



Dairy systems and environment in the Atlantic Area

***Taking better account
of the regional diversities with
the findings of the Green Dairy Project***

Green Dairy Project

Interreg Atlantic Area III B N°100

Proceedings of the final Seminar

Rennes (France), 13 - 14 December 2006



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Preface

Agricultural systems are dependent on adequate flows of nutrients to promote the growth of crops, pastures and animals at rates which allow farmers to sustain an acceptable economic return and produce sufficient amounts of high quality, nutritious feed and food. Over recent decades, many farming systems have increased their intensity of production to an extent which may result in excessive amounts of nutrients, especially of nitrogen and phosphorus, being lost from the farm and having harmful impact on the wider environment in some circumstances. Relatively inexpensive off-farm sources of nutrients have tended to encourage this. All ecosystems leak nutrients to some extent or other - global cycles of nitrogen and the function of natural systems depend upon this. Where inputs increase, the opportunity for nutrients to escape from farming management also increases. There is increasing pressure from international/ European regulations (viz. the EU Nitrates and Water Framework Directives), national initiatives and general public concern over the maintenance of a cleaner environment to reduce this leakage where it occurs. High inputs and minimal environmental impact are by no means mutually exclusive. However, there is much opportunity to make improvements in many systems, especially within dairy farms where, because of the complexity of nutrient transfers from soil to pasture/forage crop to animal to manures and back to land, with all the intervening management stages in-between, there is much opportunity for nutrients to escape into waters in drainage and to the atmosphere as gases. Good management practice to minimise these losses and increase the efficiency of nutrient use exists, not just in the research environment, but already in practical use on commercial farms. There is much need for this knowledge to be widely circulated and implemented into common management practice, not just for environmental benefit but also to contribute to the economic status of farmers.

The EU Intereg Green Dairy project has provided opportunity to do just that. Bringing together researchers and experts, the results from experimental farms, involvement of strategically placed commercial farms and their managers from 11 regions along the western Atlantic seaboard of the EU, stretching from Portugal in the south to Scotland in the north, has provided a platform to:

1. make progress in a better understanding of the complex controls over nutrient flows in a very diverse range of farming practices, climates and soils
2. investigate opportunities to improve nutrient use at the farm scale
3. understand better the impact of dairy farming on water quality in particular
4. provide a forum for researchers and contribute to a trans-national European debate, and
5. provide a mechanism for information exchange between researchers and practitioners and between farmers themselves.

The following volume contains much information which will be of value to scientists, farmers and policy makers with local, regional national and international interests.

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Dairy systems confronted by European environmental constraints

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Introduction

About a quarter of the milk of the world is produced in Europe, with its western part as most intensive centre. Specialised farms are common. Their use of fertilizers and feeds has strongly increased, because of their declining prices relative to those of the other main production factors: land and labour. Also developments in technology and education stimulated farm specialisation and intensification. As a result, the development of income of farmers was close to that of other European citizens, what is a target of the EU. However, there is concern about the environmental performance of dairy farms, because inputs of nitrogen (N) and phosphorus (P) in purchased feeds and fertilizers strongly exceed outputs in sold milk and animals, what results in large surpluses of these nutrients. On the long term surpluses are lost to the environment, and contribute to pollution of air (with ammonia and nitrous oxide), and water (with nitrate and phosphate). In addition, dairy farming is an important contributor to the emissions of the greenhouse gas methane (from animals and manure). Losses do not only damage quality of environment, but also represent a waste of limited resources, like energy (used to produce nitrogen fertilizers) or rough phosphates (used to produce phosphate fertilizers). A proper use of resources is also EU policy and, in general, bad use represents loss of income.

EU policies aim at reducing environmental degradation by legislation, education and research. Objectives and outlines for environmental legislation have been formulated in a number of Directives. National governments have to implement these directives as national legislation, and have to supply the EU with data regarding the development of the quality of environment, to evaluate the impact of legislation. Farmers have to comply with national legislation. If they don't they will lose their rights on direct payments. Income of most dairy farms is too low to continue without these payments.

