Technical report No 51

Calculation of nutrient surpluses from agricultural sources

Statistics spatialisation by means of CORINE land cover
Application to the case of nitrogen

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Cover design: Rolf Kuchling, EEA

Author: Philippe Crouzet, (Ifen / national expert seconded by the Ifen in the European Environment Agency [Copenhagen])
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European Environment Agency
Kongens Nytorv 6
DK-1050 Copenhagen K
Denmark
Tel: +45 33 36 71 00
Fax: +45 33 36 71 99
E-mail: eea@eea.eu.int
http: / / www.eea.eu.int

Contents

Tables

Figures and graphics

Warning:

The following text is the translation of the French publication jointly issued by Ifen, EEA and JRC in October 2000. This translation was carried out using the SYSTRAN facility of the European Commission; the raw text has been reviewed by the author and skimmed by Mark Tuddenham, research officer and translator at Ifen. Slight rewording was done to facilitate understanding by readers not familiar with France.

1. Preamble

The nitrogen and phosphorus surpluses resulting from agricultural activities constitute one of the links of the chain of enrichment of inland waters in nutrients. This chain is direct for nitrogen, it is more indirect, but also certain, for phosphorus which constitutes a medium-term serious threat.

Surpluses also constitute a crucial stage in the DPSIR model ([1]) of environmental assessment. The most accurate estimate at the scale of whole countries and reported by drainage basin, both of the tonnages and of the local surplus densities, is therefore required for the environmental assessment in direct support to public policies. The calculation of the nitrogen surpluses could quickly be carried out. That of the phosphate surpluses poses practical – of availability of technical coefficients – and methodological problems, of representativity of annual calculation; it therefore seemed preferable to immediately publish the findings concerning nitrogen.

The calculation of the surpluses is obviously only a stage in the construction of an information system relating to nutrient contributions and to their impact, inside an overall system of environmental information. This calculation was developed from proven methodologies, mixing modelling and statistical approaches that require a minimum data set as a response to an aim of being able to apply the method to the totality of the land areas concerned.
In particular, the calculation of the surpluses does not need to take into consideration the type of soil on which crops are grown. Obviously, when the question of the transfer will be dealt with, then, pedological criteria will be taken into account, simple and operational mechanisms being then derived from the more fundamental models implemented by the scientists on small areas.

Comparing the sources of environmental data, the statistical sources and the expertise in agronomic matters, made it possible to develop a simulation method mitigating partly the major disadvantage of the statistical sources available, namely their small degree of geographical resolution. The use of CORINE *Land cover* to spatialise statistical data was made profitable for the calculation of the nitrogen surpluses from agricultural sources and their breakdown by drainage basin on two large areas: the Loire-Bretagne Water Agency district (France) and the basin of Elba (Germany and Czech republic), covering together more than 300 000 km^2.

The results obtained with minimum data sets processed by means of a very flexible system of calculation proved completely comparable with values of reference obtained independently, with regard to both the figures and the geographical distribution of the surpluses. In the case of the drainage basins of the Loire-Bretagne Water Agency district, the surplus figures obtained with a scenario reflecting the standard coefficients defined by the agronomists, combined with transfer rates corresponding to the types of soils and with the assessments of urban and industrial contributions are in good harmony with the nitrogen fluxes calculated from river monitoring. An overall estimate verifies also for the basin of Elba, which was the subject of detailed previous study, using in particular models that are more sophisticated.
In all the cases, the taking into account of nitrogen contributions as complete as possible and in particular symbiotic fixing by the leguminous plants is necessary.

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[1] DPSIR is acronym for Driving forces, pressures, State, Impact, Response, which constitutes the conceptual model to approach the environmental problems defined by the European Environment Agency (EEA). This model is in particular used in all the evaluation reports submitted by the EEA and quoted in this publication. Details are available on the Internet site of the EEA (http://www.eea.eu.int), click 'SEARCH', and type DPSIR.

Simulations were carried out by using coefficients and a method derived from those practised by EUROSTAT, for an average year centred on 1990 for the French part. The nitrogen surplus is quantified in this case at 325 thousand tonnes a year. The drainage basin of the Loire contributes for 45 % approximately on the whole of the surpluses of the Water Agency district. The average surpluses are 37 kg N/ha/year out of the 8.8 million ha in surpluses (56 % of the total land area), this figure rising to76 kg N/ha/year for the 2 million most fertilised ha. Considering a maximalist scenario, based on non-limited supplies of fodder to the livestock, these figures rise to 492 thousand tonnes, and the land area in surpluses passes then to 9.6 million ha (62 % of the total land area).

The basin of Elba presents a weaker total surplus, for the basic scenario, that is quite comparable with the basin of the Loire proper, of 140 thousand tonnes/year, representing an average surplus of 20 kg N/ha/year for the 6.9 million ha presenting a surplus (47 % of the total land area). In this case, however, the maximum scenario relating to the feeding of livestock raises the surplus to 325 thousand tonnes, distributed among 8.2 million ha (56 % of the total land area).

The sensitivity analysis carried out showed that the use of CORINE *Land cover* provides results without bias, robust and showing the diversity of the local surpluses, even when the data set relating to agricultural statistics is deteriorated by aggregation on wider administrative entities. This result is particularly important insofar as surplus calculations on large territories can be carried out, covering several countries in which the level of resolution of agricultural statistics is notably different. For example, the use of the CORINE layer *Land cover* yields **more accurate** surplus tonnages **from statistics aggregated at the department (NUTS3),** than those obtained from statistics aggregated at the level of the 'arrondissement' (equivalent to a NUTS4 level), but in the latter case without spatialisation by CORINE *Land cover.* Obviously, the dispersion with respect to the reference is slightly larger in the first case than in the second.

These conclusions strongly suggest that it is possible to carry out relevant and comparable assessments on a large area, despite the high heterogeneities of the statistics available according to the territories. Knowing in addition that aggregated statistics are quite often available for inter-census years, follow-ups over time become possible.

In addition, comparing the results obtained using the method presented here with sales statistics showed that these last figures do not yield any correct estimate of the surpluses. On the other hand, their use is very useful as a framing factor, -applicable to wide areas-, of the agronomic hypotheses being used for the modelling of the surpluses. This scale is however inadequate for the needs of the environment.

The use of CORINE *Land cover* presents another advantage, determining for the later estimate of the transfers of nutrients towards the natural waters. It makes it possible to calculate an estimate, certainly approximate, of the distribution of the surpluses over a certain geographical area. This information is decisive because the models of transfer of the nutrients towards the waters from diffuse sources involve the taking into account of a background noise inherent to the surface under consideration and a quantity proportional, or even more than proportional, to the surplus, both depending on the local conditions (pedology, climatology, relief, etc.).

The coefficients of these equations are not all available, but will come increasingly from comparing surplus calculations with assessments of fluxes in river and with the results of much more complex models, applied to experimental drainage basins and simulating the behaviour of the nutrients in the root areas and the surface parts of the soil.

The contribution presented in this report is therefore a stage in the engineering together scientific research, agricultural statistics and the environmental follow-ups for the production of representative environmental information on national and European scales and has therefore to be considered as such.

It is therefore proposed to carry out as soon as possible calculations at the European scale, which could be carried out in a time from 12 to 15 months, and the cost of which would be limited. Indeed, the absence of detailed and uniform, therefore expensive statistics and which is difficult to obtain, can be mitigated by the proposed method. Therefore, representative and comparable figure production from one country to another and with national productions, and relevant in relation to the needs of the European Environment Agency for example, is henceforth possible.

It remains desirable to improve the modelling of the calculation of the surpluses. The objective of the study was indeed especially to show the added value given by a layer of spatialisation and the possibility of having quickly relevant figures on a large scale and not to propose a new agronomic model.

2. Problematics

2.1. The impact observed in the receiving media

The presence of nitrogen and phosphorus compounds in surface waters and groundwater is normal at low concentrations. It is even a vital need for surface water. On the other hand, the excessive presence of nitrate, phosphates and the other forms of nutrients is the sign of excessive polluting contributions and directly or indirectly causes water pollution and the eutrophication of the surface waters.

The natural values of phosphorus compounds are very low, in the range of a few microgrammes of P l^{-1}. In watercourses draining basins without significant human activity, low nitrate contents are also found, about 0.1 mg $N\text{-}NO_3 l^{-1}$. The only significant sources of nitrogen on this type of basin are the symbiotic fixing of atmospheric nitrogen by the rhizobiontes of certain families of plants, the precipitations that have dissolved nitrogen-containing molecules formed by lightning in the upper atmosphere, transport by animals, etc. The weak concentrations found in waters are the joint result of the biological activity and the high mobility of nitrate in the soils. The human activities of dwelling, manufacturing and agriculture are in fact a considerable intensification and a space concentration of natural processes, the yield of which is necessarily below 100 %. The corollary is leaching of certain substances and the increase in their concentrations in the natural environment.

Human and industrial uses are made more costly; sometimes they even become impossible for reasons of regulatory conformity or water composition demanding production processes. The state of the media is better and better known and assessed; excessive concentration values are observed in an important proportion of the various surface and underground aquatic environments. Natural concentrations are monitored only in exceptional circumstances while, according to the regions, 10 to 75 % of the control sites present concentrations going from 5 to 10 times the maximum value which can be allotted to natural processes (Crouzet, Leonard *et al.*, 1999; Scheidleder and Grath, 1999).

2.2. State of the knowledge of the causes

By contrast, the causes of disturbances are quantified only in an overall way, with an insufficient space resolution. Scientific documentation makes it possible henceforth to quantify on a small area the causal relationships between the human activities and water pollution. However, the reality of pressures cannot be related with the effects on a large area, in order to provide the elements of a suitable political response.

An exact and verifiable evaluation of the sources of water pollution by the nutrients represents therefore considerable interest. The complexity of the mechanisms requires in addition a stepping approach, producing representative results up to the pan-European level. Moreover, validation of these results by comparing them with independent sources of data should be made possible. Finally, the results should be broken-down among the various sources and according to the various environmental units concerned, mainly the surface and underground drainage basins.

It is very important to size up the orders of magnitude of the various quantities involved in the process of water pollution by the nutrients, which constitutes an important source of validation, the more so as it is strictly independent. The example taken is that of nitrogen, knowing that the differences between the various stages are amplified in the case of phosphorus.

- The figures of the first Dobris report (Stanners and Bourdeau, 1995, pages 78 and 91) make it possible to consider the order of magnitude of the overall flux of the main European rivers with regard to their flow and their average nitrate-nitrogen content. Extrapolating the 2.9 million tonnes of nitrogen calculated for the 6.6 million km^2 drained at 10.2 million km^2 of Europe, 4.5 millions tons are obtained. To this figure corresponds an average loss of 4.4 kg N $year^{-1}$ ha^{-1} of catchment. Calculating waters in two categories (close to natural and anthropized); yields a range of 3.9 to 7.8 kg N $year^{-1}$ ha^{-1} of catchment. In view of the data currently available, the uncertainty of these figures is not known. It could however be quantified after use of the data collected within the Eurowaternet implementation.

- The total quantities of nutrient that are input into the agricultural processes are not known, (in particular symbiotic fixing), but by considering the same area extension, therefore by excluding Turkey, the Dobris+3 compendium allows an estimate for 1994 of 21.3 million tonnes of nitrogen from artificial fertilizers (calculated from EUROSTAT, 1998)**.** To this figure at least 7 million tonnes of nitrogen from livestock waste, should be added (internal value calculated for the 18 countries of the EEA). A reasonable estimate of the total of nitrogen brought into play is between 28 and 37 million tonnes and is used thereafter. These values are approximate: the majority of the reports indicate only fertilisations by hectare, without mentioning the number of hectares concerned.
- Natural contributions, calculated from the median concentration of the range of the natural contents, are appraised at 0.5 million tonnes N.

- The contributions due to the metabolism of the 500 million inhabitants (~10g N $hab^{-1}day^{-1}$), saying 1.8 million tonnes N, are transferred to the waters at a rate estimated at 70 %, yielding 1.3 million tonnes.

Summarising, the share from agricultural sources could be 4.5 – (0,5+1,3) =2,7 millions of tonnes N. This value (2.6 kg N $year^{-1}$ ha^{-1} of drainage basin) ranges between 5 to 10 % of the quantities of fertilizers and livestock waste input. This very coarse value of overall contribution to water pollution is the result of two mechanisms, surplus production and their actual transfer.

The average efficient contribution of 2.6 kg N $year^{-1}$ ha^{-1} is obviously very variable. Respectively for the whole drainage basin of the Loire and for the utilised agricultural area (UAA, SAU in French documents) 9 to 20 kg N $year^{-1}$ ha^{-1} are found. These figures have to be considered at the various stages of transfer. An equivalent contribution to the aquatic systems of 4-20 kg N $year^{-1}$ ha^{-1} of drainage basin results from an effective loss from the field between 10 and 50 (or more) kg N $year^{-1}$ ha^{-1} UAA, coming in particular from a surplus ranging between 0 and 150 kg N $year^{-1}$ ha^{-1} UAA. These figures adequately reflect the issues and the importance of the knowledge of the values for each stage, with their correct geographical location.
As a comparison, the range of nitrogen and phosphorus values present or added in the agricultural land, and drawn from agronomic sources is reported in the two following tables The column 'hazardous range' stresses, in the same units the values of hypothetical loss which could cause a major disorder in the receiving waters.

Table 1: Example of range of order of magnitude of stocks and fluxes of nitrogen in a cultivated and normally fertilised soil

Stock N	of which			Inputs	Surplus	*Hazardous range*
	Mobile	Mineral	Biomass			
3000 kg N/ha	1000 kg N/ha	30 kg N/ha	100 kg N/ha	20 kg N/ha/year	20 kg N/ha/year	*10 kg N/ha/year*
5000 kg N/ha	2000 kg N/ha	300 kg N/ha	400 kg N/ha	>250 kg N/ha/year	200 kg N/ha/year	*30 kg N/ha/year*

Source: compilation of the figures from the http://unita.fr site and from (Stanners and Bourdeau, 1995, chap. 22, pages 447 and following). The hazardous range is the loss bringing 50 mg nitrate l^{-1} for a run-off between 50 and 300 mm $year^{-1}$. Surpluses include the remainder after harvest, left to the field.

It should be pointed out that the loss which can induce a risk is in the range of 1 % of the stock and 10-50 % of the annual contribution. The situation is definitely different if phosphorus is considered.

Table 2: Example of range of order of magnitude of stocks and fluxes of phosphorus in a cultivated and normally fertilised soil

Stock P	of which			Inputs	Surplus	*Hazardous range*
	Mobile	Soluble	organic			
150 kg P/ha	100 kg P/ha	0,04 kg P/ha	10 kg P/ha	10 kg P/ha/year	5 kg P/ha/year	*0,05 kg P/ha/year*
5500 kg P/ha	300 kg P/ha	0,10 kg P/ha	100 kg P/ha	50 kg P/ha/year	30 kg P/ha/year	*0,3 kg P/ha/year*

Source: compilation of the figures from the http://unita.fr site and from (Stanners and Bourdeau, 1995, chap. 22, pages 447 and following). Losses defining the 'hazardous range' are computed from the figures in the Drinking water Directive. They must be divided by 10 so that drainage contributions are virtually without effect on the surface water. Contributions and surpluses were recomputed in P from the indications expressed in P_2O_5.

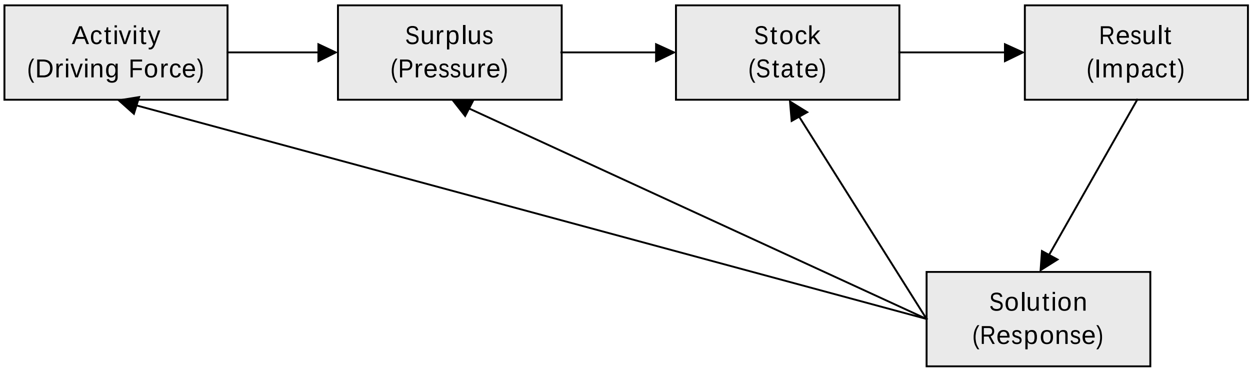
Contrary to nitrogen, the compounds of phosphorus are seldom washed out from the soils. Surpluses therefore tend probably to enrich stock and the mobile phase, which in the long term can involve harmful losses for the waters. Proportions as small as 0.05 – 0.5 % of annual contributions are potentially awkward. It was recently shown that phosphorus is actually lost from soils, even argillaceous, in consequence of the preferential movement in the macropores (Jensen, Bruun Hansen *et al.*, 1999). The measured losses are in the orders of magnitude indicated above, less than 1 %. This forces also to consider the long-term surpluses in phosphorus as a potential threat in relation with the eutrophication of waters.

This report presents motivations and the envisaged methods of calculation of the nutrient surpluses in relation to the agricultural activities. The pilot application presented is limited to nitrogen and covers two basins (the Loire and Brittany, Elba) covering together approximately 300 000 km^2.

3. Human activities and surplus concept

The ’surplus’ is the difference between the total quantity that enters the process of agricultural production and the outgoing quantity that results from production. It is therefore above all an accounting and statistical concept. The approach refers obviously to the conceptual chain DPSIR (2000) of the environmental analysis, applied to the case of the nutrient surpluses from agricultural sources. It defines a series of stages, each one of which is connected with the others and that allows in particular evaluating the political and technical answers to the identified problems. Its application is represented in the following figure.

Figure 1: Position of the surpluses in the DPSIR concept of environmental evaluation (case of the agricultural activity)



In this context, the agricultural surpluses constitute a privileged stage, of which for example the constituent components take part in the environmental assessment of the eco-taxes applied to certain inputs (Recherche Développement International (RDI), 1999)**.** The surplus is thus the analogue of raw pollution, dependent on the yield of the activity. It therefore constitutes a pressure. The resulting state, measurable or calculable is the quantity of this raw pollution that takes part in the variation of the content of the arable land. Lastly, the impact is, for example, the concentration found in the receiving media.

The policy responses can apply to all the stages. Certain agricultural forms of activity can be encouraged or limited. The quantity of surpluses can be modulated according to the methods of cultivation, to the yield of the varieties and to the management of fertilisations. Transfers can also be the subjects of technical solutions, planting grass stripes on the banks of the rivers, modulating the manners to cultivate soils to limit the losses, etc.

Only calculation and simulation make it possible to get an estimate of the quantities of substances involved and of the surpluses on a large scale. They constitute therefore a first fundamental stage to quantify the sources of water pollution and to contribute to the development of relevant policies.

