for the upper part of *La Bassée* which is still preserved. But the project has not been materialized yet.

The link between farming and biodiversity could have been achieved by mobilizing a group of experts[34] to identify consistent indicators and levels of gain and loss related to agricultural practices and cropping patterns.

[34] For instance, the *Maison de l'environnement de Seine-et-Marne*, the National Museum of Natural History, the *Conservatoire botanique national du Bassin parisien*, the *Association Nature du Nogentais* and the Chamber of agriculture.

Annex V: Supplementary material

The following documents have been produced as a contribution to the Ecosystems and conservation case study. They are accessible from the project's web site (www.epi-water.eu).

Viavattene, C. (2013). Potential impacts of land use changes on the water balance for the Bassee-Voulzie Hydrologic unit. Output no.7 of the Research Task 4.3 of the EPI-WATER project. Flood Hazard Research Centre, Middlesex University, UK.

Garzon, A., Defrance, P., Raveau, A., and Viavattene, C., (2013). Involvement on issues related to water governance, stakeholder analysis and Local Advisory Group meetings. Output no.8 of the Research Task 4.3 of the EPI-WATER project. Published in EPI-WATER WP4: MS10 - Final round of meetings of the local advisory stakeholder groups, ACTeon, France.

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Molinos Senante M., Hernandez F., Sala R. (2013a). Analysis of the consideration given to environmental protection in the objectives and measures of the successive reforms of the CAP, Output no.9 of the Research Task 4.3 of the EPI-WATER project. University of Valencia, Spain.

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