In our contribution we first discuss briefly the EU-regulations with an impact on dairy farming, and we compare the newer *Water framework directive* with the older *Nitrate directive*, to find developments in directive characteristics. Next we focus on the potentials for farm improvements, and the main stages that should be gone through to realize in practice. Finally we formulate our opinion about how to stimulate improvement of environmental performance of dairy farms, taking into account their diversity.

1. European Union regulations with impact on dairy farming

In the Treaty of Rome, by which the European Union was established in 1957, environmental protection was not an issue. It was not until the seventies that our policy makers became aware of environmental problems. In 1973 the first *Environmental Action Plan* was established for a period of 5 years. Other plans followed and today we are in the sixth, that will run until 2010. These *Environmental Action Plans* resulted in a number of Directives, intended to realise the desired quality of water, air and soil.

1.1. Water

The *Nitrates directive* was introduced in 1991, to reduce water pollution by nitrates from agricultural. Member States have to establishment codes of good agricultural practices, to monitor water quality, to determine nitrate vulnerable zones, and to formulate action programmes for these zones to realise required water quality. Action programmes have to limit the period of application of fertilizers and to prescribe the minimum capacity of manure storage. The application of nitrogen from livestock manure should be 170 kg N/ha/year at maximum (including excretion of urine and faeces during grazing). In

regions with intensive livestock farming this level causes problems, because it restricts cattle density to about one cow/ha, including young stock, or forces farms to export manure, what is costly. National governments can ask for derogation, if they can make clear that application of more manure will not be detrimental to water quality.

The objective of the *Water framework directive*, introduced in 2000, is to achieve good ecological quality status for all waters in 2015, and to guarantee a sustainable availability of water as a limited natural resource. This has to be achieved by setting up River Basin Management plans. These have to be formulated in 2010 at latest. For dairy farming it is important that not only pollutions by nitrogen compounds have to be limited, but also those by phosphates, pesticides and medicines. Besides, this directive deals with water quantity, and therefore can restrict irrigation of grassland and forage crops.

1.2. Air

In 2001 the EU published *Directive 2001/81/EC, the National Emissions Ceilings*. The aim is to limit gaseous emissions of acidifying and eutrophying pollutants. Member states must limit national emissions with on average 10%, by 2010. It is up to the member states to decide what measures to take. For dairy farmers the needed reduction in the emission of ammonia is relevant, because the major part of volatilized ammonia originates from manure, produced by cattle farms.

In 2000, the European Commission launched the *European climate change programme*. This programme contains plans for how the EU will meet its Kyoto Protocol commitment, to reduce greenhouse gas emission by about 8% in 2012. There are three main sources for emissions from agriculture: 1) nitrous oxide (N₂O) from soils, mainly due to nitrogen fertilisation; 2) methane (CH₄) from intestinal fermentations by ruminants and 3) methane and nitrous oxide from manure. Cattle farms are the main contributors to these emissions.

1.3. Soil

Soil degradation processes can cause soil to lose its capacity to carry out its main functions. The EU Commission's communication *Towards a thematic strategy for soil protection* (2002) outlines the strategy to avoid soil degradation. Standards of good agricultural practices, to prevent erosion and to guarantee the maintenance of soil organic matter, have to be formulated by national authorities. For dairy farmers restrictions related to ploughing up grassland and the obligation to grow cover crops, directly after harvesting fodder crops, are most important.

Compared to the older *Nitrate directive*, newer EU-regulations provide more opportunities to take specific regional circumstances into account. The *Water framework directive*, for instance, demands implementation on the scale of the water basin. Newer regulations deal with several emissions, not with only one like the *Nitrate directive* does. The *Water framework directive* includes not only nitrates but also phosphates and pesticides. The *Nitrate directive* describes measures that should be taken in detail, like the maximum amount of manure that can be applied per ha. The newer directives are goal based, define environmental quality standards or limit the acceptable emissions per unit area. Also new is that the *Water framework directive* gives farmers the right to be involved in plan making (article 14).