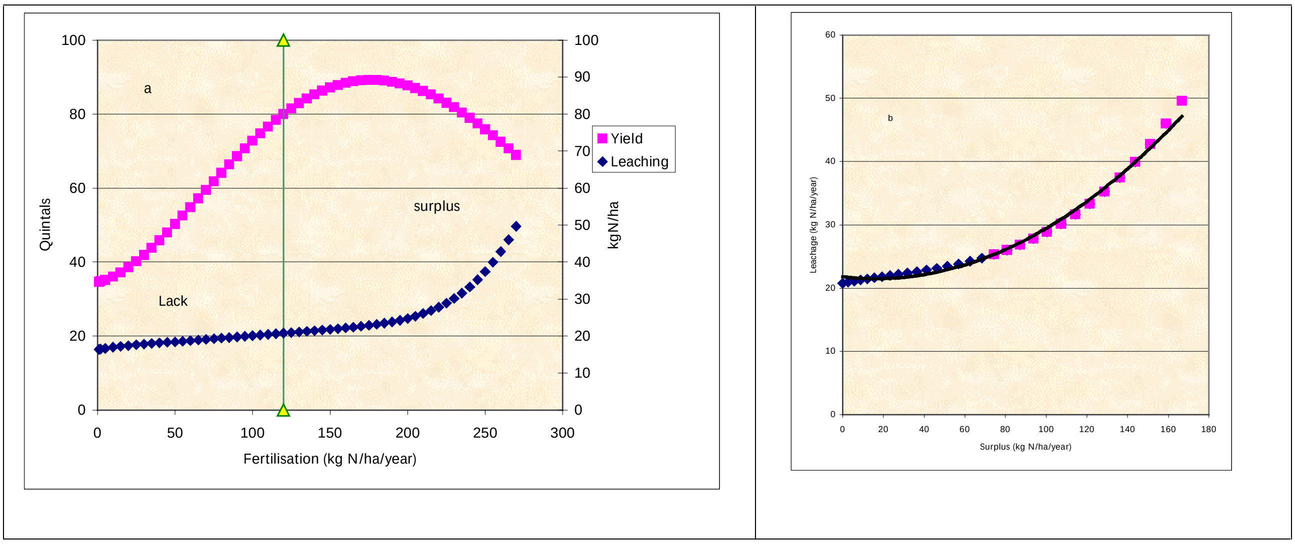
3.1. Specific case of agricultural surpluses

Agronomists use the term of ‘remainder’ to designate the nutrients present in soil at the end of the cultivation cycle. The remainder has a complex development: to enrich stock, to be mineralised and to take part in the next vegetable cycle and for a part, to be washed off by the waters. The term of surpluses is rather used to stress an accounting approach, applicable on a large scale and not claiming to agronomic representativity, even if its objective is to be an operational estimator of it. It also differs of the French concept of *structural surplus,* being used to designate those surfaces where the annual surplus of animal sources exceeds 170 kg N/ha UAA/year, concept formalised by the decree of 2 November 1993 ([2]).

In a more or less indirect way, the remainders and the nutrients stocks in the soil are the sources of the nutrients washing-off towards the waters. There is however no immediate relationship. The transfer mechanisms, i.e., in practice of effective loss, depend on numerous factors and comprise several stages in the soil, the vadose zone and the deep waters. With regard to nitrogen, the nature of the soils, its persistence or volatilisation capacities in various forms are the deciding factors (Stanners and Bourdeau, 1995, chap. 22)**.**

The final loss, that is indeed measurable by monitoring the composition of waters, can be correlated with the surplus. Schematically, and all other things being equal, the immediate loss rate are all the larger as the surplus is higher. What is true for the root area or the drainage waters, is not necessarily observed in the assessment at the level of the water-course, in consequence of the complex retention mechanisms in the later transfer stages.

Figure 2: Relations between the yield, the loss of nitrogen and the fertilisation surplus



Source of data: Ascov experimental station, Denmark (www.unifa.fr/home5/).
Method of calculating: Yields and the fertilising amounts suggest that the plant is maize, exporting therefore 1.5 kg N/quintal. Although this value is in fact dependent on the yield of cultivation, it was taken as reference. After digitalisation and adjustment of the values to polynomial curves, the above graphics were built. The agronomic surplus starts to appear at 120 kg N applied per hectare, materialised by the vertical arrow on graphic A. The harvest optimum is for 150 kg N applied per hectare. A loss, resulting from the simple fact of cultivation and of the mobilisation of the organic nitrogen of the soil exists, even in the insufficient fertilisation area. The surplus increases sharply after the yield optimum, and the associated loss grows quicker than the surplus. It is obvious that the loss curve associated with the surplus would reach a maximum, without being able to exceed the value of brought fertilisation.

According to the authors, the relationships between the actual losses and the loss mechanisms are reported to the surplus (since it is an overall concept rather easily calculable) and sometimes to the components of the soil nutrient balance (remainders, etc.) not easily measurable. Studies in lysimeters showed that the loss of nitrogen, constant for a weak

[2] 'A canton is considered being in 'structural surplus of nitrogen connected with livestock-farming' since the total quantity of livestock-farming effluents produced annually by the livestock of the canton would lead, if it were completely spread on the canton, to nitrogen inputs higher than 170 kg of nitrogen per hectare of spreadable acreage per year.' (JOURNAL OFFICIEL DE LA RÉPUBLIQUE FRANCAISE of 26/11/1993)

agricultural activity, grows then, until approaching the value of the surplus (Simon, 1995). However, in the case of nitrate an operational relationship between the surplus and the loss is even appreciated over several years, in consequence of the cycles of organisation and of mineralization of nitrogen in the soils, which are strongly under the dependence of the weather (Denys, Mariotti *et al.*, 1995; Bordenave, Bouraoui *et al.*, 1999). A quantified illustration of these relationships is reported in Figure 2.

On the other hand, the final loss rate, which includes the effect of later denitrification, can be in opposite proportion, because denitrification seems all the stronger as the surplus is larger, perhaps resulting from the simultaneous inputs of organic matter in excesses (ENSAR, 1995). Recomputing results of measurement and simulation carried out in Brittany (Abrassart, 1999; Durand, Mérot *et al.*, 1999), it comes that the overall loss rate can be represented as a linear function of the surplus, with slope 20 % to 60 % and with ordinate at the origin between 10 and 50 kg N/ha/year. These figures are very consistent with those of Figure 2; beyond a surplus of 75 kg N/ha/year, in this case, the slope is 25 %.

These final loss values are very consistent with estimates on large areas. In Northern Germany, where soils show tendencies towards hydromorphy, the loss / surpluses ratio is weak also (Behrendt, ; Behrendt and Bachor, 1999). In a recent study (BETURE-CEREC, 2000), it was shown that on the basin of the river Vilaine, the fluxes measured in rivers could not be explained by a high transfer rate, taking also into account urban and industrial inputs.
On the other hand, the hypothesis of a very high transfer rate (close to 80 %) has to be envisaged seriously when soils are scarcely or not hydromorphic and if surpluses originate from chemical fertilisation. This is the case in particular in the basin of the Loire (BETURE-CEREC, 2000) where the considerable increase in the nitrate fluxes between 1970 and 1990 is explained only by a strong transfer rate of the surpluses, taking into account urban and industrial contributions as well.

With regard to phosphorus, the retention capacity of the argilo-humic complex, more decisive than for nitrogen makes the transfer mechanism even more complex, but the existence of causality between surpluses and loss is henceforth certain (Cann, Bordenave *et al.*, 1999). In the latter case, the greatest share of phosphorus is transferred towards the waters in particulate form, simultaneously with surface erosion. The contribution of the dissolved fraction appears increasingly frequently, in proportions becoming considerable: 30 % of agricultural contributions on the German part of the basin of Elba are indicated to reach waters in this form (Bundesanstalt für Gewässerkunde, 1998).

The surplus is therefore a very important operational concept, constituting an obligatory intermediate stage in the DPSIR framework. The fundamental question is to calculate a surplus with a method that provides answers according to space and temporal appropriate distribution fitting the needs of the organisations that report on the state of the environment, since a nutrient surplus on a certain surface cannot be compensated by a lack in another surface. In addition, the final pollution of the waters can be evaluated only over a certain time, on average, in consequence of the time lags between the activities and the real transfer (Bordenave, Bouraoui *et al.*, 1999). **The result is that water pollution is in relation to all the positive surpluses over a certain period, and only to these. The method of calculating has therefore to be discriminating enough to account these in this way.**

Overall surplus calculations were presented by EUROSTAT, according to a method taking only into account the fertilizer contributions, therefore leaving aside symbiotic fixing, and based on agricultural statistics at a national scale (Joint EUROSTAT/EFTA Group, 1997b). The results of these calculations, in graphic form, were reported in the evaluation of groundwater in Europe (Scheidleder and Grath, 1999). National aggregation smoothes the surplus values for the diversified soil countries and does not make it possible therefore to connect the surpluses with an impact on the media, since the proportionality factor between loss and surpluses depends on the regional conditions. To that is added the taking into account of a lag between the generation of surplus and water pollution. Extremely variable values, reaching as much as 50 years, are suggested for the basin of Elba (Mohaupt, Bach *et al.*, 2000).

3.2. The constraints of the calculation of surpluses on a wide area

To answer in a useful way at the environmental level, a method of calculating the nutrients surpluses resulting from agricultural activities has to satisfy several seemingly contradictory constraints:

1. It has to provide sufficiently differentiated results so that the calculation of the surplus really constitutes the basis for subsequent evaluation of the risk of contamination of the waters, with a view to calculating the actually transferred share. This approach in two stages is very similar to risks evaluation methods in which the evaluation of the danger is separated of that of the exposure, to evaluate a risk. Transposed in the context of diffuse pollution, the surplus is the analogue of the danger, but, in certain cases, the transfer methods can reduce the exposure in such a proportion that the final risk is negligible.
2. It has to be adaptable to all the countries or all the areas concerned, despite the geographical differences.
3. It has to provide comparable results that can be aggregated and mapped according to several methods, (administrative and drainage basin in particular).
4. It has to require a data set as limited as possible, to allow realisation of it with an acceptable cost, without additional collection of primary data.
5. It has to allow a validation by comparison with the other sources of information.

Means of satisfying these constraints were imagined and were applied within the framework of pilot studies covering wide areas. The method used and the results obtained are presented in the following chapters.

4. Modelling the agricultural surpluses

4.1. Why model?

4.1.1. The possible methods

The surplus is the first essential stage in the knowledge of the causal chain between the agricultural activities and the final pollution of receiving waters. By definition, it is the difference between the total quantity of nutrient ([3]) entering agricultural production and the quantity exported in exit of the process. The very definition of the surplus, which is therefore an algebraic value, makes its direct measure impossible.

There are therefore only two possible approaches to quantify the surpluses: statistical approach or modelling.

A statistical approach consists in surveying all the elements of the assessment on a representative sample of farms and then to extrapolate the results to the areas for which the sample was designed. This approach gives results the precision of which is known beforehand. It poses on the other hand complex problems of survey methodology. It is expensive for large territories, which restricts its application in practical terms to limited surfaces and a goal that justifies the expenditure of the survey.

The known cases concern limited drainage basins, from a few hectares to a few hundred km^2, within the framework of an assessment of the mechanisms of agricultural contribution to water pollution. The detailed survey makes it possible to acquire essential elements of production management to elucidate the mechanisms. These studies are therefore very valuable and made it possible to validate hypotheses and calculation rules used in modelling. The justification of the working hypotheses, and in particular of the desirable resolution of surplus calculations, rested on the estimate of the phosphorus losses carried out in Brittany basins (Cann, Bordenave *et al.*, 1999) and on the assessment more centred on the losses of nitrogen on an sub-catchment contributing to the drinking water supply of the Brest agglomeration (Launay, 1997).

On broader area, the government of Eire applied a method using surveys and field measures on small sub-catchments to validate the HARP/NEUT recommendations within the framework of data provision required under the OSPAR Convention. (Kirk McKlure Morton, 1999). Secondly, this information was used for extrapolation on the totality of the studied basin, that of the Shannon river (10 600 km^2).

Contrary to the statistical approach, modelling applies immediately to the whole area under consideration. It rests for that on the mechanical expression of causalities between activities and a result. Modelling cannot therefore either free itself from the need to have high quality data, but it can compensate for the absence of some of these, given the possibility of generating the missing data by calculation.

[3] The term ‘nutrient‘ is used to designate the forms of nitrogen and of phosphorus, without taking account of their sources. The term of ‘fertilizer‘ and the related terms will be used to specify the use of nutrients with a view to allowing agricultural production.

In practice, the differences between the two approaches are not indeed so clear-cut, and each one uses as much as possible the possibilities offered by the other. The specificity of modelling is that it can have certain hypotheses to vary and to calculate the effect of these variations on the results. On the other hand, it is rather difficult to consider the accuracy of the outputs provided by modelling, while it forms the very basis for the construction of the statistical survey.

4.1.2. Types of models

The approach described in this report can appear very simplistic compared to the very sophisticated and more integrated models that are used on certain European basins. Approaches and computer codes that deal with the loss of nutrients taking into account cultivations, the types of contributions, the characteristics of the soil, meteorology, etc., are available on the market. For example, within the framework of the harmonisation HARP/OSPAR procedures, very tempting tools at the research level are proposed.

The Swedish approach (Arheimer and Brandt, 1998) aims at the final simulation of the quantities exported in the aquatic system. The model however is gauged from the measures in river, which should make the use of it delicate where dense populations are spread over the hydrographic network. However, the general approach is based on relatively simplified simulation of the catchment, more detailed specific characteristics being entered where requested. It does not seem that results of agronomic nature (nutrient balance) are calculated. The model requires however a huge database. It is operational only because this data seems available in Sweden and because of the existence of systematic modelling of the transfers in the root area.

In the same Working Group, Dutch research workers (ALTERRA Green World Research, 2000) describe a pseudo-two-dimensional N/P transfer model. It does not seem to have been applied or gauged on significant areas, and asks for a considerable set of coefficients, some ones being strongly spatialised. In addition, it is mainly directed towards the enrichment of the subsoil waters and not of the running waters.

4.2. Selected model

In addition, the dilemma to be solved is to know whether it is better to try applying a model describing as far as possible the pedological and chemical phenomena, at the risk of having to use standard values for almost all the constants, or to choose an overall assessment type model. The latter asking for only a limited number of constants and that can be gauged in comparison with more detailed work and also against independent sources. This second option was retained, while seeking however to optimise the output of the simple models already developed.

The choice of a modelling method resulted from a compromise between the constraints assigned to the results and to the availability of well-tested models. Although the calculation equations used are simple, -this involves most of the time rules of three-, the large number of elements to be calculated and the links between those can involve errors when the programmes are transcribed. The existence of results validated on small areas was therefore sought for to use them as benchmark.

Rapid exploration of the few programmes already written showed that there was none that could be directly integrated into the database designed to manage current and present applications. It is recalled that the aim is not to carry out calculations with a stand-alone programme but to incorporate the computing processes of the surpluses into an environmental information production system. The choice therefore concerned the adaptation of a model developed by the SCEES (Central Department of Statistical Surveys and Studies within the French Ministry of Agriculture) (SCEES, 1995). This model was intended initially to help the calculation of the balance sheet of fertilizers at the farm level based on the methodology by the CORPEN ([4]) (Ministère de l'Agriculture, Ministère de l'Environnement *et al.*, 1998). Initially developed to be calculable by means of a spreadsheet (SCEES, 1997), it was provided to Ifen, modified and integrated in the NOPOLU *Système 2* package used by Ifen to build the database of inland waters information and modelling.

The data necessary for calculation is limited to five sets:

1. The CORINE *Land cover* layer of land cover,
2. The administrative, hydrographical and geographical layers, according to projection compatible with CORINE *Land cover,*
3. Census type information on agriculture, according to the smallest possible administrative entity, in view of the remarks made in the next section regarding the accuracy of the data and the absence of bias resulting from survey techniques and from the application of the statistical confidentiality rules,
4. Agronomic information on actual fertilisations and yields of the crops. It would be desirable to have this detailed information within time and for small geographical areas. It is in fact available only in an overall way for large territories. Developing scenarios that allow corrections on any geographical scale mitigated this information deficit.
5. Technical coefficient sets relating to crops and livestock, unit quantity of dejections per capita of cattle, content in nutrient of the crop products, etc.

4.2.1. The core role of CORINE Land cover

The idea of using CORINE *Land cover* in order to better assess diffuse sources is not completely new. A systematic correlation test between the types of land cover and the nitrate contents of the watercourses was tried at the European scale (NERI, 1998). Results showed that this relation could not be established because causality between the losses of nitrate and the type of occupation of the land is not direct. On the other hand, this test showed that CORINE *Land cover* constitutes a powerful tool to spatialise statistics, which appeared extremely promising and in conformity with the nature of the data obtained by this geographical layer.

The carrying out of modelling of data on a large territory is necessarily the result of a compromise between the degree of detail of the calculation equations and the existence of data to be calculated. In the reported case, the specific aim of reporting the results by drainage basin had in addition to be achieved, including the assessment of the diversity of the surpluses in each surface unit of reporting.

In addition, the best homogeneous and available data on a large territory are those resulting from agriculture censuses. This data is by definition, aggregated by statistical unit of survey (in France, by commune, NUTS5). However, the application of the statistical secrecy rule results in the masking of the elements of aggregates coming from three individuals or less. For example, if only three farms of a commune breed pigs, then the total number of pigs of this commune will not appear. In addition, the geographical attachment of information is the administrative residence of the holding. In other words, if the address of the holding of a

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[4] CORPEN is acronym of *Comité d'orientation pour la réduction de la pollution des eaux par les nitrates, les phosphates et les produits phytosanitaires provenant des activités agricoles* (Steering Committee for the reduction of water pollution by Nitrates, Phosphates and Pesticides from Agricultural source, French Ministry of the Environment).

farmer is in commune A while his fields are in commune B, the crops land areas will be counted in commune A.

Consequently, and in a rather paradoxical way, the best calculation accuracy on a drainage basin will not necessarily be obtained from communal data if these are protected, but for a slightly larger aggregation unit. In practice, a method of distribution of cantonal aggregates ([5]) based on a breakdown from CORINE *Land cover* areas was developed.

The principle is simple: an agricultural activity is exerted, in certain territories, on certain types of land cover. Consequently, the cross-assignment between the activities (for example, wheat cultivation) and the types of land cover (for example, arable land) makes it possible to calculate surpluses on a reasonably fine scale, the total and distribution of which are allotted to each element of drainage basin. Obviously, this breakdown method applies only to field balances, and not at the farm level.

The geographical layer CORINE *Land cover* has therefore a double role in the overall process of calculation of the inputs from diffuse sources. It is used for calculating and distributing the surplus correctly. In a second stage, it will take part in the modulation of the transfer factors, along with other sources of information.

This process is in conformity with the recent scientific developments relating to the aggregation of data on various geographical scales (Launay, 1997).

4.2.2. Principles of the nutrient balance method

The envisaged model belongs to the type *soil-surface balances,* as opposed to the holding level assessment *'farm-gate',* according to functional classification (Joint EUROSTAT/EFTA Group, 1997a). In practice, the difference covers mainly the data to be collected for calculation.

Modelling is the calculation of balance between the inputs and the outputs of the farming system, which involves some working hypotheses:

1. One supposes farming to be in steady operation centred over a reference year, for which the technical coefficients are available,
2. It is supposed that the farming practices are adapted (proportioning, frequency of fertilisations etc.), defined according to the crops and that harvests are carried out normally.
3. The successions of mineralization/organisation of the nitrogen of the soils are not taken into account, since they are considered to balance each other in steady operation.
4. The management of the animal manure involves immediate and during storage losses which are taken into account implicitly by means of the technical coefficients. Land areas where manure spreading is possible depend on local rules, which the model should be able to take into account.

In theory, the fertilizer inputs are mainly re-exported as crops or through consumption by herbivorous animals. In the latter case, it must be considered if the fodder produced locally or from imports provides the bulk of their food. In the first case indeed, the quantities of nutrients contained in livestock waste have to be rectified to reset the balance. In the second case, mainly represented in the regions with many large livestock factory farms, animal feeding constitutes net fertilizer imports.

[5] In fact, the pseudo-canton is used, since it is a strict aggregate of communes. The true 'canton' is a pooling entity, specific to France, clustering small agricultural communes and a fraction of urban communes, not representing an actual area.

4.2.3. *The adaptation of the method to meet the constraints*

The model of the SCEES was developed for the sake of the French Ministry of Agriculture. It is therefore completely dependent on the classification used for the French agricultural census. The first adaptation therefore consisted in replacing this classification by a European provisional classification (Joint EUROSTAT/EFTA Group, 1997b)**,** to be able to deal with the data from any countries, despite a certain loss in accuracy due to a smaller number of variables taken into account. This classification has however had to be re-examined when close crops carry out economic functions with very different behaviour with respect to fertilisation. It is in particular the case of the fodder crops, for which maize forages (fertilised) was separated from lucern and other leguminous crops (not or little fertilised).

The principal adaptations were:

- To envisage external modules of conversion of national statistics, using the *ad hoc* technical coefficient sets, and which are developed where needed.
- To make the technical coefficients variable in time (change in yields, progress in animal nutrition, etc.), while sticking to the principle of steady operation.
- To make the model suitable for calculating nutrient balance and not only an assessment of the fertilizer balance.
- The inclusion of special calculation for the plants fixing nitrogen, initially this assimilation is simulated by nitrogen contribution counted separately, pending for a more complete method.
- The introduction of the phosphorus assessment, in addition to that of nitrogen. This calculation is however dependent on the availability, still imperfect, of suitable technical coefficients.
- To allow the model to function with downgraded data sets, by permitting the taking into account of default values for defined geographical aggregates. The corollary is the possibility of testing the sensitivity of the model to more detailed coefficients.
- To envisage the possibility of outputs of partial and intermediate results at several aggregation levels, in particular to compare results from different sources.