2. Potentials for improvement

Improvement means that we have to reduce the differences between farm nutrient inputs and outputs, because the difference, the surplus, will be lost and damage environment. To find room for improvements of dairy systems we have to be aware of the intensive interactions among soil, crops and animals. Cows are fed home-grown and purchased feeds, in order to produce milk, which also causes manure production. The partitioning of mineral nutrients between milk and manure depends strongly on feed characteristics, which can be manipulated through the composition of the diet. Management also influences the durability of cows as 'milk producing engines' and therefore the number of young animals needed to replace cows. In general young stock uses proteins in the diet less efficient than lactating cows. Grass and forage crops are fertilized with home-made manure and

mineral fertilizers. However, not all nutrients in these fertilizers are taken up by the crops. A part is lost to ground- and surface waters or atmosphere. The uptake of fertilizer nutrients can to some extent be managed by the farmer. Management also affects soil quality in the long-term, with consequences for soil sensitivity to leaching and erosion. The cattle component and the soil/crop component of a farm interact not only through home-grown feed and manure, but also through grazing. Grazing is thought to improve animal health and quality of the grass-sod. Besides it is a cheap way of harvesting grass. However, grazing contributes also to grassland fertilisation by dropped faeces and urine, and the uptake from these droppings is much lower than from excrements produced indoors, and applied as slurry.

A farmer has to realize his ambitions at farm level. As nutrients are cycled from the soil, via home grown feed, through cattle and then back to the soil in manure, a measure taken to reduce nutrient losses from one part of the farming system often affects also other parts. Therefore, a measure can be beneficial for some environmental outputs but detrimental to others. As a consequence, environmental performance should be optimised by a farming system approach, controlling losses simultaneously in all stages of the cycle, taking into account the specific farm conditions (like region, soil type, hydrology, quota/ha, possibilities for investments or export of manure). As a result, the internal cycling of nutrients will be improved, what reduces needs for inputs of nutrients as mineral fertilizers or purchased feeds. Inputs can also be lowered by reducing the needs of cattle and crops. A reduction of the young stock to the level urgently needed to replace milking cows, can reduce the feed needs per ton milk quota considerably. The fertilisation needs of grassland are in general higher than those of fodder crops. However, fodder crops produce less protein and more energy. Balancing the areas of grass and forage crops in order to reduce fertilizer needs and to optimize protein and energy production will be beneficial.

What are the potentials of improvement ? It can be illustrated by comparing the results of the dairy farms on sandy soils in the Netherlands in the mid nineties, with today's results of the experimental farm De Marke, also on sandy soils. In the mid nineties most farmers became aware that environmental performance of their farms would no longer be accepted by society, and therefore they had to start changing. Experimental farm De Marke started in 1992, and has to realise very tight environmental goals, at lowest costs. All available knowledge is used to optimize a low emission system with a milk quota per ha close to Dutch average of all soil types. Milk production of the conventional farms was 12.8 tons milk/ha, that of De Marke was with 12.0 tons/ha somewhat lower.

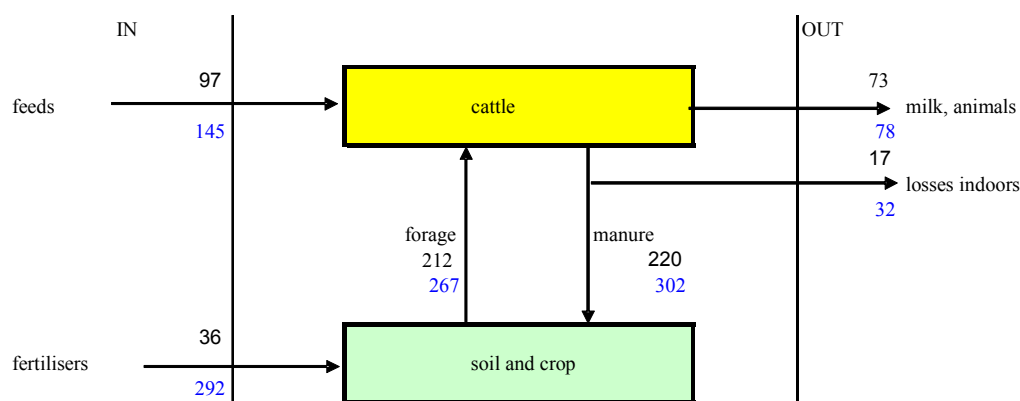


Figure 1: The main N-flows (kg/ha) of conventional dairy farms in the mid nineties (lower, bleu figures) and those of experimental farm De Marke in the period 2002-2005 (upper, black figures).

The dairy farm of the mid nineties imports 292 kg N/ha as mineral fertilizer and 145 kg N as purchased feed. Total N-input therefore is 437 kg. Only 78 kg N is sold as milk and animals, what results in a surplus on the farm gate balance of 359 kg/ha or 28 kg/ton milk (Figure 1). It means that only 18 % of the inputs leave the farm as dairy products, so 82% is lost to the environment. The phosphate surplus is 89 kg/ha or 7 kg/ton milk.

Fertiliser N-inputs at De Marke includes fixation by clover. Since 2005 mineral fertiliser is no longer applied. Results show a surplus of only 61 kg N/ha or 5 kg N/ton milk, a reduction of 83% compared

to the average practice in 1995 (Table 1). More than half of the N-inputs were recovered in dairy products. Phosphate surplus is only 1 kg/ha, what means that fertilisation and crop yield regarding P are almost in balance. The reduction of the phosphate surplus is almost 100%. Costs of milk production on De Marke are higher than those on commercial farms, mainly because of the higher costs of low emission housing, the enlargement of the slurry storage, and additional cost of health care, necessary to realize a high lifetime production per cow. Additional costs were estimated at about 2 cent per kg milk, but can be reduced by technological developments.

Table 1: Nutrient surpluses (kg/ha) on the farm gate balances of conventional dairy farms in the mid nineties, and those of experimental farm De Marke in the period 2002-2005.

	Conventional 1995	De Marke 2002-2005	Change
N			
- surplus/ha (kg)	359	61	- 83%
- surplus/t milk (kg)	28	5	
P₂O₅			
- surplus/ha (kg)	89	1	- 99%
- surplus/t milk (kg)	7	0	

The results of De Marke are not attainable by commercial farmers. A farmer has no access to all needed information, has in general not enough money for all investments and he cannot take the financial risks related to strong system changes, because his income is rather low. Nevertheless, De Marke shows potentials, and motivates farmers to consider improvements.

3. Main stages in farm improvement

In our opinion, there are three main stages in improving environmental performance by dairy farmers (Figure 2). The most difficult, and therefore maybe the most time consuming, is the first one: to get start. The farmer has to decide to change the way of farming. About 80% of the information that a farmer uses is applied by the man who sells him fertilizer and feed. He has to tell his main adviser that he takes the risk, related to a reduction in input. He has to find access to other information resources, to come closer to 'good agricultural practice, resulting in reduced wastes of inputs. But results will show an increased and stable income, what will stimulate him to accelerate his efforts. In that second stage he goes further than good agriculture practice. He optimizes his systems, being aware of farm specific circumstances. He is very interested in the opinion of other farmers, advisory man and scientists about possibilities for improvement. His income increases further but the system becomes more risky and asks for more management skills. In the third stage, costs of additional measures are only slightly lower, equal or even higher than profits. The farmer will only continue reducing surpluses if forced by legislation, or if research finds new attractive improvements.