The calculation system comprises two groups of functionalities. The first comprises all the equations of calculation of the nutrients balance; the second performs the breakdowns between the CORINE *Land cover* entities, the administrative entities, the drainage basins, etc. The comparison between the land areas of a certain CORINE *Land cover* type and the crops takes into account the proportion of the surface of CORINE *Land cover* types to which certain cultivations can be affected. The values of reference, adjustable in the model, were entered according to expert judgement. They are reported in Annex 1.

4.2.4. *The system of calculation of the surpluses*

The system of calculation of the balance comprises 7 families of equations whose purpose is described hereafter. For reasons of reading facility, these equations are reported in a semi-literary form. Indeed, each one treats a number of activities: cultivation, livestock. Each activity is connected to coefficients, that are equally connected to a geographical entity and to a period. This involves a series of indexes, necessary for the calculation as such, but useless for the comprehension of the mechanism.

Equation 1: Balance Equation

The assessment is the algebraic sum of (supplies to the crops) – (exports by the crops) + (the corrected inputs from animal manure) – (outputs by grazing).

The quantities supplied by the animal manure can be corrected in the event of livestock feeding with not very productive meadows (option of the model).

Equation 2: Unitary contribution by CORINE Land cover *entity*
It is equal to the product of inputs per hectare of cultivation by the land area assigned to this cultivation.
The fertilisation supply value is adjusted according to the dual membership of the land area under consideration to an administrative unit and to a catchment, according to the fertilisation values considered in the calculation scenario.

Equation 3: Unitary output by CORINE Land cover *entity*
It is equal to the product of the land area devoted to cultivation by the yield and by the unit content in nutrient of the harvest of that cultivation.
In this model intended for calculation on a large area, the unit content of the harvest (expressed in kg quintal^{-1} for example) is assumed to be constant, whatever the yield. However, yields as well as the unit contents are adjustable for any geographical entity.

Equation 4: Nutrient production by livestock
It is equal to the product of the number of units by a specific coefficient.
The concept of livestock covers all animal products. This production is the net nutrient content of animal waste. The value of the emission coefficient takes account of several factors: type of food, duration of stay of the animals in the livestock-farming cycle, etc.

Equation 5: use of dejections as a fertilizer
Animal waste generated is assumed to be spread over in their geographical area of origin. It is considered in addition that only certain crops can receive this type of supply, and for a certain fraction of their land area. Within the framework of modelling, that amounts to imposing a geographical area (basic entities of calculation) where animal waste spread. The estimate of this land area, sometimes called 'speadable acreage' (ENSAR, 1995) could be refined taking into account the crossing of several geographical layers (Launay, 1997)**,** the distance to the rivers, to the dwellings, etc.

This method of calculating has to be improved on several points:

1. To be able to take account of the *liquid manure banks* or the spreading plans allowing transfers between geographical areas. The question did not arise in the pilot study, but it deserves examination, because this practice develops, with favourable effects on the nitrogen balance, perhaps less valid for phosphorus. It requires however rather complex data to be collected. The taking into account of the domestic and industrial sewage treatment plant land disposals of sewage sludge involves the same computing process, but also depends on data that are practically non available.
2. To be able to take account of the partial awareness of the farmers of the fertilising inputs of animal waste in their fertilisation forecast. It is recognised that animal waste are added in excess to fertilizer contribution supplied to the crops, according to complex behaviour of the farmers (Têtu, 1999)**.** However, chemical contribution is often lower than the needs, while the total chemical plus animal waste can create considerable surpluses, including structural surpluses. In the absence of sufficient knowledge of this process, it was not modelled within the framework of the pilot study.

Equation 6: taking meadows into account
Meadows constitute an individual system, insofar as they constitute a source of alternative food (with other harvested fodder) but not necessarily entirely consumed. The principle of

calculation is that the nutritive resource of cultivated fodder is exhausted initially, according to requirements of the animals aggregated over a certain land area. The complement is provided by meadows, expressed by the product of its surface and of its yield in dry matters and an equivalent content in nutrient.

If requirements were not met, areas of poor grazing grounds are considered, the nutrient content of which is lower, with for corollary the reduction in the animal excrement load. Meadows are in addition included in the land areas on which animal waste spreading takes place.

Ploughing meadows, which causes considerable mineralization and can involve considerable peaks of losses of fertilizers, was not modelled, in the absence of rules and especially in the absence of data. This is an element of local under-assessment of the surpluses likely to contribute to water pollution.

4.2.5. The breakdown of the results

The principle of the breakdown of the results is very simple, but its implementation becomes quickly complex in details, because of the very large number of overlaps between the administrative, hydrological surfaces and land cover entities.

All surplus calculations are first made at the level of the smallest entity of collection of census information. In the case of the pilot study, it is therefore the pseudo-canton. These calculations are obviously led by reallocating all the figures by relevant CORINE *Land cover* entity.

From this basis for calculation, all the required reassignments are carried out. That can lead during an intermediate stage to calculating administrative entities smaller than the collection entity. This method was adopted to make the calculation procedure independent of the source data level. However, for obvious reasons for relevance of the produced results, logical bolts are placed in order to permit only result output for aggregations consistent with the basic data. The administrator of application can raise these bolts.

It is possible to carry out aggregations of results for levels non-relevant with respect to environmental pressure, but for which comparison data exists. In particular, this is the case for the statistics of departmental sales of artificial fertilizers that are examined in a later section. The totality of the calculation system was established as a component of the Ifen's workshop database on inland waters, developed within the framework of the NOPOLU *Système 2* software. This workshop database makes it possible to carry out the necessary connections with other elements of use or comparison with the results of the surplus calculation model: integrated assessment of the emissions discharged to water, calculation of nutrient fluxes conveyed by water-courses, to mention only the modules having direct relationships with the surplus calculation.

5. Calculation of the nitrogen surpluses in the basins of the Elba and the Loire

5.1. Sources of data of both test basins

5.1.1. The Loire-Bretagne Water Agency district

The first selected basin is the Loire-Bretagne Water Agency district, which covers 156 217 km^2 and concerns three major hydrographical entities: the drainage basin of the Loire and the tributaries of its estuary (118 054 km^2), the Brittany basins (29 533 km^2) and the coastal basins of the south of the Loire ('Vendée', 8 630 km^2). All these basins are located in France. The Brittany basins were the subject of previous calculation of the surpluses on a communal basis with the assistance of the statistical services of the Ministry of Agriculture (ENSAR, 1995)**.** The results were therefore used as a validation of the calculation procedures, knowing that discrepancies between the figures are normal, in view of the differences in method and in level of aggregation of the data used.

The CORINE *Land cover* layer is obviously available at Ifen, which was in charge of its production for France.

The administrative and hydrological layers are available in France on a common projection carried out by the National Geographical Institute (IGN). The smallest limits of drainage basins of the data base CARTHAGE (RNDE, 1997) are sets of coding entities of elementary drainage basins, named 'hydrographical zones '. They are 6315 for the whole of France, at the time of update of the layer used. The study territory comprises 1402 zones. In a later stage, they were aggregated in 299 *sub-sectors*, according to the CARTHAGE terminology.

For its own sake, Ifen carried out a systematic crossing of the three geographical layers referred to above. This crossing produced a quantified database, comprising 46 fields: code of the commune (NUTS5), codes of the hydrographical area, land areas of the 43 CORINE *Land cover* land types in the intersection, and sum as a control. This base is named HYDROSOL. The data of agricultural use comes from the last agricultural census (RGA), which unfortunately dates back to 1988. The next is scheduled for the autumn 2000. Therefore, no data that are more recent are available for a large area. The data used is the pseudo-cantonal data, already mentioned in the section dealing with methodology. The total values of the agricultural activity were recomputed according to the European classification used for the 1379 pseudo-cantons of the departments of the studied area. In a second stage, a clustering in 103 entities was done, for the purpose of comparison with the calculations carried out on the basin of Elba.

This European classification defines the animals in number of heads, grouped by categories (for example; equidae). By contrast, the RGA gives results according to variable units depending on production. Cattle are counted in number of heads, rabbits as number of cages, certain poultry by occupied surface and the butchery pigs as places.

All the values were aggregated and homogenised after transformation into the number of equivalent individuals on an annual basis. This was done by multiplying an **equivalence coefficient** (for example a donkey is worth 0.5; a saddle horse is worth 1 and one draught horse is worth 1.5 'equivalent-horse'), by a **presence coefficient,** expressing the fraction of the time of presence of the animal, and by a **density coefficient,** to replace the surfaces or the cages by number of individuals. Systematic calculation is possible, the neutral values of the last two coefficients being one. Results are summarised in the following table.

Table 3: Overall statistics of the agricultural activities on the three sub-catchments of the Loire-Bretagne Water Agency district

Group of activities (European nomenclature)	Unit	Sub-catchment			Total
		Loire	Brittany	South-Loire	
Crops					
Cereals (off maize) (D/01-D/05)	ha	1 672 143	374 147	137 322	2 183 612
Maize (D/06)	ha	477 263	99 165	46 938	623 366
Other cereals (D/07 D/08)	ha	43 331	10 462	1 949	55 742
Unfertilized fodder (D/09/a,D/18/b2)	ha	189 328	35 453	32 081	256 862
Other fodder plants (D/O9/b, D/18,D/18/b,D/18/b2, D/12)	ha	590 072	437 514	128 542	1 156 128
Root crops (D/10, D/11)	ha	22 531	17 816	158	40 505
Industrial crops (D/13/a-D/13/d,D/13/d3 et 31,D/19, D/20)	ha	5 025	669	514	6 208
Oil seeds (D/13/d1-D/13/d2)	ha	543 587	38 069	74 108	655 764
Fruits and vegetables (D/14-D/17)	ha	42 813	122 897	2 367	168 077
Temporary meadoxs (D/18/a)	ha	783 646	523 187	70 786	1 377 619
Permanent meadows (F)	ha	2 915 823	318 588	141 198	3 375 609
permanent crops (G/01-G/03/b)	ha	44 606	5 861	1 803	52 270
Vineyards (G/04-G/04/d)	ha	68 851	8	2 755	71 614
Other permanent crops (G/06, G/07)	ha				
TOTAL		*7 399 019*	*1 983 836*	*640 521*	*10 023 376*
Livestock					
Equidae (Horse Equivalent) (J/01)	Horse-Eq	89 537	20 777	5 416	115 730
Bovines (BCE) (J/02-J/08)	Bovine-Eq	4 156 622	1 896 512	414 816	6 467 949
Ovines, goats (J/09-J/10/b)	Ovine-Eq	3 839 599	189 222	216 220	4 245 042
Pigs ((Eq butchery pig)	Pig-Eq	6 024 867	20 229 357	484 205	26 738 429
Poultry (Eq laying hen)	Poultry-Eq	30 422 575	51 863 817	4 295 244	86 581 637
Other small animals (Eq other)	Other-Eq	414 803	181 301	57 450	653 554

Source: Ifen/BETURE-CEREC. Basic data, Ministère de l'Agriculture et de la Pêche, RGA 1988.

5.1.2. Basin of Elba

The basin of Elba drains a total land area of 147 635 km^2. The largest part, downstream, (65.4 %) is in Germany. The upstream part is very unequally distributed between the Czech Republic, 34.2 % and Austria that owns only 0.4 % of the basin. The latter part, which moreover is covered mainly by forests, was neglected in the study.

Part located in Germany

The collection of the German data was led jointly by the *'Projektgruppe Elbe-Ökologie'* ([6]) and by the Federal Statistics Office (*Umweltbundesamt),* respectively with Dr. Dirck Börnhoëft's and Mr Albrecht Wirthmann's assistance.

The CORINE *Land cover* data was provided by the German Federal Statistics Office. Within the rather short time of the study, only data more aggregated than the data used in France could be obtained, corresponding at the NUTS3 level and to the year 1995 census. The administrative layer comprises 138 entities, whilst the hydrographical layer comprises 290 of it. The structure of the statistical data provided is very different from those of the French RGA. It comprises 37 variables, of which 14 do not concern agricultural activities. It was necessary to add 5 variables, calculated from the 23 above, after validation by the data supplier. The technical coefficients published by EUROSTAT for Germany were used initially (Joint EUROSTAT/EFTA Group, 1997b).

6 At the end of 1998, this group was hosted by the Federal Office for Inland Waters (Bundesanstalt für Gewässerkunde), Schnellerstraße 140, 12439, Berlin.

Czech data
Except for the administrative layer, bought to the MEGRIN organisation, and comprising 56 units, all the Czech data was gathered and prepared by the PHARE Topic Link ([7]), in particular the 104 drainage basins.
The use of the CORINE layer *Land cover* posed specific problems, due to the absence of polygons for the type 211 (non-irrigated arable land). Consequently, the later 'HYDROSOL' type crossings (c.f., page 24) have had to be partly carried out manually.

The agricultural census data comprises 24 variables relating to the crops and 4 variables of livestock, therefore already strongly aggregated. They were corrected, and transformed according to the European classification, whenever possible.

Synthesis of agricultural statistics

Table 4: Overall statistics of the agricultural activities on the two countries concerned by the basin of Elba

Group of activities (European nomenclature)	Unit	Germany	Czech rep.	Total
Crops				
Cereals (off maize) (D/01-D/05)	ha	3.767.427	1.109.273	4.876.700
Maize (D/06)	ha	56.456	11.722	68.178
Other cereals (D/07 D/08)	ha	252.235	16.554	268.789
Unfertilized fodder (D/09/a,D/18/b2)	ha	1.040.566	299.512	1.340.077
Other fodder plants (D/O9/b, D/18,D/18/b,D/18/b2, D/12)	ha			
Root crops (D/10, D/11)	ha	468.728	107.412	576.140
Industrial crops (D/13/a-D/13/d,D/13/d3 et 31,D/19, D/20)	ha	943.420	354.739	1.298.159
Oil seeds (D/13/d1-D/13/d2)	ha			
Fruits and vegetables (D/14-D/17)	ha	122.097	18.555	140.652
Temporary meadoxs (D/18/a)	ha	204.668	309.349	514.018
Permanent meadows (F)	ha	2.449.485	727.216	3.176.701
permanent crops (G/01-G/03/b)	ha		32.840	32.840
Vineyards (G/04-G/04/d)	ha	1.598	634	2.232
Other permanent crops (G/06, G/07)	ha			0
TOTAL		9.306.681	2.987.806	12.294.487
Livestock				
Equidae (Horse Equivalent) (J/01)	Horse-Eq			0
Bovines (BCE) (J/02-J/08)	Bovine-Eq	7.171.104	1.245.454	8.416.558
Ovines, goats (J/09-J/10/b)	Ovine-Eq	1.385.828	68.269	1.454.097
Pigs ((Eq butchery pig)	Pig-Eq	7.787.310	2.573.609	10.360.919
Poultry (Eq laying hen)	Poultry-Eq	13.065.121	19.884.904	32.950.025
Other small animals (Eq other)	Other-Eq			0

Source: Ifen/BETURE-CEREC. Basic data, Umweltbundesamt, PHARE Topic Link/CLC. Data was aggregated (greyed plainly) or is missing (greyed dark).

It must be pointed out that, by contrast with Table 3, certain boxes were aggregated, in the absence of detailed data and that some others are not filled, no piece of data being available. An unexpected difficulty was in the considerable discontinuities of hydrographical divisions between Germany and the Czech Republic. In particular, the sub-catchments intersected by the border Germany - Czech Republic all are contained in a single basin on the Czech side. An individual procedure of breakdown of the results has had to be applied.

5.1.3. General comment on the agricultural data

The respective agriculture of both basins present great differences: more cattle on the Elba side, more pigs and poultry, especially concentrated in Brittany, for the Loire-Bretagne Water Agency district, as shown in the comparative graph below.

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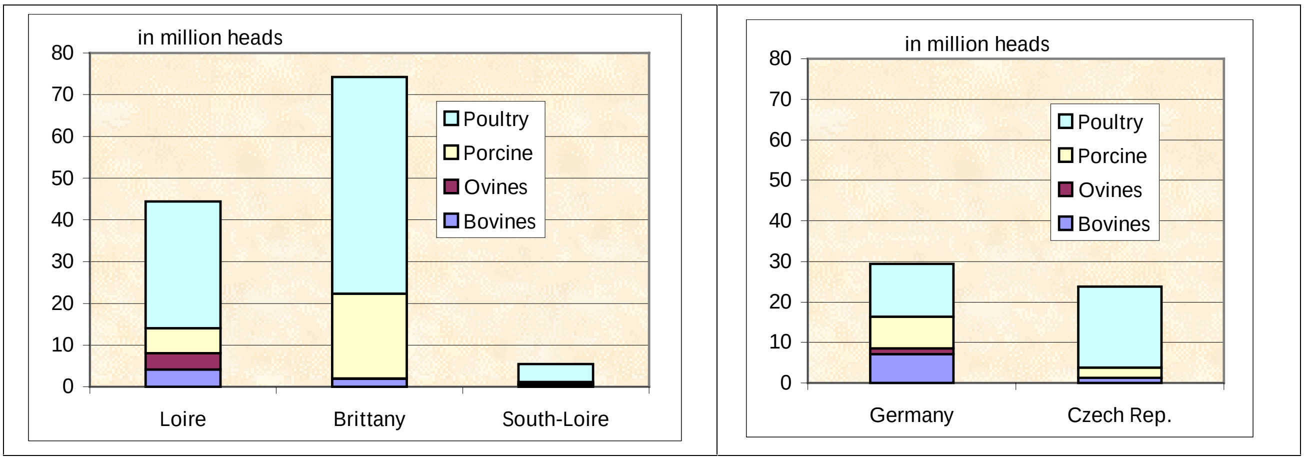
[7] 'Phare Topic Links' are groups of experts and organisations devoted to common work with the European Topic Centres and that aim to the progressive integration of accession countries to EEA works. About PHARE, see http://europa.eu.int/comm/enlargement/pas/phare/index.htm

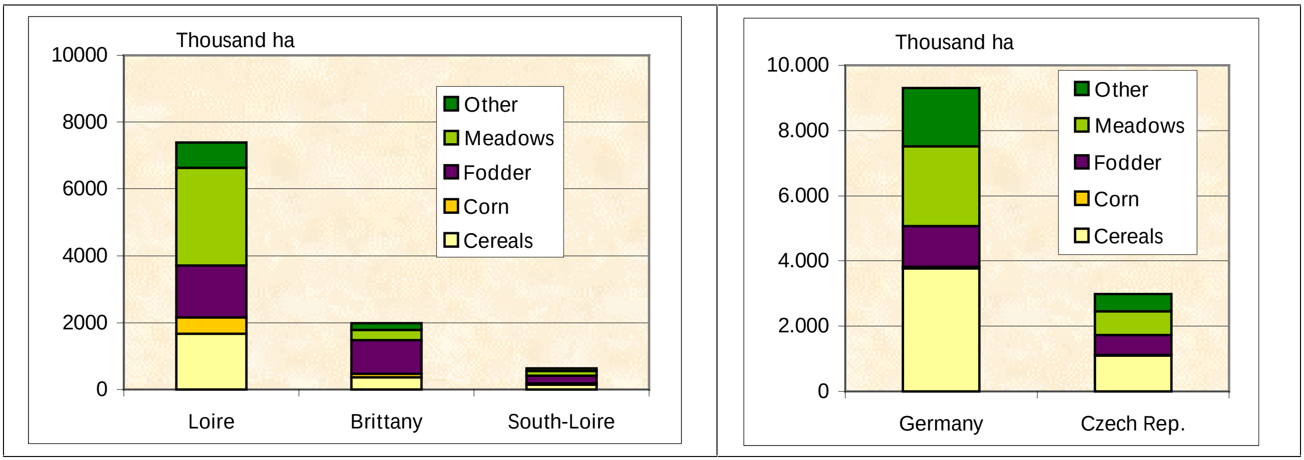
Figure 3: Histograms of distribution of the animal products on the Loire-Brittany basins and Elba



Source: EEA on Ifen/BETURE-CEREC. Livestock names are those of Eurostat nomenclature.

On the other hand, the distribution of the field crops shows a preponderance of cereals in the Elba basin. On the French basins, meadows are in a majority on the basin of the Loire, but the share of the fodder crops (including temporary meadows) is much more marked than on the basin of Elba.

Figure 4: Histograms of distribution of the crop products on the Loire-Brittany basins and Elba



Source: EEA on Ifen/BETURE-CEREC

One can therefore expect regular distribution of moderate nutrient surpluses on the basin of Elba, and small islands of strong surpluses, as well as sectors in apparent deficit on the Loire-Bretagne Water Agency district, as consequence of the presence of a large number of animals and broad areas of permanent meadow land as well.

5.1.4. Statistics on the geographical entities calculated

The geographical layers available in France being more detailed than those available for Germany and the Czech Republic at the time of the study, later regroupings could be carried out so as to make a study of the sensitivity and robustness of the modelling method. These basic figures are given in the table below.

Table 5: Indication of the complete number of administrative intersections and drainage basin taken into account in the various scenarios

AELB	Area (ha)	# Hydrographic zones (ZH)	# Communes (CM)	# intersections ZH-CM	# Sub-sectors (SS)	# Cantons (CT)	# "Arrondis-sements" (AR)	# intersections SS-CT	# intersections SS-AR
Brittany	2 971 442	306	1 383	3 322	87	217	24	645	206
Loire river basin	11 769 888	1 022	5 940	14 085	183	767	90	2 022	606
South Loire	865 669	74	454	947	29	64	11	177	65
Total	*15 606 999*	*1 402*	*7 628*	*18 354*	*299*	*996*	*105*	*2 844*	*877*

Light shading : Total <> Sum (administrative entities laying over two catchments)

ELBE	Area (ha)				# Catchments ("SS")		# Nuts2 ("AR")		# intersections "SS"-"AR"
Germany	9 756 548				290		138		900
Czech Rep.	4 986 985				104		56		333
Total	*14 743 533*				*353*		*194*		*1.233*

Dark shading: Total <> Sum (hydrographic entities laying over two countries)

Source: Ifen/BETURE-CEREC

It is seen therefore that the minimum intersection that can be processed in France has an average land area of 8.5 km^2, whilst the intersection between canton and sub-sector, corresponding to the agricultural data available has an average land area of 54,9 km^2. On the side of the basin of Elba, the intersections have an average land area of 119.6 km^2, intermediate between the canton / sub-sector and 'arrondissement' / sub-sector intersections, which average land area is 178 km^2.

The spatialisation of statistics by means of CORINE *Land cover,* applied to the drainage basins results in practice in calculating each canton in three subsets (respective average land areas of 156.7 and 54.9 km^2) and in apportioning the districts into 8 subsets (respectively 1486 and 178 km^2). It will be seen, in the section devoted to the sensitivity analysis that this contribution is quite real and does not consist of a spurious information gain.

5.2. Results on the Loire-Bretagne Water Agency district

5.2.1. Validation of the model (Scenario 1)

The calculations previously mentioned for Brittany (ENSAR, 1995) were carried out by using a rather different procedure, the outstanding points of which are as follows. First, no assignment of the crops by means of a layer of the land cover was made. Second, drainage basins used to apportion the surpluses were calculated with a digital elevation model (DEM /MNT), which outputs homogeneous elementary drainage basins.

The most outstanding differences are however in the taking into account of fertilisation. The work undertaken in Brittany was based on the hypothesis of uniform mineral fertilisation of all the crops with 114 kg N ha UAA^{-1} year^{-1} (within the acceptation of the RGA 1988), which is drawn from average fertilizer sales. To these fertilisations are added those provided by the animal manure, applied to a 'spreadable UAA acreage', calculated especially for the study. The yield values and the technical coefficients used are not mentioned in the publication. On the other hand, the statistics used are communal data (perhaps non censored). Consequently, this only available study cannot be regarded as a basis for calibrating the model.

The results published are by surplus classes, and so the only comparison, whose objective, let it be recalled, is to check the performance of the calculation program and not the correctness of the results, dealt with the distribution of the surplus class.

Model calculations (assumed to be ‘scenario 1’) give surpluses, on average, higher by 30 kg N ha^{-1} $year^{-1}$, value calculated from the medians of classes. Reference calculations having been made with a uniform value of 114 kg N ha^{-1} $year^{-1}$ for mineral fertilisation, the findings are that the technical coefficients used from the CORPEN (Ministère de l'Agriculture, Ministère de l'Environnement *et al.*, 1992; Ministère de l'Agriculture, Ministère de l'Environnement *et al.*, 1998) and from EUROSTAT (Joint EUROSTAT/EFTA Group, 1997b) give higher results. The geographical distribution of the surpluses is identical, thus allowing considering that the calculation program functioned correctly. The validity of the coefficients and the results has however to come from the use of the scenarios and from comparisons with measurements of actual contents in the natural environments.

5.2.2. *The calculation scenarios*

The correctness of the value of the calculated surplus depends mainly on the correctness of the three fundamental parameters of the assessment equations, namely the quantities of fertilisation supplied as fertilizers and as animal manure, the yield of the crops and finally the contents of the harvests in nutrients. This data is never available with a sufficient level of detail; they are even approximate at the level of a whole country.

Consequently, the only manner of correctly approaching the balances is to calculate scenarios taking account of agronomic knowledge, the local practices, etc. The values input in the scenarios can always be improved by surveys next to the various agricultural advisers and by exploiting literature. Within the very limited temporal and financial framework of the pilot project, only the values compiled by specialised organisations were retained to calculate two basic scenarios in addition to that of the software validation. The compilation of the data concerning phosphorus is underway at the time of writing of this report. Other scenarios were calculated, but they cover only different space aggregates. Fundamentally, only two calculation scenarios therefore exist.

– Scenario 2: Calculation of nitrogen without symbiotic fixing
This scenario comprises a fertilisation value adjusted for each cultivation, according to the agronomic recommendations compiled by the CORPEN (Ministère de l'Agriculture, Ministère de l'Environnement *et al.*, 1992; Ministère de l'Agriculture, Ministère de l'Environnement *et al.*, 1998). The symbiotic fixing plant crops are not fertilised.
The detailed values of the technical coefficients are reported in Annex 2.

– Scenario 3: taking into account the symbiotic fixing of nitrogen

For the crops comprising plants capable of symbiotic fixing of atmospheric nitrogen, a value of 90 kg N ha^{-1} $year^{-1}$ was retained. It was also considered that these crops were not fertilised, contrary to a practice that develops, but which seems to have been anecdotic for the 1988 census year. The detailed values of the technical coefficients are also reported in Annex 2.

5.2.3. *Results in terms of nitrogen surplus*

The calculation was carried out over all the departments (NUTS3) concerned, since a Water agency district intersects departmental borders. Results were then aggregated by hydrographical sub-sectors. Only the results of the scenario including symbiotic fixing seem consistent with what is known of field reality. The taking into consideration of the large areas of leguminous crops has indeed a considerable impact on the value of the result ([8]). It is calculated by separating the areas of surpluses from the deficit areas (within the meaning of

[8] It is specified on this occasion that the apparent precision of the figures does not have to make illusion. Those are provided with details only to prevent the reader from having problems with round-offs in the tables. The results of synthesis are always given rounded.

the model) because deficit sectors do not compensate for sectors in surpluses. It is interesting however to present both results so as to show the differences between them.

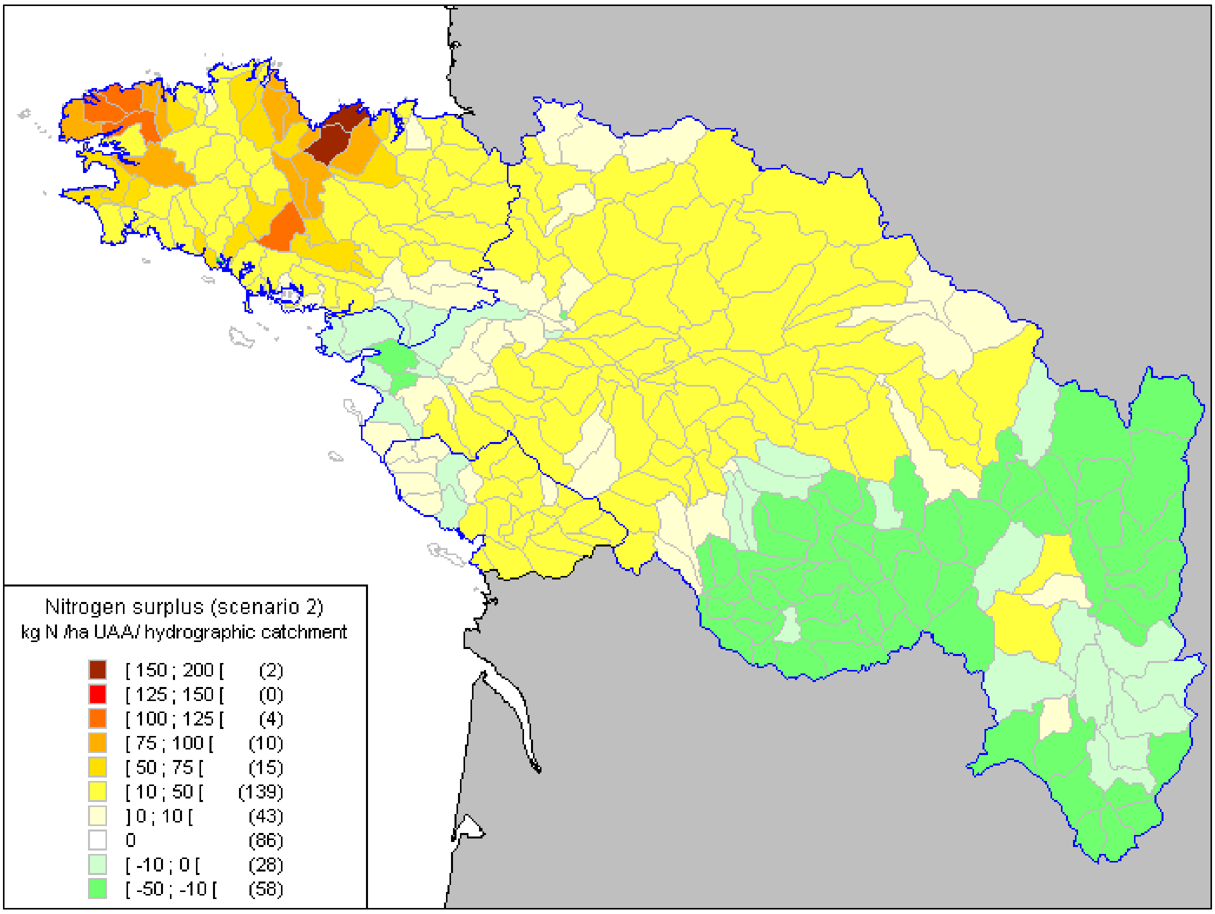
Table 6: Aggregated results relating to scenario 2 (without symbiotic fixing). Results for an average year with practices of 1990 approximately.

	Total surplus Tons N	Area with surplus ha	Average surplus kg/ha/year	Total of deficiencies Tons N	Areas with deficiencies ha
Loire river basin	83 955	4 670 441	18	47 866	3 042 703
Brittany	99 585	2 022 305	49	199	55 944
South-Loire	6 890	531 217	13	1283	299 872
TOTAL	190 430	7 223 963	26	49 348	3 398 519

Source: Ifen and BETURE-CEREC, 1998

This scenario leads to exaggerating deficits, which appears quite unlikely. One of the causes is the optimistic estimate of the productivity of the pastures, in the upstream part of the basin of the Loire, but especially the non-taking into consideration of symbiotic fixing.

Figure 5: Geographical distribution of the average nitrogen surplus per hectare, according to scenario 2



Source: Redrawn from Ifen and BETURE-CEREC, 1998.

The application of scenario 3 distinctly changes the appearance of and corresponding results. The most important effect is the dramatic drop of the extent and the value of the total of the apparent deficit in nitrogen. Indeed, the taking into account of the symbiotic fixing, which concerns mainly crops grown on the basin of the Loire, adds to it 90 634 tonnes of nitrogen to the general assessment. However, the total of the surpluses increases there only by 60 720 tonnes ([9]). This scenario circumscribes the deficit sectors only to those regions where pasture is the main farming.

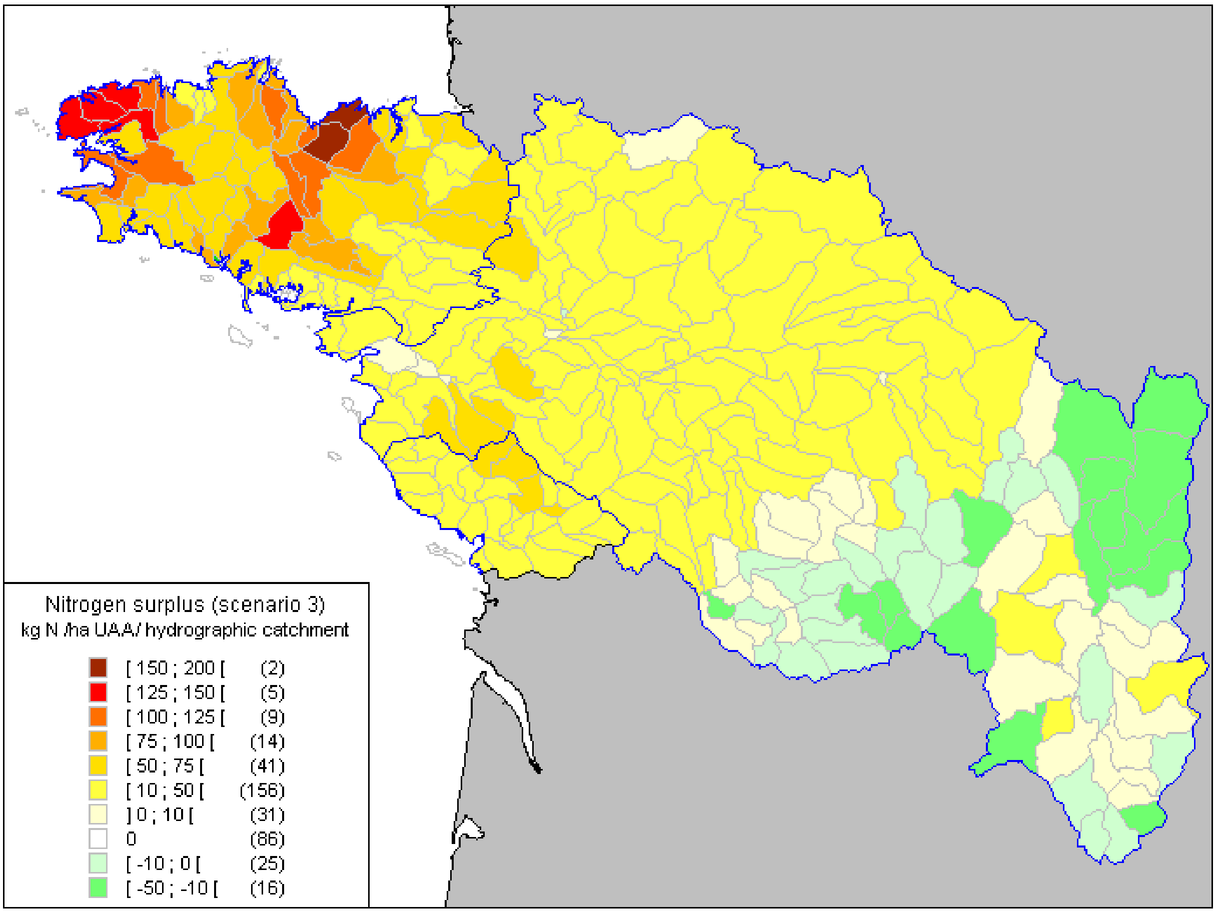
The results and the comparisons with Table 6 are reported in the table below.

Table 7: Aggregated results relating to scenario 3 (with symbiotic fixing). Results for an average year with practices of 1990 approximately

	Total surplus Tons N	Area with surplus ha	Average surplus kg/ha/year	Total of deficiencies Tons N	Areas with deficiencies ha
Loire river basin	144 675	5 915 275	24	17 952	1 797 870
Brittany	157 299	2 077 393	76	85	857
South-Loire	23 544	831 090	35	0	0
TOTAL	325 518	8 823 758	37	18 037	1 798 727

Source: Ifen and BETURE-CEREC, 1998.

Figure 6: Geographical distribution of the average nitrogenous surpluses per hectare, according to the scenario 3



Source: Redrawn from Ifen and BETURE-CEREC, 1998.

One points out that Brittany, numerous sectors of which are considered in structural surpluses, generates a surplus virtually equal to that of the basin of the Loire, about 150 000

[9] The increase in the surpluses is equal to 144 675–83 955, that is 60 720, but the total assessment difference is this difference increased by the reduction in the deficits, saying 47 866–17 952, i.e., 29 914, i.e. 60 720 + 29 914 = 90 634.

tons of nitrogen per year each one. The total for the Loire-Bretagne Water Agency district is therefore approximately 320 000 tonnes of nitrogen per year, for an average year centred over 1990.

The surplus is only the difference between the input and output quantities of the farming system. Summing the various items makes it possible to quantify the percentage of surpluses, as calculated by scenario 3, with those items.

Table 8: Assessment of the input-outputs for the Loire-Bretagne Water Agency district (scénario3)

All figures in thousand T N/year	Loire basin	Brittany	South-Loire	Total
Total chemical fertilisers	565	157	54	776
Total inputs from symbiotic fixing	94	58	15	166
Total animal waste	279	176	27	481
Sub total	*938*	*391*	*95*	*1 423*
Total outputs	811	233	71	1 115
Raw balance (algebraeic input-output)	127	157	24	308
Net balance (sum of positive surplus)	154	167	24	345
in % of input	*16%*	*43%*	*25%*	*24%*
in % of outputs	*19%*	*72%*	*34%*	*31%*

Source: (Ifen and BETURE-CEREC, 1998)

The figures of this table show that where the vegetable crops are the majority, the surplus rate (here 16 %) is very close to the high value of the average considered on a pan-European scale (cf. page 8). By contrast, in the areas receiving a great deal of nutrient inputs from livestock sources, the surplus seems more marked, reaching 43 % of total nutrient input in Brittany.

5.2.4. Comparison with nitrate fertilizer sales

The sales of artificial fertilizer constitute the only source of independent information the figures of which can be useful to tally with the estimates of the model. These fertilizers constitute in addition an important source of nutrients, or even the majority contribution where livestock is not very numerous. Fertilizer sales in addition being published in the form of departmental statistics, aggregation at this level was calculated. As the limits of a Water Agency district intersect the departmental limits, maps and calculations concern therefore the total land area of the departments concerned, thus allowing a comparison on identical basis. With regard to sales, only the statistics of 1990 could be obtained.

Figure 7: Comparison between nitrate fertilizer sales and the calculated surpluses.