With the intention to implement the Nitrate Directive the Dutch government introduced a mineral accounting system in 1998, with defined maxima for surpluses of N and P. Permitted surplus decreased over time and should be about 140 kg N/ha in 2005, the level that was thought to match with a content of 50 mg nitrate per litre in the upper groundwater of sandy soils. For phosphate a surplus of 20 kg/ha was the target. If surpluses exceeded the permitted levels, farmers had to pay high taxes. Farmers were free to decide how to realise reduced surpluses and free help was offered by independent knowledge institutes. Forced by that accounting system the average N-surplus of the dairy farms decreased to a level of 195 kg N/ha in 2002, a reduction of 46% compared to the level in the mid nineties. It was mainly the result of a strongly reduced input of mineral fertilizer (from 292 to 129 kg N/ha). Most important reason was the improved utilisation of animal manure (method of application, and time and quantity per application) and the reduction of grazing. As a result the efficiency of the farm (output/input) increased from 18% to 28%. Phosphate surplus decreased from 89 to 24 kg/ha, a reduction of 73%. No excellent management skills or high investments were needed to realise these results. At the start, farmers feared losses of income. No data are available, but most farmers now agree that income increased, by savings on purchased fertilizers. In 2002, the average Dutch farmer was in the middle of stage 2.

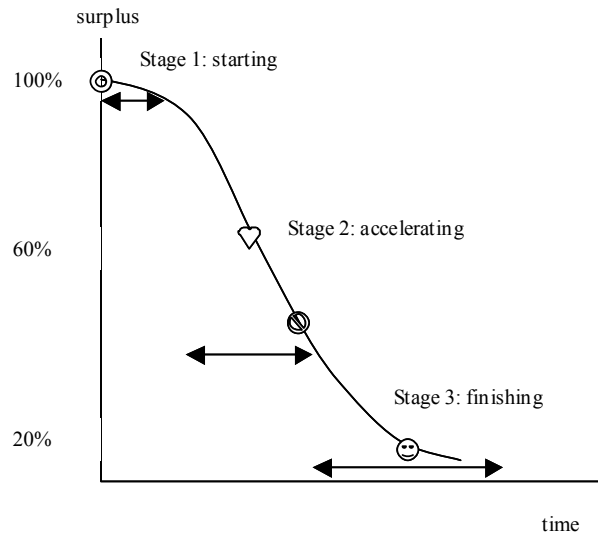


Figure 2: The main successive stages of improving environmental performance, and the position of Dutch farms (average mid nineties⊙ , average 200♥ , pilot farmers 2002-2004⊙ , experimental farm De Marke 2002-2005 😊; 100% = 359 kg N/ha).

Ten pilot farmers on sandy soils, participating in the project ‘Cows & Opportunities’ that started in 1999, agreed to realise the tight 2005 surplus targets as soon as possible, but certainly before 2003. Milk production per ha of these farms was over average, to make it more difficult. Farmers were advised by scientists (to make it extra difficult). However, they had to decide (and to argue) personally what measures to implement. The pilot farmers realised the target surplus of 140 kg N/ha, and reduced the surplus of phosphate to 13 kg/ha, about halve the level of their conventional colleagues and below the target level of 20 kg/ha. Compared to conventional farmers, they further improved the functioning of the soil/crop component, among others by growing a catch crop after maize. They also improved the cattle component, by reducing the protein content of the diet of milking cows, and by reducing the number of calves to a level urgently needed to replace cows. Financial analyses showed that the improvement of the environmental performance of the pilot farms also improved income, as a result of savings in purchases in fertilisers and feeds. On average, the annual incomes increased with 3,000 € per farm, but over average professional skills were needed to manage the farm properly. These farms reached almost the end of stage 2.

The introduction of the farm gate balance system showed to be successful in reducing surpluses. Nevertheless, the Dutch government had to decide to change legislation, because the measure oriented *Nitrate Directive* forces to formulate application norms for fertilizers. Goal oriented surplus norms for farm gate balances were not accepted by the European Commission as alternatives.