Figure 7–a: Raw values by department (in kg N/ha/year)

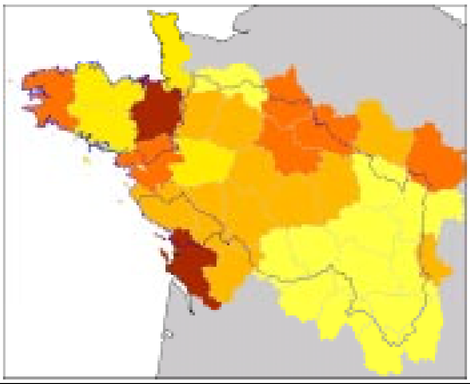
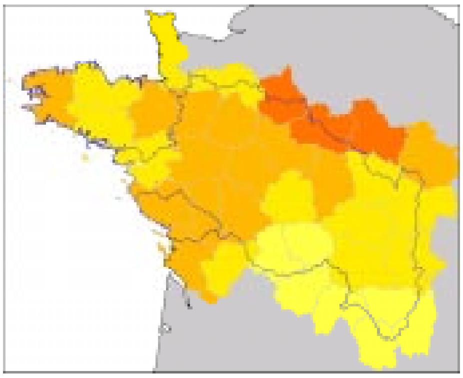
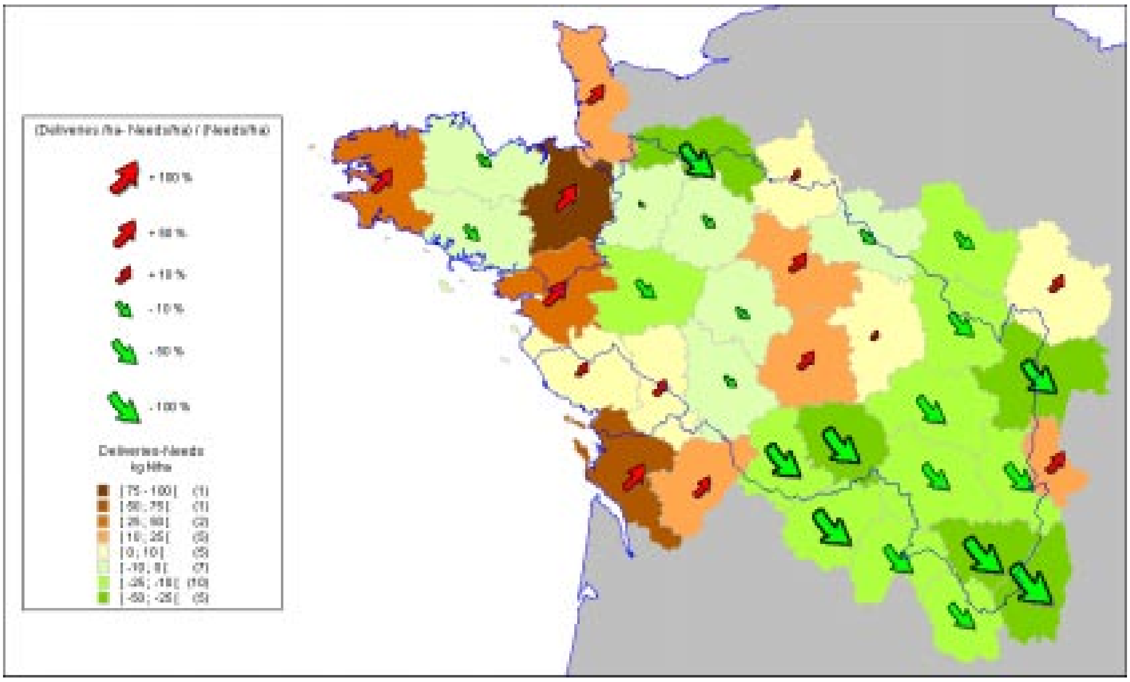
Department sales (1990)	**Nitrogen needs (scenario3)**	**Legend**
		kg N/ha SAU 150 - 200 125 - 150 100 - 125 75 - 100 50 - 75 10 - 50 0 - 10

Figure 7–b: Differences between the reported deliveries and the needs, calculated per hectare of UAA



Source: Redrawn from (Ifen and BETURE-CEREC, 1998).

The above figures show a seemingly paradoxical situation. It is in the parts where surpluses are the highest that very strong apparent over-fertilising would result from the taking into account of the sales of fertilizers instead of the agronomic criterion. Three departments are particularly exemplary from this point of view: the Ille et Vilaine, Loire-Atlantique and the Charente-Maritime. It is in these three departments that commercial harbours are located where fertilizers forward, namely Saint-Malo, Nantes and La Rochelle. It is therefore highly probable that bias connected with the geographical position of the trade company headquarter affect apparent fertilizer sales, used as an indicator of the department of use, in the absence of more precise data. The case of the Finistère is slightly more complex, even if a good part of animal feed is imported via the harbour of Brest, but this piece of data is not taken into account in the model.

These results confirm that modelling based on agronomy rather than on sales statistics is justified. The latter should however be used to validate the values considered by the model. This validation involves being able to have an identical perimeter of aggregation. The limited surface of the calculations presented here even does not make it possible to envisage the regional scale (NUTS2).

5.2.5. Contribution of the surpluses to the fluxes monitored in the downstream part of the water-courses

The nutrients transported by the watercourses result from direct inputs from the cities and industries and from non-registered inputs, of which diffuse inputs from agricultural sources account for the main share.

Two methodological developments were tested on a pilot basis on the Loire-Bretagne Water Agency district, covering respectively the calculation of nutrient fluxes at the mouth of the rivers and the assessment of nutrient emissions, all sources taken together.

Two results are presented, for the Loire and the Vilaine in the following table.

Table 9: Nutrients inputs and fluxes measured on the basins of the Loire and the Vilaine rivers

All figures are in thousand Tons N	Vilaine	Loire
Net surplus	46,3	130,0
Retention hypothesis	70%	30%
Non-point agricultural inputs (net surplus *(1-retention))	13,9	91,0
Other non-point sources	1,0	9,2
Direct emissions (urban and industrial)	1,8	26,0
Total of emissions to rivers	16,7	126,2
Calculated flux (interannual average)		
Inorganic nitrogen	14,9	87,0
Organic nitrogen	1,9	44,2
Total flux	16,8	131,2
	Hypothesis of strong retention, according to local surveys	*Hypothesis of weak retention, according to local surveys and soil types*

Source: Compilation of results of two study reports to be released, carried out by BETURE CEREC on behalf of the Loire-Bretagne Water Agency and Ifen.

The calculation of fluxes constitutes an absolute reference for assessing inputs from any source. Obviously, these inputs are not found in an accounter's way in measured fluxes. In the watercourses system, nutrients are stored (especially phosphorus), or disappear (especially nitrogen). On average over a few years, the good orders of magnitude are expected, taking into account the transfer factors for the nutrients from diffuse sources, the numerical values of which are very dependingt on the types of soils, on moisture, etc.

5.3. Results on the basin of Elba

5.3.1. Scenarios used

The data available on the basin of Elba, in its entirety, are more aggregated than those available in France are. Moreover, the technical coefficients proposed for Germany according to EUROSTAT's compilation (Joint EUROSTAT/EFTA Group, 1997b) have numerical values notably different from those used up to now, in particular with regard to the fodder needs of livestock and the productivity of the grazing grounds. The direct application of these figures leads to very unlikely results. In this case indeed, 65 % of the basin would have an average deficit of 31.7 kg N ha^{-1} year^{-1}, which does not correspond to the data of the bibliography, or just to the common sense.

To distinguish the calculations of those carried out on the French part, individual scenarios were constituted, on the basis of scenarios 2 and 3. They are numbered '7', consisting in aggregating the equivalents-animal on the whole basin (for the purposes of sensitivity test), '8', by taking the EUROSTAT technical coefficients and '9', in which the technical coefficients relating to fodder and to animal feed were corrected, in view of the results of the scenario 8.

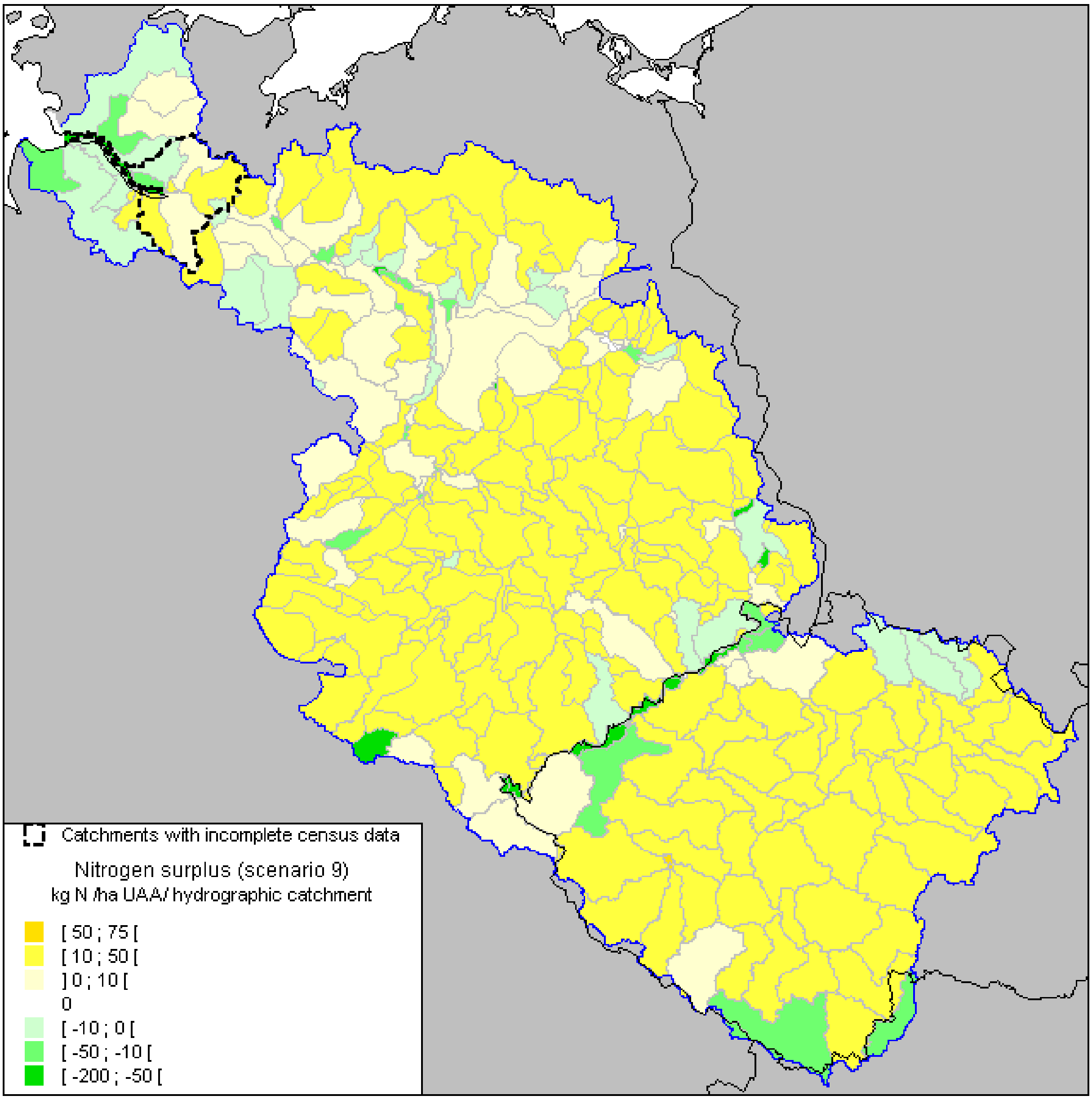
5.3.2. Results

According to the first scenario used ('scenario 7'), the overall surplus of the German part is 96 116 tons. The total agricultural land area is 4 754 535 ha, which gives an average surplus 20.2 kg N ha^{-1} year^{-1}. This value, as well as that calculated with scenario 9 (17.6 N ha^{-1} year^{-1}) is very close to that calculated on a comparable basin, that of the Loire (25.8 kg N ha^{-1} year^{-1}, using the same set of coefficients).

A critical analysis of the various coefficients, tested in several complementary scenarios, leads to propose results consistent with the German publications. The studies undertaken on the German part of Elba, by using modelling of nitrogen in the root zone area, give a figure of 109 000 t N year^{-1} (Bundesanstalt für Gewässerkunde, 1998)**.** This figure, 12 % higher than our calculations, does not contradict them. It leads us, on the contrary to completely reject the hypotheses of scenario 8. Additional information on the joint existence of significant contamination of the waters of Elba by nitrate from agricultural sources, and of large denitrification in soils (Berhendt and Optitz, 1999)**,** also leads us to admit the existence of a sufficient surplus to fuel this contamination despite the reduction performed by natural denitrification. The sources of the constants of this scenario, known as 'scenario 9', are reported in Annex 4. The scenario 9 is a composite of the scenarios 7 (coefficients relating to fodder and to the meadows) and 8 (all the others).

The same constant values were taken for the Czech part of the basin of Elba, for which no individual piece of data was obtained.

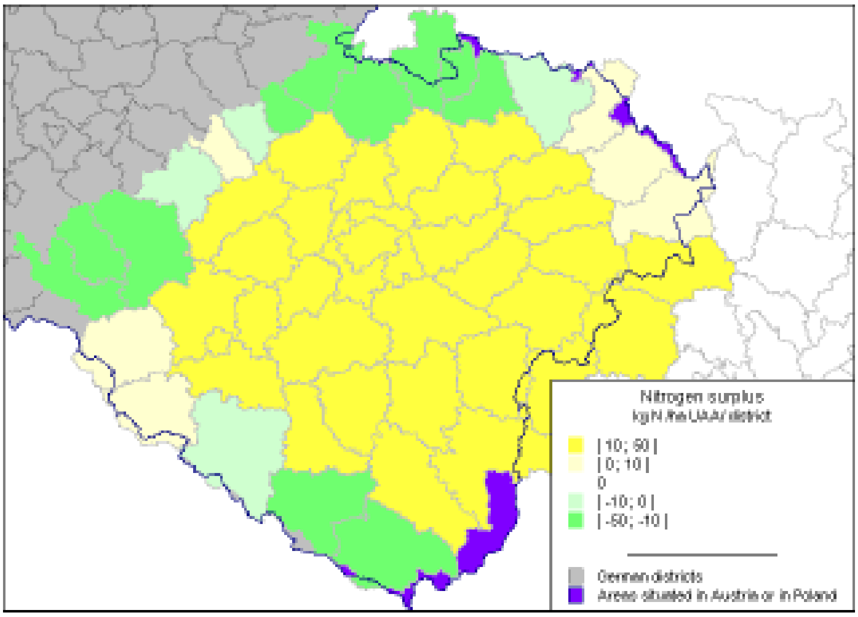
Figure 8: Results on the German and Czech parts of the basin of Elba, by drainage basin 'scenario 9'



Source: Redrawn from Ifen and BETURE-CEREC, 1998.

In the case of the Czech part, result proofing by basin and by administrative entity reveals distribution differences particularly marked next to the German border.
The deficit sectors appear along the German border, and to a lesser extent, along the Austrian and Polish borders. In the latter case however, the drainage basin concerned with the administrative entities is that of the Oder and not Elba.

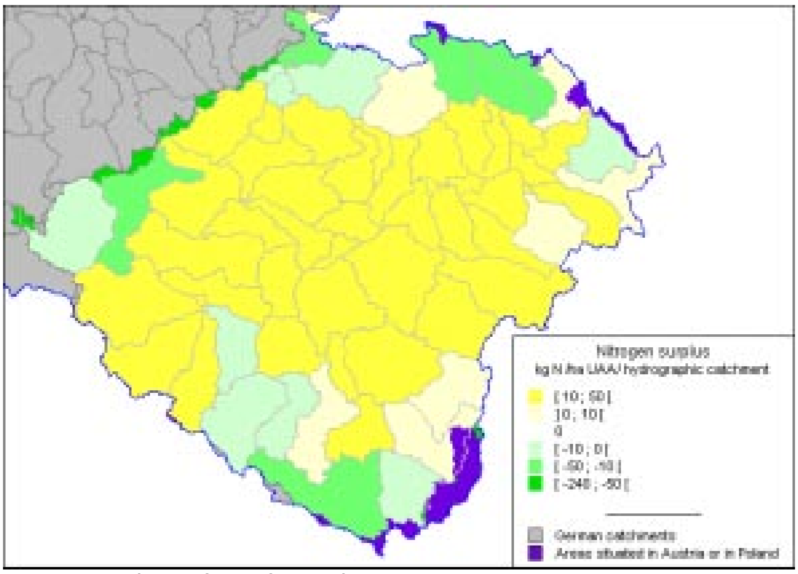
Figure 9: Results on the Czech part of the basin of Elba, ‘scenario 7’, breakdown by administrative entity



Source: Redrawn from Ifen and BETURE-CEREC, 1998.

Aggregating the results by drainage basin, the apparent deficit on the administrative entities located along the border appears indeed to be very located (and more intense) on a very narrow land stretch, on which there are no crops, but only forests and grazing grounds. This is very visible on the following figure.

Figure 10: Results on the Czech part of the basin of Elba, ‘scenario 7’, breakdown by drainage basin



Source: Redrawn from Ifen and BETURE-CEREC, 1998.

These results come from a series of circumstances probably due to the recent history. Scrutinizing CORINE *Land cover* maps of the region shows indeed a mainly forestry stretch along the border, while very small drainage basins, are delineated. The border with Germany limits these drainage basins, which have weak hydrological relevance. It is therefore important to envisage a recasting of the European hydrographical limits, so as to ensure continuity of them, independently of the political limits.

5.3.3. *Synthesis*

After the calculations carried out independently on the sub-catchments of each State, so as to validate as much as possible the data, all the files were merged, with some problems due to the absence of continuity of the 41 cross-border sub-catchments, which were adjusted 'by hand'. A number of 355 sub-catchments were recomputed at the same time.

Table 10: Summary of the results obtained on the basin of Elba and summary of the results on the basin of the Loire

Elbe		Total surplus (1000*T of N)	Average surplus (kg N/ha/year)	Total deficit (1000*T of N)	Average deficit kg N/ha/year	Deficit area % of Agricultural area (A.A.)	A.A. (1000*ha)	Total area (1000*ha)
Scenario 7	Czech Republic	43.6	20.5	8.5	14.8	21%	2 695	5 046
	Germany	96.1	20.2	13.0	15.6	15%	5 586	9 647
	Total	139.7	***20.3***	21.4	***15.3***	***17%***	**8 281**	**14 693**
Scenario 8	Czech Republic	13.6	13.6	67.4	39.8	63%	2 695	5 046
	Germany	28.3	14.6	115.5	31.6	65%	5 586	9 647
	Total	41.9	***14.3***	182.9	***34.2***	***65%***	**8 281**	**14 693**
Scenario 9	Czech Republic	42.0	16.9	4.1	19.4	8%	2 695	5 046
	Germany	93.8	19.5	6.7	8.6	14%	5 586	9 647
	Total	135.9	***18.6***	10.8	***10.9***	***12%***	**8 281**	**14 693**

Loire	Total surplus (1000*T of N)	Average surplus (kg N/ha/year)	Total deficit (1000*T of N)	Average deficit kg N/ha	Deficit area % of Agricultural area (A.A.)	A.A. (1000*ha)	Total area (1000*ha)
Scenario 3	147,9	25.8	25,2	12.3	26.4	7 804	11 770

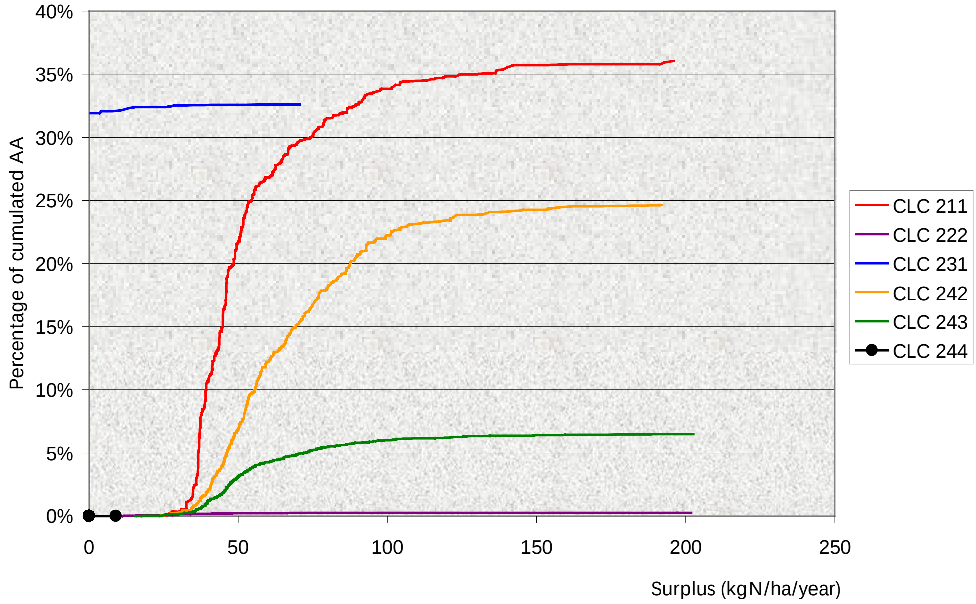
Source: Ifen./ BETURE-CEREC, NB: The reported values are so with all the figures calculated, for the sake of consistency with the final tables and aggregates. This implies no information about the accuracy of the results

5.4. Relations between the surpluses and the type of occupation of the land

Only six types of land cover contribute to surplus production. These are modalities 211 (Non-irrigated arable land), 222 (Fruit trees and berry plantations), 231 (Pastures), 242 (Complex cultivation patterns), 243 (Land principally occupied by agriculture, with significant areas of natural vegetation) and in a very marginal way, the occupation of type 244 (Agro-forestry areas).