Conclusion: How to stimulate improvement of environmental performance of dairy farms?

Results of these examples show that improvement of environmental performance of intensive dairy farming systems can be substantial and financial attractive. Only for the last step (stage 3) a reduction in farmer’s income cannot be avoided. Why is it that farmers make no profits by implementing the first two steps voluntarily? Main reason is that farmers are not fully aware of the possibilities to gain profits from improved nutrient management. Most of the information they gather is provided by companies, selling them feed and fertilisers. For these companies high farm inputs are attractive. An education program and independent free advise can make farmers aware of the value of home made manure and forage, of the possibilities to reduce inputs of concentrates, to reduce the protein levels in the diet, and of other measures to improve the system. Scientist and pilot farmers should work out and demonstrate improved systems for the main practical situations, and tell farmers about how to get the financial benefits. It can help to translate common rules regarding ‘good agricultural practices’, intended to avoid wastes, into measure based regulations.

For stage 2 (accelerating) more and more farm specific information is needed and farmers have to be better technical educated. Measure oriented regulations can be contra productive, because they can hamper implementation of the best fitting farming system for the specific circumstances. Therefore, regulations should be goal oriented. The farm gate nutrient balance with maxima on permitted surpluses should be preferred in this stage. Acceptable levels of surpluses can be made dependent on regional conditions (soil type, hydrology, location) and goals. European countries should cooperate, like they do in the project 'Green Dairy', to find attractive ways to improve dairy farming systems, and to help to formulate environmental legislation that is cost-effective and secure.

For stage 3 more research is needed to improve measures and to find new ones, to judge sets of measures on experimental and pilot farms and to improve education. European knowledge should be combined into joint projects.

Dairy systems in the European regions of the Atlantic Area:

A discussion of the economic characteristics to complement the « Green Dairy » project

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Summary

The eleven regions participating in the project « Green Dairy »¹ are responsible for about a quarter of the dairy production of the EU-15. Although situated in the same climatic zone under oceanic influence, the diversity of the physical environment, the structures and the production systems remains considerable. To define this internal and external regional diversity and to place the groups of pilot farms of the "Green Dairy" project in perspective, a processing of individual data from the European FADN for the years 1999 to 2003 was realized. This communication is structured around three sections 1) some methodological elements necessary for the understanding of the results ; 2) the technical characteristics notably the dynamics of the structures, the productivity of the work and the feeding systems ; 3) the production costs and economic results of the farms as well as the regional dairy dynamic. The final discussion will concern the main assets and constraints of the systems and regions studied compared with the challenge of the future: the probable end of milk quota, a more open European and World market, the increase of the price of energy and more restrictive environmental regulations.

Introduction

The eleven regions participating in the « Green Dairy »² project are responsible for about a quarter of the dairy production of the European Union (EU 15). Although situated in the same bio-geographical area facing the Atlantic Ocean, the diversity of environments and, in particular, of climates is still great. The summers are hot and dry in the South justifying irrigation whilst they are mild with a relatively high rainfall in the North and thus favourable to grassland and grazing. The role of dairy production in the total farming production context varies according to regions, going from less than 10% in Aquitaine and in Scotland to more than 30% in Brittany, Galicia and Ireland. This regional diversity of the dairy sector is also to be found at the farm scale, in terms of the level of specialisation, intensification (animal and forage) or special feed systems.

To define this diversity, to account for the variations internal to each region and to place the farmers' groups of the pilot farms of the "Green Dairy" project in perspective, individual data from the European Farm Accounting Data Network (FADN) for the years 1999 to 2003 were processed. This discussion is structured around three sections: the first presents some methodological approaches taken to understand the results presented; the second deals with the dynamics of the structures at the level of work productivity and the feeding systems adopted; and the third centres on the level of production costs, the economic results of the holdings and the collective dynamic internal to each region. The concluding comments discuss the principal strengths and weaknesses of the systems studied compared with the challenges of the future: the probable end of milk quotas, the accelerated expansion of the market, the increase in the price of energy, and more restrictive environmental regulations.