The figure below presents the cumulated percentages of agricultural land, according to the value of the surplus, for the entire the Loire-Bretagne Water Agency district. It can be seen that the meadows, which constitute a considerable fraction of the land areas, do not exceed 50kg N/ha surpluses in practice.

Figure 11: Distribution of the cumulated land areas, according to the surplus (Loire-Bretagne Water Agency district)



Source: EEA and Ifen/BETURE-CEREC. NB CLC XXX refer to the CORINE land cover types mentioned in the paragraph above.

Only three types contribute significantly to the surplus (211, 242 and 243). Values, in surplus classes, are reported in the table below.

Table 11: Percentages of land, according to the CORINE Land cover codes, according to the surplus class. Values rounded at the nearest 0.01 %. Only CLC classes with surplus are represented.

CLC type	Surplus class					
	0 to 10 kg/ha/year	10 to 50 kg/ha/year	50 to 100 kg/ha/year	100 to 150 kg/ha/year	more than 150 kg/ha/year	Total
CLC 211		21,63%	12,21%	1,89%	0,32%	36,05%
CLC 222	0,01%	0,20%	0,03%			0,24%
CLC 231	32,07%	0,50%	0,03%			32,60%
CLC 242		6,81%	15,40%	2,06%	0,37%	24,64%
CLC 243		3,11%	2,89%	0,38%	0,10%	6,48%
Total	32,08%	32,25%	30,56%	4,33%	0,79%	100,01%

Source: EEA on Ifen/BETURE-CEREC

It is instructive to note that the activities over the classes 211 (*Non-irrigated arable land*), and 242 (*Complex cultivation patterns*) have a notably different impact. Whereas the class 211 contributes to strong surpluses only for 14.4 % of the land areas, the class 242 contributes to it for 17.8 % of the land areas. In view of the respective proportions of each type, the second therefore has a double impact. On this type, as for the type 243 (Land principally occupied by agriculture, with significant areas of natural vegetation) sectors with low surplus are hardly found.

6. Methodological findings

6.1. Impact of the heterogeneity of the basic data

The calculation model was developed in order to apply it to very wide areas. Consequently, it is essential to evaluate the possible effect of the heterogeneity of the source data likely to be mobilised on the results, knowing that it cannot be expected to find homogeneous statistics at a pan-European scale.

In this pilot application, this heterogeneity is clear; it concerns mainly three groups of information:

1. Basic administrative and hydrographical divisions being used to calculate the CORINE *Land cover* areas of the intersections. The assumption, not completely verified, is made that the CORINE *Land cover* layer is homogeneous for all the territories concerned. With regard to the Loire-Bretagne Water Agency district, there are18 354 intersections of communes and drainage basins, i.e., an average land area of 8.5 km^2. In the case of the basin of Elba, the geographical layers available made it possible to calculate only 1233 intersections, of average land area of 120 km^2.
2. The size of the elementary territorial units of supplying agricultural statistics. In France, the cantonal RGA is available. It comprises 1 379 units for the departments of the studied area, the basin itself by including only 996 units. On the other hand, for the basin of Elba, only 138 statistical units were obtained for the German part and 56 units for the Czech part, i.e., 194, after deduction of a German unit (obviously urban) lacking agricultural information.
3. The already mentioned classification differences between the countries.

To evaluate the impact of these differences on the results, the only standard available was the Loire-Bretagne Water Agency district, by applying various aggregation rules to the different available data sets.

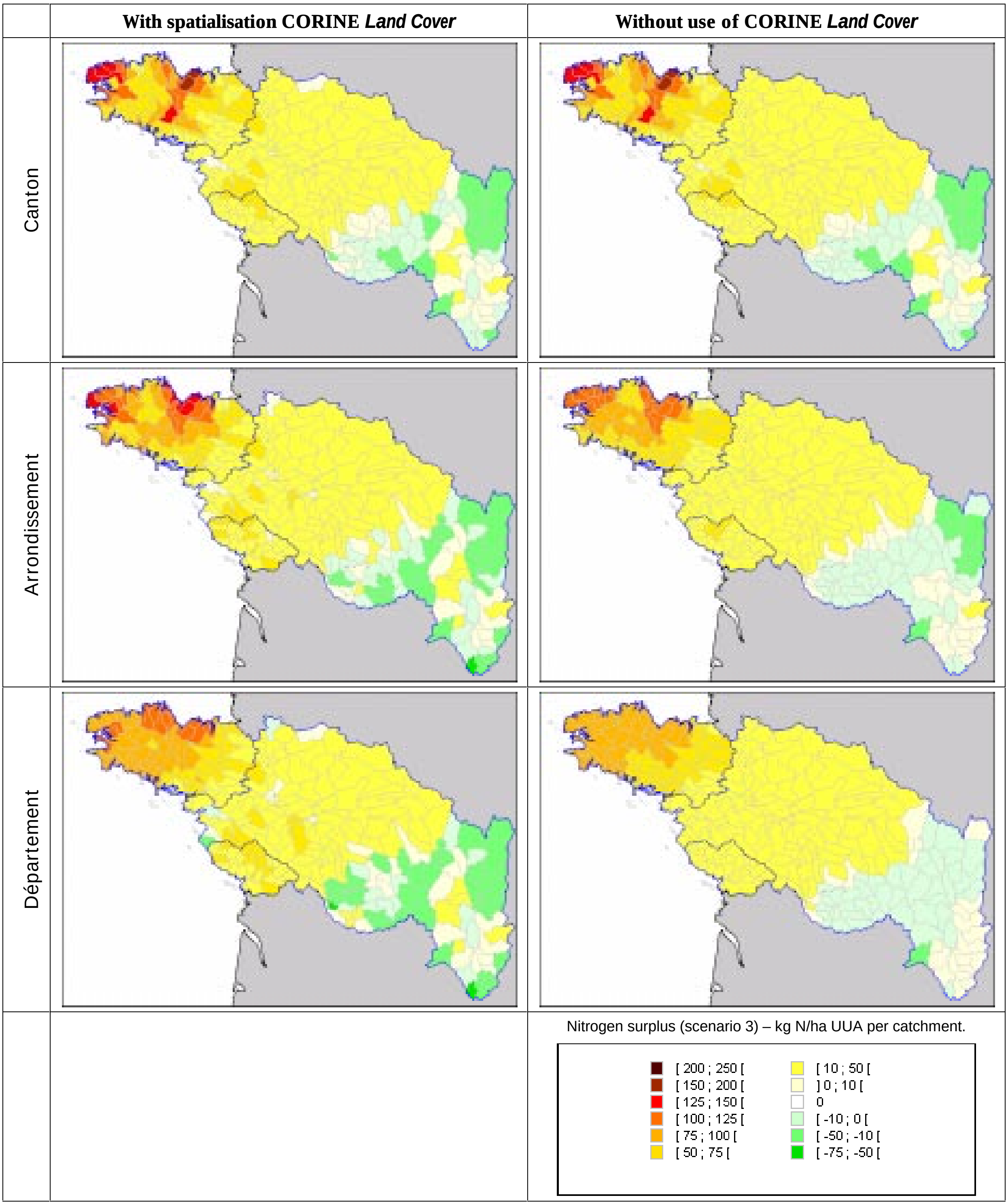
Two types of comparisons were carried out. The first obviously consists in aggregating the combinations involving CORINE *Land cover* in larger units, the 30 402 initial intersections being merged into 1 133 intersections, of average land area close to the intersections available on the basin of Elba. The results obtained were tested in parallel, with and without use of CORINE *Land cover.*

Second aggregation consisted in clustering the census variables in groups similar to the groups available for the basin of Elba, before carrying out standardisation according to the European classification. This aggregation makes it possible to consider the effect of simplification of the classifications on the result. It mainly consisted in recomputing equivalence of livestock, taking into account the composition of livestock (considering that for example, a dairy cow rejects at least 73 kg of nitrogen a year, compared to 43.8 per ox 1-2 year-old).

These aggregations and calculations were carried out for the canton, the ‘arrondissement’ (the 103 units mentioned above) and the department (36 units of NUTS3 level). The aggregation of the variables was also tested at the levels of the region (10 NUTS2 level entities) and of the totality of the Water Agency district. These latter results, without relevance, are not discussed any more.

6.2. Incidence of the level of aggregation and of the use of CORINE *Land cover*

Figure 12: Values of the surpluses by sub-sector, according to the level of aggregation of the statistical data and of the taking into account or not of CORINE *Land cover*



Source: Ifen/BETURE-CEREC

The maps in Figure 12 distinctly show a gradient of evenness of the results from cantonal calculation spatialised with CORINE *Land cover* until departmental calculation without spatialisation.

The analysis of the results was carried out by correlating the results of surpluses by sub-sector, by density and by absolute value, while taking as reference the calculation that were obtained by canton with the use of CORINE *Land cover.*

Obviously, the difference between the results spatialised or not is expected to be all the larger as basic statistics are aggregated over a greater land area. If statistics were available on equal or smaller units than units CORINE *Land cover,* then its use would obviously be unjustified.

Since the aim is to check the identity of the results, the correlation and the regression are calculated with a linear model, the constant of which is forced to zero. In this case, the value of the correlation coefficient indicates the consistency of the series, while the slope indicates the difference between the calculated values, if it deviates from the unity.

Table 12: Statistics on the validity of the results modelled with and without the use of CORINE Land cover

Results related to:		Cantons (without CLC)	"Arrondissements" (with CLC)	"Arrondissements" (without CLC)	Departments (with CLC)	Departments (without CLC)
Surplus (1000 T/year)	r2 coefficient	0,99	0,93	0,91	0,86	0,82
	Slope	0,98	0,97	0,91	0,94	0,85
Density (kg/ha/year)	r2 coefficient	0,98	0,86	0,84	0,75	0,71
	Slope	0,98	0,99	0,95	0,99	0,93

Source: EEA on Ifen/BETURE-CEREC

The figures of Tableclearly show the superiority of modelling based on spatialisation. Although the correlation coefficients relating to the departments calculated with CORINE *Land cover* are not as good as those of the ‘arrondissements’ calculated without it, the slope is closer to 1, which suggests a better estimate of the total value, despite a more substantial dispersal. In the case of the departments, the gain given by CORINE *Land cover* is clear in the case of the calculation of the total surplus. It appears less obvious in the case of the surplus densities. In fact this comes from a de facto standardization of the surpluses to a value of ~100 kg N $year^{-1}$ ha^{-1}, which created a very strong discrepancy between the reference figures and the values tested in this range of values.

Table 13: Overall results on the Loire-Bretagne Water Agency district (reference scenario 3)

Results related to:	Cantons (with CLC, reference)	Cantons (without CLC)	"Arrondissements" (with CLC)	"Arrondissements" (without CLC)	Departments (with CLC)	Departments (without CLC)
Surplus (1000 T/year) (sum of positive values)	326	323	328	319	331	316
Surplus (1000 T/year) (sum of negative values)	18	16	26	13	35	8

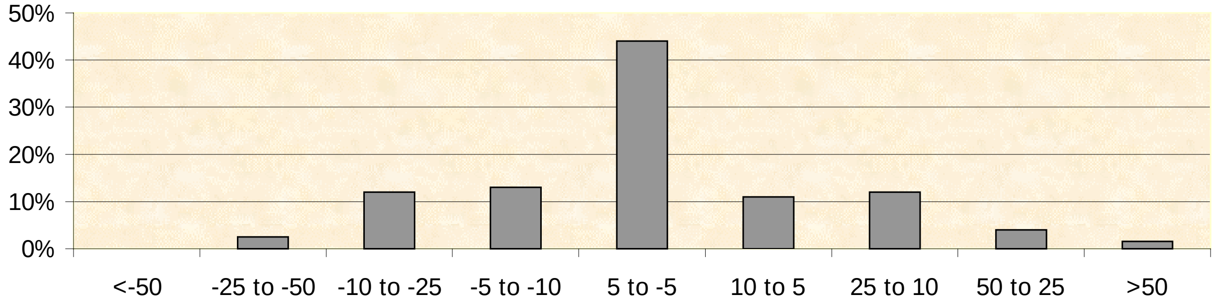
Source: EEA on Ifen/BETURE-CEREC

6.3. Incidence of statistical data (aggregation in space and of the variables)

Aggregations of the statistical variables and surplus calculations by sub-sector were also carried out. Comparisons are also made in relation to reference calculation (scenario 3). Scenario 4 uses statistics aggregated to the ‘arrondissement’. The three other scenarios (5 to 7) use the same statistics, but with technical coefficients increasingly aggregated from the department to the Water agency district. For reasons of consistency, and not to multiply the number of calculations, scenarios 5 to 7 are assigned to geographical aggregation at the level of the ‘arrondissement’. In this case, space aggregation is therefore cumulated with that of the variables themselves.

The principal differences obviously appear between scenarios 3 and 4: statistics are aggregated by a factor 13 and geographical division is aggregated by a factor 27. However, results are much less different than it could have been feared. An entity-to-entity comparison shows that 70 % of the entities have a calculated surplus falling within ±10 kg N ha^{-1} $year^{-1}$ of that of the baseline scenario, and can therefore be considered identical.

Figure 13: Distribution of the differences (in percentage terms of the hydrographical entities) of the calculated surpluses (scenarios 3 and 4), whole basin



Source: (Ifen and BETURE-CEREC, 1998).

Considering in detail the differences connected with the aggregation of the variables, it is noted that the effect is different according to the principal agricultural production of the surfaces under consideration. In the majority of intensive livestock-farming sectors, the density increases slightly, while it decreases more in the op en field livestock-farming sectors.

Table 14: Comparison of the results of the scenarios 3 to 7, according to the degree of aggregation

	Loire		Bretagne		Vendée	
	Total (in T)	kg/ha/year	Total (in T)	kg/ha/year	Total (in T)	kg/ha/year
Reminder of scenario 3 results	144 675	24,5	157 300	75,7	23 544	35,3
difference (3-4) in %	-1,9%	-5,7%	-0,4%	0,4%	2,1%	-2,5%
difference (3-5) in %	-2,1%	-5,7%	0,5%	1,3%	2,5%	-2,0%
difference (3-6) in %	-2,0%	-4,9%	-0,5%	0,3%	2,6%	2,5%
difference (3-7) in %	-2,3%	-5,3%	0,2%	0,9%	0,2%	0,0%

Source: recomputed of Ifen and BETURE-CEREC, 1998. The difference is (surpluses in scenario 3) – (surpluses in scenario 4).

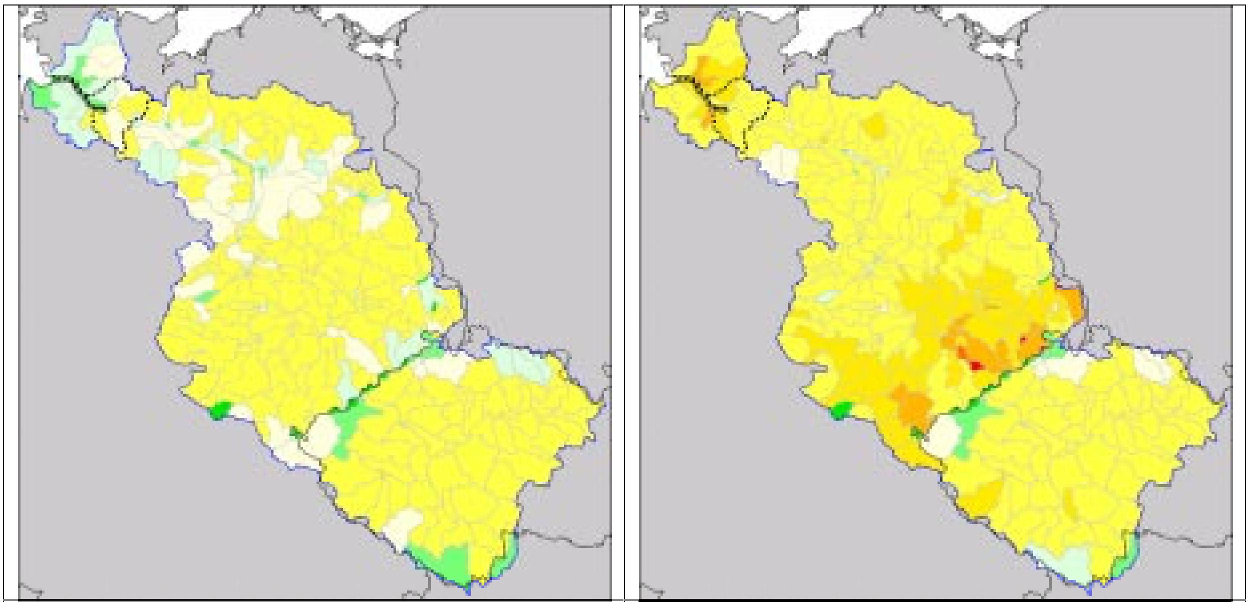
Generally speaking, the overall result is not changed in a perceptible way, only about 2 % of the total, and from 0 to 6 % of the surplus expressed in density. On the other hand, but in a way simultaneously connected to the effects of space and of variables aggregations, the largest surplus values tend to disappear, but in 2 to 3 % of the cases, over-estimate between 25 to 50 kg N ha^{-1} $year^{-1}$ results from aggregation.

6.4. Incidence of the differentiated taking into account of animal feed

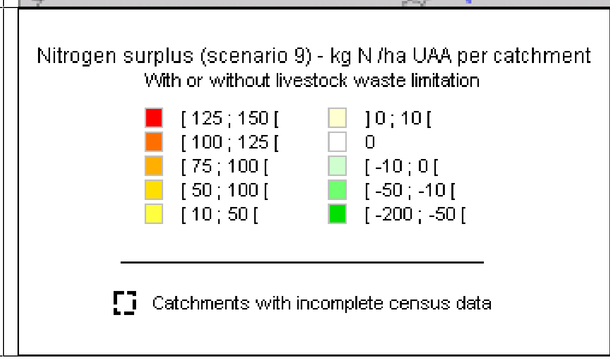
The modelling method comprises the implicit hypothesis of the self-sufficiency of each unit of calculation with respect to animal feed. Consequently, if local fodder production is lower than the needs of livestock, the quantity of livestock waste is reduced automatically in proportion to the feed intake supposedly provided.

However, in the areas where livestock is numerous, animals are fed mainly by means of imported food. In this case, the hypothesis of reduction of the emissions no longer holds, and the quantity of nutrients supplied by livestock waste is likely to be higher than that calculated and presented in this report. Additional calculations were therefore carried out, systematically inhibiting the function of limitation in equation 1 (cf. page 21). In the case of the Loire-Bretagne Water Agency district and the basin of Elba, this modification of calculation results in a substantial increase in the surpluses.

Figure 14: Change in the surpluses expressed in density (kg/N/ha/year) with taking into account (on the left) or not of the abatement for limitation of animal feed. Case of the basin of Elba



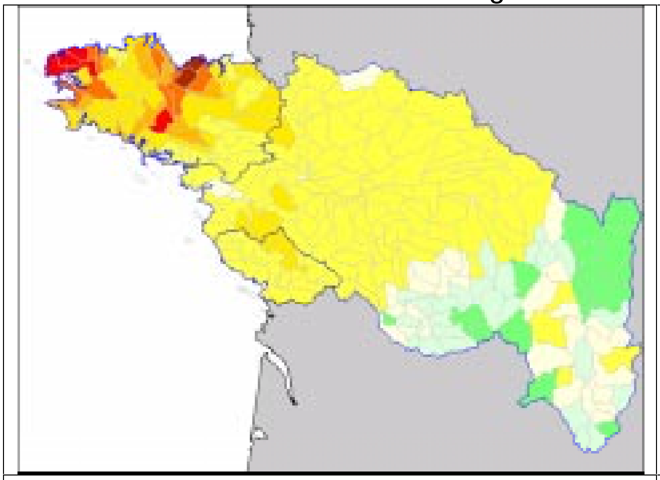
The difference between the two approaches concerns 882 thousand ha that shifts from negative surplus to a positive surplus, and the surpluses of which contribute then for 32 thousand tonnes to a total increase in 185 thousand tonnes (i.e. an increase of 131 % with respect to the baseline scenario).

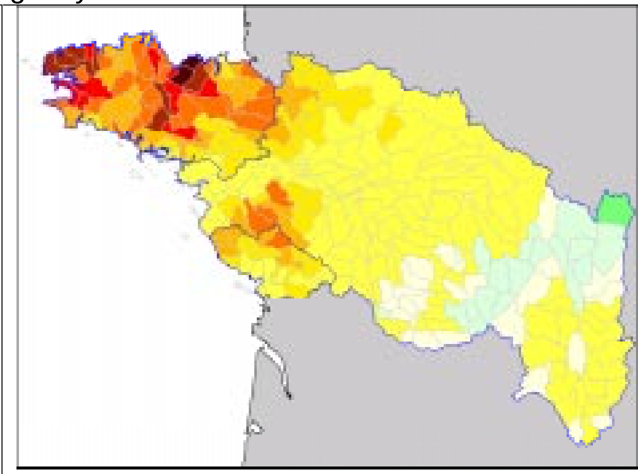


Source: Ifen//BETURE-CEREC

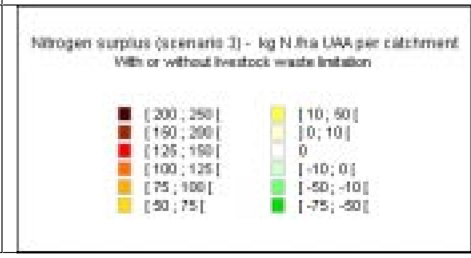
In the case of the basins of the Loire and Brittany, where the livestock-farming methods are very contrasted, very differing changes are observed. In the basin of the Loire, food import almost ends up eliminating the sub-sectors in deficit.

Figure 15: Change in surpluses expressed in density (kg/N/ha/year) with the taking into account (on the left) or not of the abatement for limitation of animal feed. Case of the Loire-Bretagne Water Agency district



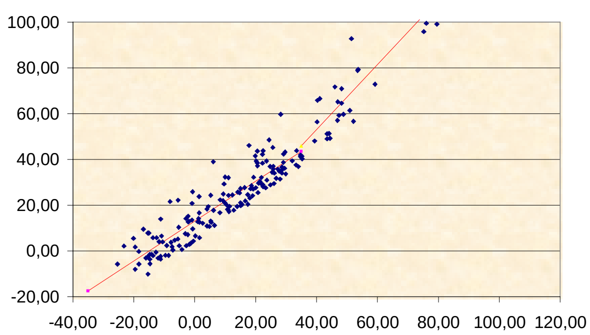


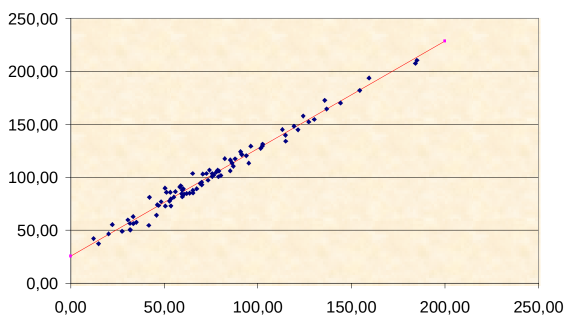
Source: Ifen/BETURE-CEREC.



The statistical analysis of the results tends to show the existence of a double population of sub-catchment on the basin of the Loire, compared to a single population in Brittany. In the case of the basin of the Loire, a group of sub-sectors with weak initial surplus (<35 kg N ha^{-1} year^{-1}, including those with negative surplus), and a group of initial surpluses ≥35 kg N ha^{-1} year^{-1} can be distinguished.

Figure 16: Final surplus (without abatement according to the surplus calculated with abatement





In the horizontal axis, the initial surplus (SI), taking into account the abatement for lack in the feeding of livestock. In ordinate, the final surplus (SF), without considering the abatement. All the figures are in kg N ha^{-1} year^{-1} and each point represents one sub-sector. Total items number is 298.

Basin of the Loire. For the values of SI <35, SF=13+.87 SI,, For SI ≥ 35, SF=-4+1.42SI. Respective R^2 are 0.82 and 0.89.	Brittany. SF=25,6+1.015SI. The R^2 is 0.98 Source: Calculations EEA

The simplest explanatory hypothesis of the double slope observed on the Loire basin is algebraic: a slope higher than 1 would increase the deficit of the negative surpluses mechanically. The hypothesis of double population would therefore be an artefact. In

Brittany, the slope is almost 1. Apart from the algebraic explanation, different structures of agricultural production have to be envisaged. These are implied by the dispersion of the points. In Brittany, surpluses are mainly due to livestock, the change is therefore systematic and much narrowed. In the basin of the Loire, there is a more complex situation, reflecting a more diversified origin of the surplus.

This analysis shows however the need to calculate alternative scenarios, to mitigate agronomic and statistical information that are sometimes lacking. However, the maximalist hypothesis presented here neglects its corollary, the reuse of livestock waste, sometimes outside the canton. It should therefore be regarded only as a hypothesis for testing and not as an indication of a possible surplus.

In terms of assessment, the differences between the two extreme forms of taking into account of the animal needs give following tonnages.

Table 15: Comparison of the assessments, by geographical sector, according to the taking into account or not of the hypothesis of limitation of animal feed. Values in 1000×tonnes and in land area concerned

	Areas with surplus, (thousands ha) with abatement		Areas with surplus, (thousands ha) without abatement		Difference (thousands ha)	
	Positive	Negative	Positive	Negative	Positive	Negative
Loire basin	6006	1798	6811	993	805	-805
Brittany	2093	0,9	2093	0,9	0	0
South-Loire	666	0	666	0	0	0
Total	8765	1799	9570	994	805	-805
Germany	4433	694	5094	33	661	-661
Czech Rep.	2075	81	2155	1	80	-80
Shared catchment	725	275	866	134	141	-141
Total	7233	1049	8115	167	882	-882
	Surplus (with abatement) in thousands T		Surplus (without abatement), in thousands T		Difference (thousands ha)	
	Positive	Negative	Positive	Negative	Positive	Negative
Loire basin	154	-23	229	-3	75	19
Brittany	167	-0,1	225	-0,1	58	0
South-Loire	24	0	39	0	15	0
Total	345	-23	492	-3	147	19
Germany	80	-6	215	-1	136	5
Czech Rep.	50	0	70	0	20	0
Shared catchment	11	-5	40	-3	29	1
Total	140	-11	325	-4	185	7

Source: EEA from Ifen/BETURE-CEREC.

Differences are obviously quite significant, and clearly raise the question of the accuracy of the agronomic coefficients taken into account for modelling. They rise however this question only in terms of scenarios. However impressive these figures are, maybe they do not show anything except the uncertainty attached to inputs that are non-registered or calculated by standard coefficients. In this respect, the range of the values of the population equivalent according to the countries exemplifies this discrepancy. For example, for phosphorus these values are between 1 and 1.5 kg P capita^{-1} year^{-1} and for nitrogen between 2.2 and 5.5 kg N capita^{-1} year^{-1}, by considering only official figures of the countries of the European Union (Crouzet, Leonard *et al.*, 1999). These divergences, respectively of 50 % and 104 % apply however to pollution production by persons, which should in theory result in rather homogeneous figures, while tens of different agricultural activities are taken into account in an agricultural model, even simplified.

7. Conclusions

The previous tests and the calculations carried out show that the results obtained by modelling the surpluses with the use of CORINE *Land cover* are mainly sensitive, by order of decreasing importance: firstly to the **technical coefficients and to the values of yield from the crops,** secondly to the **degree of aggregation of basic statistics** and finally, but in a very marginal way, to the more or less major degree of *aggregation* of the collected **statistical variables**.
These results are very encouraging because they show the robustness of the approach and its capacity to provide usable results even by using censuses, which results are aggregated over tens of km^2 and which number of variables is limited to about twenty.

Certainly, the results obtained are even more dispersed as the basic variables and the technical coefficients available are lumped. On the other hand, results are hardly biased, i.e., the total values in tonnage as well as the density of the surpluses are preserved. This result suggests that the use of a geographical layer compensates for to a certain extent the loss of information introduced by the increase in the degree of aggregation of statistics. **In other words, overall distribution is well preserved, as well as the quantity of the surplus even if the location becomes increasingly vague as the degree of aggregation increases.**

The good sensitivity of the model to the values of the technical coefficients does not present only disadvantages. The structure of the model allows in addition a keen adjustment of calculations, there only where it is necessary. It is therefore a tool for evaluating the relevance of the coefficients.

This means that the use of CORINE *Land cover* makes it possible to eliminate an uncertainty factor, which is the heterogeneity of the statistics of the agricultural censuses. Consequently, it only now remains to solve the questions related to the technical coefficients and crop yields. These questions are obviously of importance, but they rather pertain to the field of the agronomists, of experts and of the analysis of literature. It therefore becomes possible to produce in next future homogeneous and comparable results with limited efforts, because the questions to be solved fall within the domain of engineering and not within the basic statistical data gathering. The method reduces therefore the dependence of those who have to produce the results with respect to the organisations responsible for the production of the basic data. In addition, the reliability brought to the model by the introduction of the CORINE *Land cover* layer makes it possible to envisage the production of correct results with acceptable accuracy at the scale of a few hundred to a few thousands km^2, with relative independence of the degree of aggregation of basic agricultural statistics scale. Acceptable scales range from the cantonal level (units from 100 to 150 km^2) as far as the departmental level (units from 3 000 to 6 000 km^2).

Hence, the use of CORINE *Land cover* makes it possible to compensate mainly for the absence of availability of spatially homogeneous statistics. Despite that, it becomes possible to produce usable results, because they are sufficiently exact and comparable. Obviously, only detailed statistics would allow production of correct and accurate results. Spatialisation by means of CORINE *Land cover* makes simply possible to evaluate quickly the range of the agricultural surpluses in Europe, even using the heterogeneous data currently available. Moreover, the possibility of producing usable evaluations from data available at a large scale (department level for example) could be made profitable to calculate intermediate states between two censuses of agriculture, and therefore to evaluate better the trends.

It remains henceforth to apply this method of calculating to the widest possible territories, aiming at having eventually comparable figures for the whole of Europe, and to be able to compare these figures with the state of the environment. Such work could be carried out within 12 to 15 months. It would constitute a particularly valuable comparison point with the figures that could be produced by using the update of CORINE *Land cover* currently under way.

It obviously also remains necessary to continue the development of the complementary tools, in particular the study of transfers, derived from research work and using the other sources of spatial data, in particular soil and elevation maps.

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Annex 1: Relation between the crops and the utilisation rate of the various land areas of occupation of the land, by CORINE *Land cover* code

* (all the annexes result directly from the database)

In census	European variables		211	212	213	221	222	223	231	241	242	243	244
		Usable area:	95%	100%	95%	95%	95%	95%	95%	80%	80%	60%	50%
	D	ARABLE LAND	X								X	X	
	D/01->D/08	+ Cereals for the production of grain (including seed)	X								X	X	
X	D/01	¤ Common wheat and spelt	X								X	X	
X	D/02	¤ Durum wheat	X								X	X	
X	D/03	¤ Rye (including meslin)	X								X	X	
X	D/04	¤ Barley	X								X	X	
X	D/05	¤ Oats (including summer meslin)	X								X	X	
X	D/06	¤ Grain maize	X								X	X	
	D/07	¤ Rice			X								
X	D/08	¤ Other cereals	X							X	X	X	
	D/09	+ Pulses for harvest as grain(including seed and mixture of pulses and mixtures of pulse and cereals)	X							X	X	X	
X	D/09/a	¤ Single crops for fodder: field beans, vetches, sweet lipins	X								X	X	
X	D/09/b	¤ Others (single or mixed)	X							X	X	X	
	D/10->D/12	+ Root crops	X								X	X	
X	D/10	¤ Potatoes (including early potatoes and seed potatoes)	X								X	X	
X	D/11	¤ Sugar beet (excluding seeds)	X								X	X	
X	D/12	¤ Forage roots and tubers (excluding seeds)	X								X	X	
	D/13	+ Industrial crops (including only seeds for herbaceaous oil seed plants)	X								X	X	
X	D/13/a	¤ Tobacco	X								X	X	
X	D/13/b	¤ Hops	X								X	X	
	D/13/c	¤ Cotton	X								X	X	
X	D/13/d	¤ Other industrial plants	X							X	X	X	
	D/13/d1	* Oilseeds	X								X	X	
X	D/13/d11	- Of rape and turnip	X								X	X	
X	D/13/d12	- Of sunflower	X								X	X	
X	D/13/d13	- Soya	X								X	X	
X	D/13/d2	* Aromatic plants, medicinal and culinary plants	X								X	X	
X	D/13/d3	* Other industrial crops	X								X	X	
	D/13/d31	- Sugar cane	X								X	X	
X	D/14->D/15	+ Fresh vegetables, melons, strawberries	X								X	X	
	D/14	¤ Fresh vegetables, melons, strawberries - outdoor or under low (non-accessible) cover	X								X	X	
X	D/14/a	* Open field of fresh vegetables, melons, strawberries, outdoor or under low cover	X								X	X	
X	D/14/b	* Market gardening of fresh vegetables, melons, strawberries, outdoor or under low cover	X								X	X	
	D/15	¤ Crops under green house, glass or high (accessible) cover	X								X	X	
	D/16->D/17	+ Flowers and ornamentals plants	X								X	X	
X	D/16	¤ Flowers and ornamental plants outdoor	X								X	X	
	D/17	¤ Flowers and ornamental plants under glass	X								X	X	
	D/18	+ Forages plants	X								X	X	
X	D/18/a	¤ Temporary grass meadows	X							X	X	X	X
	D/18/b	¤ Other forage plants	X							X	X	X	X
X	D/18/b1	* Excluding legumineous plants	X							X	X	X	X
X	D/18/b2	* Legumineous plants	X							X	X	X	X
	D/19	+ Seeds and seedlings (excluding cereals, pulses)	X							X	X	X	X
	D/20	+ Potatoes and oil seed plants, other arable crops	X							X	X	X	X
	D/21	+ Fallows	X							X	X	X	X

In census		European variables	211	212	213	221	222	223	231	241	242	243	244
		Usable area:	95%	100%	95%	95%	95%	95%	95%	80%	80%	60%	50%
	F	PERMANENT PASTURES AND MEADOWS							X				
X	F/01	+ Excluding rough grazing							X				
	F/02	+ Rough grazing							X				
	G	PERMANENT CROPS	X				X				X	X	
X	G/01	+ Fruits and berries					X						
X	G/01/a	¤ Fresh fruits and berries of temperate zones					X						
X	G/01/b	¤ Fresh fruits and berries of subtropical zones					X						
	G/01/c	¤ Nuts and dry fruits					X						
	G/02	+ Citrus plantations					X						
	G/03	+ Olive plantations						X					
	G/03/a	¤ Olive plantations for table olives						X					
	G/03/b	¤ Olive plantations for olive oil production						X					
X	G/04	+ Vineyards				X							
	G/04/a	¤ For quality wine				X							
	G/04/b	¤ For other wines				X							
	G/04/c	¤ For table grapes				X							
	G/04/d	¤ For raisins				X							
	G/05	+ Nurseries											
	G/06	+ Other permanent crops											
	G/07	+ Permanent crops under glass or high (accessible) cover											
X	J/01	EQUIDAE, TOTAL	X						X		X	X	
	J/02->J/08	BOVINE ANIMALS (including buffaloes)	X						X		X	X	
X	J/02	+ Under 1 year old	X						X		X	X	
	J/02/a	¤ male	X						X		X	X	
	J/02/b	¤ female	X						X		X	X	
X	J/03	+ One year but under 2 years, male	X						X		X	X	
X	J/04	+ One year but under 2 years, female	X						X		X	X	
X	J/05	+ Two years and older, male	X						X		X	X	
X	J/06	+ Two years and older, heifers	X						X		X	X	
X	J/07	+ Dairy cows	X						X		X	X	
X	J/08	+ Other cows	X						X		X	X	
	J/09	SHEEPS (all ages)	X						X		X	X	
X	J/09/a	+ Breeding females	X						X		X	X	
X	J/09/b	+ Other sheeps	X						X		X	X	
	J/10	GOATS (all ages)	X						X		X	X	
	J/10/a	+ Breeding females	X						X		X	X	
X	J/10/b	+ Other goats	X						X		X	X	
	J/11->J/13	PIGS, TOTAL	X						X		X	X	
X	J/11	+ Piglets having a live weight of under 20Kg	X						X		X	X	
X	J/12	+ Breeding sows weighing 50 Kg and over	X						X		X	X	
X	J/13	+ Other pigs	X						X		X	X	
	J/14->J/16	POULTRY	X						X		X	X	
X	J/14	+ Broilers	X						X		X	X	
X	J/15	+ Laying hens	X						X		X	X	
X	J/16	+ Other poultry (ducks, turkeys, geese, guinea-fowl)	X						X		X	X	
X	J/17	RABBITS, BREEDING FEMALES	X						X		X	X	

Annex 2: Coefficients of fertilisation, of yield, of export, content in dry matters of fodder for the 3 scenarios applied in France

European variables		Fertilisation (kg/ha)	Exportation (kg/quintal)	Yield (quintal/ha)	Dry matter rate
D	ARABLE LAND		1,62	141,18	
D/01->D/08	+ Cereals for the production of grain (including seed)	114	1,79	53,23	
D/01	¤ Common wheat and spelt	114	1,90	66,00	
D/02	¤ Durum wheat	114	2,20	39,90	
D/03	¤ Rye (including meslin)	114	1,40	39,40	
D/04	¤ Barley	114	1,50	55,40	
D/05	¤ Oats (including summer meslin)	114	1,90	43,20	
D/06	¤ Grain maize	114	1,50	80,50	
D/07	¤ Rice		2,20	49,70	
D/08	¤ Other cereals	114	1,70	51,70	
D/09	+ Pulses for harvest as grain(including seed and mixture of pulses and mixtures of pulse and cereals)		1,70	49,70	
D/09/a	¤ Single crops for fodder: field beans, vetches, sweet lipins		1,70	49,70	
D/09/b	¤ Others (single or mixed)	114	1,70	49,70	
D/10->D/12	+ Root crops	114	0,27	538,33	
D/10	¤ Potatoes (including early potatoes and seed potatoes)	114	0,35	356,60	
D/11	¤ Sugar beet (excluding seeds)	114	0,20	720,60	
D/12	¤ Forage roots and tubers (excluding seeds)	114	0,26	537,80	0,125
D/13	+ Industrial crops (including only seeds for herbaceaous oil seed plants)		3,16	22,14	
D/13/a	¤ Tobacco	114	4,10	23,90	
D/13/b	¤ Hops	114	50 kg/ha	17,90	
D/13/c	¤ Cotton		3,16	22,14	
D/13/d	¤ Other industrial plants	114	2,22	24,63	
D/13/d1	* Oilseeds		4,17	24,63	
D/13/d11	- Of rape and turnip	114	3,50	28,40	
D/13/d12	- Of sunflower	114	1,90	20,90	
D/13/d13	- Soya		7,10	24,60	
D/13/d2	* Aromatic plants, medicinal and culinary plants	114	0,50	24,63	
D/13/d3	* Other industrial crops	114	2,00	24,63	
D/13/d31	- Sugar cane		2,00	24,63	
D/14->D/15	+ Fresh vegetables, melons, strawberries	114	0,50	141,18	
D/14	¤ Fresh vegetables, melons, strawberries - outdoor or under low (non-accessible) cover		0,50	141,18	
D/14/a	* Open field of fresh vegetables, melons, strawberries, outdoor or under low cover	114	0,50	141,18	
D/14/b	* Market gardening of fresh vegetables, melons, strawberries, outdoor or under low cover	114	0,50	141,18	

European variables		Fertilisation (kg/ha)	Exportation (kg/quintal)	Yield (quintal/ha)	Dry matter rate
D	ARABLE LAND		1,62	141,18	
D/01->D/08	+ Cereals for the production of grain (including seed)	114	1,79	53,23	
D/01	¤ Common wheat and spelt	114	1,90	66,00	
D/02	¤ Durum wheat	114	2,20	39,90	
D/03	¤ Rye (including meslin)	114	1,40	39,40	
D/04	¤ Barley	114	1,50	55,40	
D/05	¤ Oats (including summer meslin)	114	1,90	43,20	
D/06	¤ Grain maize	114	1,50	80,50	
D/07	¤ Rice		2,20	49,70	
D/08	¤ Other cereals	114	1,70	51,70	
D/09	+ Pulses for harvest as grain(including seed and mixture of pulses and mixtures of pulse and cereals)		1,70	49,70	
D/09/a	¤ Single crops for fodder: field beans, vetches, sweet lipins		1,70	49,70	
D/09/b	¤ Others (single or mixed)	114	1,70	49,70	
D/10->D/12	+ Root crops	114	0,27	538,33	
D/10	¤ Potatoes (including early potatoes and seed potatoes)	114	0,35	356,60	
D/11	¤ Sugar beet (excluding seeds)	114	0,20	720,60	
D/12	¤ Forage roots and tubers (excluding seeds)	114	0,26	537,80	0,125
D/13	+ Industrial crops (including only seeds for herbaceaous oil seed plants)		3,16	22,14	
D/13/a	¤ Tobacco	114	4,10	23,90	
D/13/b	¤ Hops	114	50 kg/ha	17,90	
D/13/c	¤ Cotton		3,16	22,14	
D/13/d	¤ Other industrial plants	114	2,22	24,63	
D/13/d1	* Oilseeds		4,17	24,63	
D/13/d11	- Of rape and turnip	114	3,50	28,40	
D/13/d12	- Of sunflower	114	1,90	20,90	
D/13/d13	- Soya		7,10	24,60	
D/13/d2	* Aromatic plants, medicinal and culinary plants	114	0,50	24,63	
D/13/d3	* Other industrial crops	114	2,00	24,63	
D/13/d31	- Sugar cane		2,00	24,63	
D/14->D/15	+ Fresh vegetables, melons, strawberries	114	0,50	141,18	
D/14	¤ Fresh vegetables, melons, strawberries - outdoor or under low (non-accessible) cover		0,50	141,18	
D/14/a	* Open field of fresh vegetables, melons, strawberries, outdoor or under low cover	114	0,50	141,18	
D/14/b	* Market gardening of fresh vegetables, melons, strawberries, outdoor or under low cover	114	0,50	141,18	

In census	European variables		Fertilisation (kg/ha)	Exportation (kg/quintal)	Yield (quintal/ha)	Dry matter rate
	D	ARABLE LAND	117,15	1,62	141,18	
	D/01->D/08	+ Cereals for the production of grain (including seed)	122,00	1,79	53,23	
X	D/01	¤ Common wheat and spelt	156,00	1,90	66,00	
X	D/02	¤ Durum wheat	150,00	2,20	39,90	
X	D/03	¤ Rye (including meslin)	120,00	1,40	39,40	
X	D/04	¤ Barley	124,00	1,50	55,40	
X	D/05	¤ Oats (including summer meslin)	70,00	1,90	43,20	
X	D/06	¤ Grain maize	154,00	1,50	80,50	
	D/07	¤ Rice	122,00	2,20	49,70	
X	D/08	¤ Other cereals	80,00	1,70	51,70	
	D/09	+ Pulses for harvest as grain(including seed and mixture of pulses and mixtures of pulse and cereals)	117,15	1,70	49,70	
X	D/09/a	¤ Single crops for fodder: field beans, vetches, sweet lipins		1,70	49,70	
X	D/09/b	¤ Others (single or mixed)		1,70	49,70	
	D/10->D/12	+ Root crops	130,00	0,27	538,33	
X	D/10	¤ Potatoes (including early potatoes and seed potatoes)	130,00	0,35	356,60	
X	D/11	¤ Sugar beet (excluding seeds)	130,00	0,20	720,60	
X	D/12	¤ Forage roots and tubers (excluding seeds)	130,00	0,26	537,80	0,125
	D/13	+ Industrial crops (including only seeds for herbaceaous oil seed plants)	85,89	3,16	22,14	
X	D/13/a	¤ Tobacco	85,89	4,10	23,90	
X	D/13/b	¤ Hops	85,89	50 kg/ha	17,90	
	D/13/c	¤ Cotton	85,89	3,16	22,14	
X	D/13/d	¤ Other industrial plants	85,89	2,22	24,63	
	D/13/d1	* Oilseeds	117,67	4,17	24,63	
X	D/13/d11	- Of rape and turnip	203,00	3,50	28,40	
X	D/13/d12	- Of sunflower	50,00	1,90	20,90	
X	D/13/d13	- Soya	100,00	7,10	24,60	
X	D/13/d2	* Aromatic plants, medicinal and culinary plants	40,00	0,50	24,63	
X	D/13/d3	* Other industrial crops	100,00	2,00	24,63	
	D/13/d31	- Sugar cane	100,00	2,00	24,63	
X	D/14->D/15	+ Fresh vegetables, melons, strawberries	80,00	0,50	141,18	
	D/14	¤ Fresh vegetables, melons, strawberries - outdoor or under low (non-accessible) cover	80,00	0,50	141,18	
X	D/14/a	* Open field of fresh vegetables, melons, strawberries, outdoor or under low cover	80,00	0,50	141,18	
X	D/14/b	* Market gardening of fresh vegetables, melons, strawberries, outdoor or under low cover	80,00	0,50	141,18	

In census	European variables		Fertilisation (kg/ha)	Exportation (kg/quintal)	Yield (quintal/ha)	Dry matter rate
	D/15	¤ Crops under green house, glass or high (accessible) cover	80,00	0,50	141,18	
	D/16->D/17	+ Flowers and ornamentals plants	135,00	1,62	141,18	
X	D/16	¤ Flowers and ornamental plants outdoor	135,00	1,62	141,18	
	D/17	¤ Flowers and ornamental plants under glass	135,00	1,62	141,18	
	D/18	+ Forages plants	150,00	2,30	42,50	
X	D/18/a	¤ Temporary grass meadows		3,50	50,00	
	D/18/b	¤ Other forage plants	150,00	1,10	35,00	0,25
X	D/18/b1	* Excluding legumineous plants	150,00	1,50	35,00	
X	D/18/b2	* Legumineous plants		0,66	35,00	
	D/19	+ Seeds and seedlings (excluding cereals, pulses)	117,15	1,62	141,18	
	D/20	+ Potatoes and oil seed plants, other arable crops	117,15	1,62	141,18	
	D/21	+ Fallows	117,15	1,62	141,18	
	F	PERMANENT PASTURES AND MEADOWS	40,00	3,50	35,00	
X	F/01	+ Excluding rough grazing	40,00	3,50	35,00	
	F/02	+ Rough grazing	40,00	3,50	35,00	
	G	PERMANENT CROPS	50,00	0,33	65,80	
X	G/01	+ Fruits and berries	50,00	0,50	65,80	
X	G/01/a	¤ Fresh fruits and berries of temperate zones	50,00	0,50	65,80	
X	G/01/b	¤ Fresh fruits and berries of subtropical zones	50,00	0,50	65,80	
	G/01/c	¤ Nuts and dry fruits	50,00	0,50	65,80	
	G/02	+ Citrus plantations	50,00	0,15	119,00	
	G/03	+ Olive plantations	50,00	0,33	8,00	
	G/03/a	¤ Olive plantations for table olives	50,00	0,33	8,00	
	G/03/b	¤ Olive plantations for olive oil production	50,00	0,33	8,00	
X	G/04	+ Vineyards	50,00	50 kg/ha	70,40	
	G/04/a	¤ For quality wine	50,00	50 kg/ha	70,40	
	G/04/b	¤ For other wines	50,00	50 kg/ha	70,40	
	G/04/c	¤ For table grapes	50,00	50 kg/ha	70,40	
	G/04/d	¤ For raisins	50,00	50 kg/ha	70,40	
	G/05	+ Nurseries	50,00	0,33	65,80	
	G/06	+ Other permanent crops	50,00	0,33	65,80	
	G/07	+ Permanent crops under glass or high (accessible) cover	50,00	0,33	65,80	

Scenario 3

In census	European variables		Fertilisation (kg/ha)	Exportation (kg/quintal)	Yield (quintal/ha)	Dry matter rate
	D	ARABLE LAND	117,15	1,62	141,18	
	D/01->D/08	+ Cereals for the production of grain (including seed)	122,00	1,79	53,23	
X	D/01	¤ Common wheat and spelt	156,00	1,90	66,00	
X	D/02	¤ Durum wheat	150,00	2,20	39,90	
X	D/03	¤ Rye (including meslin)	120,00	1,40	39,40	
X	D/04	¤ Barley	124,00	1,50	55,40	
X	D/05	¤ Oats (including summer meslin)	70,00	1,90	43,20	
X	D/06	¤ Grain maize	154,00	1,50	80,50	
	D/07	¤ Rice	122,00	2,20	49,70	
X	D/08	¤ Other cereals	80,00	1,70	51,70	
	D/09	+ Pulses for harvest as grain(including seed and mixture of pulses and mixtures of pulse and cereals)	117,15	1,70	49,70	
X	D/09/a	¤ Single crops for fodder: field beans, vetches, sweet lipins	90,00	1,70	49,70	
X	D/09/b	¤ Others (single or mixed)	90,00	1,70	49,70	
	D/10->D/12	+ Root crops	130,00	0,27	538,33	
X	D/10	¤ Potatoes (including early potatoes and seed potatoes)	130,00	0,35	356,60	
X	D/11	¤ Sugar beet (excluding seeds)	130,00	0,20	720,60	
X	D/12	¤ Forage roots and tubers (excluding seeds)	130,00	0,26	537,80	0,125
	D/13	+ Industrial crops (including only seeds for herbaceaous oil seed plants)	85,89	3,16	22,14	
X	D/13/a	¤ Tobacco	85,89	4,10	23,90	
X	D/13/b	¤ Hops	85,89	50 kg/ha	17,90	
	D/13/c	¤ Cotton	85,89	3,16	22,14	
X	D/13/d	¤ Other industrial plants	85,89	2,22	24,63	
	D/13/d1	* Oilseeds	117,67	4,17	24,63	
X	D/13/d11	- Of rape and turnip	203,00	3,50	28,40	
X	D/13/d12	- Of sunflower	50,00	1,90	20,90	
X	D/13/d13	- Soya	100,00	7,10	24,60	
X	D/13/d2	* Aromatic plants, medicinal and culinary plants	40,00	0,50	24,63	
X	D/13/d3	* Other industrial crops	100,00	2,00	24,63	
	D/13/d31	- Sugar cane	100,00	2,00	24,63	
X	D/14->D/15	+ Fresh vegetables, melons, strawberries	80,00	0,50	141,18	
	D/14	¤ Fresh vegetables, melons, strawberries - outdoor or under low (non-accessible) cover	80,00	0,50	141,18	
X	D/14/a	* Open field of fresh vegetables, melons, strawberries, outdoor or under low cover	80,00	0,50	141,18	
X	D/14/b	* Market gardening of fresh vegetables, melons, strawberries, outdoor or under low cover	80,00	0,50	141,18	

In census	European variables		Fertilisation (kg/ha)	Exportation (kg/quintal)	Yield (quintal/ha)	Dry matter rate
	D/15	¤ Crops under green house, glass or high (accessible) cover	80,00	0,50	141,18	
	D/16->D/17	+ Flowers and ornamentals plants	135,00	1,62	141,18	
X	D/16	¤ Flowers and ornamental plants outdoor	135,00	1,62	141,18	
	D/17	¤ Flowers and ornamental plants under glass	135,00	1,62	141,18	
	D/18	+ Forages plants	150,00	2,30	42,50	
X	D/18/a	¤ Temporary grass meadows	90,00	3,50	50,00	
	D/18/b	¤ Other forage plants	150,00	1,10	35,00	0,25
X	D/18/b1	* Excluding legumineous plants	150,00	1,50	35,00	
X	D/18/b2	* Legumineous plants	90,00	0,66	35,00	
	D/19	+ Seeds and seedlings (excluding cereals, pulses)	117,15	1,62	141,18	
	D/20	+ Potatoes and oil seed plants, other arable crops	117,15	1,62	141,18	
	D/21	+ Fallows	117,15	1,62	141,18	
	F	PERMANENT PASTURES AND MEADOWS	40,00	3,50	35,00	
X	F/01	+ Excluding rough grazing	40,00	3,50	35,00	
	F/02	+ Rough grazing	40,00	3,50	35,00	
	G	PERMANENT CROPS	50,00	0,33	65,80	
X	G/01	+ Fruits and berries	50,00	0,50	65,80	
X	G/01/a	¤ Fresh fruits and berries of temperate zones	50,00	0,50	65,80	
X	G/01/b	¤ Fresh fruits and berries of subtropical zones	50,00	0,50	65,80	
	G/01/c	¤ Nuts and dry fruits	50,00	0,50	65,80	
	G/02	+ Citrus plantations	50,00	0,15	119,00	
	G/03	+ Olive plantations	50,00	0,33	8,00	
	G/03/a	¤ Olive plantations for table olives	50,00	0,33	8,00	
	G/03/b	¤ Olive plantations for olive oil production	50,00	0,33	8,00	
X	G/04	+ Vineyards	50,00	50 kg/ha	70,40	
	G/04/a	¤ For quality wine	50,00	50 kg/ha	70,40	
	G/04/b	¤ For other wines	50,00	50 kg/ha	70,40	
	G/04/c	¤ For table grapes	50,00	50 kg/ha	70,40	
	G/04/d	¤ For raisins	50,00	50 kg/ha	70,40	
	G/05	+ Nurseries	50,00	0,33	65,80	
	G/06	+ Other permanent crops	50,00	0,33	65,80	
	G/07	+ Permanent crops under glass or high (accessible) cover	50,00	0,33	65,80	

Annex 3: Correspondence between the European primary variables and the variables used on the basins of the Loire and Elba according to the German and Czech available data

PRIMARY EUROPEAN VARIABLES		AGGREGATED EUROPEAN VARIABLES	
D/01	¤ Common wheat and spelt	D/01	¤ Common wheat and spelt
D/03	¤ Rye (including meslin)	D/03	¤ Rye (including meslin)
D/04	¤ Barley	D/04	¤ Barley
D/05	¤ Oats (including summer meslin)	D/05	¤ Oats (including summer meslin)
D/06	¤ Grain maize	D/06	¤ Grain maize
D/02	¤ Durum wheat	D/08	¤ Other cereals
D/08	¤ Other cereals		
D/09/a	¤ Single crops for fodder: field beans, vetches, sweet lipins	D/09	+ Pulses for harvest as grain(including seed and mixture of pulses and mixtures of pulse and cereals)
D/09/b	¤ Others (single or mixed)		
D/10	¤ Potatoes (including early potatoes and seed potatoes)	D/10	¤ Potatoes (including early potatoes and seed potatoes)
D/11	¤ Sugar beet (excluding seeds)	D/11	¤ Sugar beet (excluding seeds)
D/12	¤ Forage roots and tubers (excluding seeds)	D/12	¤ Forage roots and tubers (excluding seeds)
D/13/b	¤ Hops	D/13/b	¤ Hops
D/13/d	¤ Other industrial plants	D/13/d	¤ Other industrial plants
D/13/d12	– Of sunflower		
D/13/d13	– Soya		
D/13/d2	* Aromatic plants, medicinal and culinary plants		
D/13/d3	* Other industrial crops		
D/13/a	¤ Tobacco		
D/13/d11	– Of rape and turnip	D/13/d11	– Of rape and turnip
D/14->D/15	+ Fresh vegetables, melons, strawberries	D/14->D/15	+ Fresh vegetables, melons, strawberries
D/14/a	* Open field of fresh vegetables, melons, strawberries, outdoor or under low cover		
D/14/b	* Market gardening of fresh vegetables, melons, strawberries, outdoor or under low cover		
D/16	¤ Flowers and ornamental plants outdoor	D/16->D/17	+ Flowers and ornamentals plants
D/18/b1	* Excluding legumineous plants	D/18	+ Forages plants
D/18/b2	* Legumineous plants		
D/18/a	¤ Temporary grass meadows		
F/01	+ Excluding rough grazing	F	PERMANENT PASTURES AND MEADOWS

PRIMARY EUROPEAN VARIABLES		**AGGREGATED EUROPEAN VARIABLES**	
G / 01	+ Fruits and berries	G / 01	+ Fruits and berries
G / 01 / a	¤ Fresh fruits and berries of temperate zones		
G / 01 / b	¤ Fresh fruits and berries of subtropical zones		
G / 04	+ Vineyards	G / 04	+ Vineyards
J / 01	EQUIDAE, TOTAL	J / 01	EQUIDAE, TOTAL
J / 05	+ Two years and older, male	J / 02->J / 08	BOVINE ANIMALS (including buffaloes)
J / 08	+ Other cows		
J / 06	+ Two years and older, heifers		
J / 04	+ One year but under 2 years, female		
J / 03	+ One year but under 2 years, male		
J / 02	+ Under 1 year old		
J / 07	+ Dairy cows		
J / 09 / a	+ Breeding females	J / 09	SHEEPS (all ages)
J / 09 / b	+ Other sheeps		
J / 10 / b	+ Other goats	J / 10 / b	+ Other goats
J / 11	+ Piglets having a live weight of under 20Kg	J / 11->J / 13	PIGS, TOTAL
J / 12	+ Breeding sows weighing 50 Kg and over		
J / 13	+ Other pigs		
J / 14	+ Broilers	J / 14->J / 16	POULTRY
J / 15	+ Laying hens		
J / 16	+ Other poultry (ducks, turkeys, geese, guinea-fowl)		
J / 17	RABBITS, BREEDING FEMALES	J / 17	RABBITS, BREEDING FEMALES

Annex 4: Coefficients of the scenarios 7 and 8 having been used for the final composite scenario applied to the basin of Elba (scenario 9)

European variables		Yield		Exportation	
		Scenario 7	Scenario 8	Scenario 7	Scenario 8
D/01	¤ Common wheat and spelt	66.00	65.90	1.90	2.20
D/03	¤ Rye (including meslin)	39.40	45.10	1.40	2.00
D/04	¤ Barley	55.40	50.00	1.50	2.10
D/05	¤ Oats (including summer meslin)	43.20	47.70	1.90	2.00
D/06	¤ Grain maize	80.50	80.20	1.50	2.90
D/08	¤ Other cereals	44.17	52.50	2.02	2.00
D/09/a	¤ Single crops for fodder: field beans, vetches,	49.70	49.70	1.70	1.70
D/10	¤ Potatoes (including early potatoes and seed	356.60	392.50	0.35	0.40
D/11	¤ Sugar beet (excluding seeds)	720.60	548.30	0.20	0.50
D/12	¤ Forage roots and tubers (excluding seeds)	537.80	1049.10	0.26	0.20
D/13/d	¤ Other industrial plants	21.05	21.05	2.04	2.04
D/13/d11	– Of rape and turnip	28.40	28.30	3.50	3.40
D/14->D/15	+ Fresh vegetables, melons, strawberries	141.18	141.18	0.50	**70.00**
D/18	+ Forages plants	42.50	42.50	2.30	2.30
D/18/a	¤ Temporary grass meadows	50.00	92.80	3.50	3.20
D/18/b	¤ Other forage plants	35.00	35.00	1.10	1.00
D/18/b1	* Excluding legumineous plants	35.00	35.00	1.50	1.50
F	PERMANENT PASTURES AND MEADOWS	35.00	80.60	3.50	3.20
G/04	+ Vineyards	70.40	127.40	**50.00**	**50.00**
		Unit: quintal/ha		*Unit: kg/quintal*	

European variables		Manure		Fodder needs	
		Scenario 7	Scenario 8	Scenario 7	Scenario 8
J/02->J/08	BOVINE ANIMALS (including buffaloes)	44.74	58.22	3048.41	3229.34
J/09	SHEEPS (all ages)	7.61	13.00	376.38	427.01
J/11->J/13	PIGS, TOTAL	1.48	1.87		
J/14->J/16	POULTRY	0.07	0.07		
		Unit: kg N/head/year		*Unit: kg/head/year (dry matter)*	

List of the peer reviewers

The draft of this report was submitted for validation to the following experts and their comments have been completely taken into account:

EEA:

Anna-Rita Gentile,

Chris Steenmans,

David Stanners,

Domingo Jimenez-Beltran,

Gordon McInnes,

Hans Luiten

Jef Maes

Niels Thyssen

Ronan Uhel,

JRC

Vanda Perdigão

DG-Environnement

Jean Duchemin (OSPAR correspondant)

IFEN

Bernard Morel

Christophe Germain

Françoise Nirascou

Jacques Theys

Jean-Louis Weber

SCORPEN

Alain Creusot

Scientific councils

Dr Jean-Claude Lefeuvre (IFEN et EEA),

Dr Philippe Bourdeau (EEA)

Prof.Dr. Winfried E.H. Blum

Topic centres

Jan Kolar (PTL/CLC)

Stefan Keleeschulte (ETC/CLC)

Tim Lack (as ETC/IW)

Participants to the primary study

Dirck Börnhöft (Elbe Ökologie)

François Dubois de la Sablonnière (AELB)