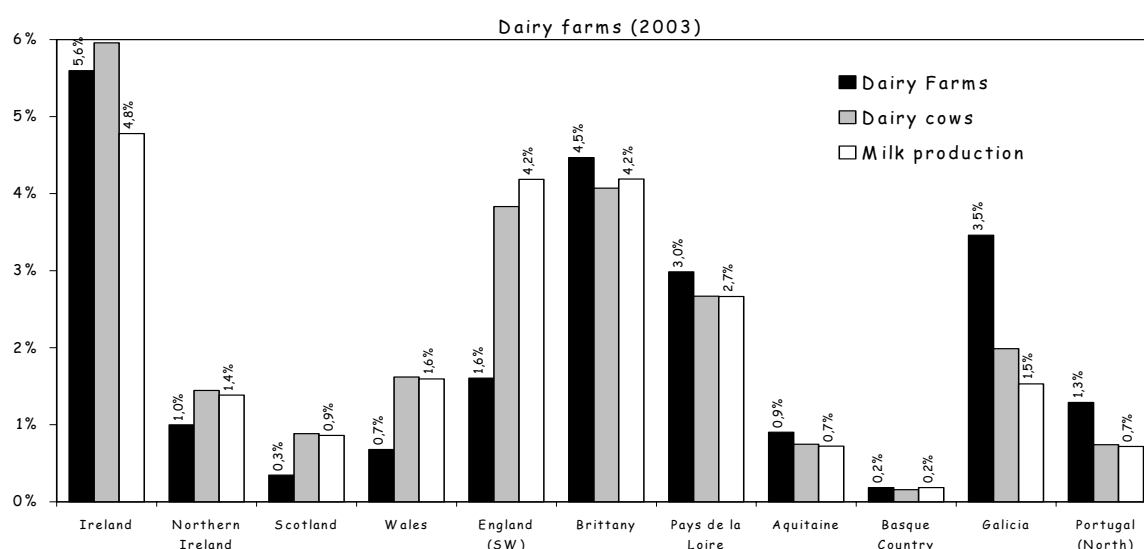
¹ The European project "Green Dairy" aims at comparing the environmental impact of the systems milkmen of the European Atlantic Space (Pflimlin and al, on 2006). Two networks of exchanges were set up : the one on the environmental evaluation (streams and losses of nitrogen and phosphor) of complete systems led (driven) in experimental stations in the various countries partners ; other one on the axes of progress recommended in exploitations dairywomen.

² The « Green Dairy » European project compares the environmental impact of dairy systems of the European Atlantic Area (Pflimlin et al, 2006). Two networks for information exchanges have been set up: one on the environmental assessment (flows and losses of nitrogen and phosphorus...) of complete systems managed in experimental stations in the different partner countries; the other on the opportunities for progress recommended for dairy holdings.

1. Some method elements

This discussion is based on data of the FADN³, a harmonized survey carried out each year for over thirty years in all the EU Member States. The FADN is a statistical tool constructed to be representative of fully commercial farms⁴ (Chantry, 2003 ; Blogowski, 2003). It provides detailed information on their structure, economic results and financial situation.

A first separation within the data base was applied to isolate "dairy" holdings. In this paper we defined these as all farms which have more than five dairy cows. This definition, which is different from the one that determined Types of Farming (EU classification), makes it possible to regroup the whole of dairy production into a single type but to also take into account those holdings which have associated other farming production systems along with the dairy activity (Chatellier, Jacquerie, 2004). At the EU level, the FADN (2003) groups together 13,586 dairy farms which should represent 457,700 dairy units (numbers after extrapolation) (table 1) As there are very few non-commercial holdings in the dairy sector, those units selected for our survey account for almost all of the Community dairy production. The eleven areas of the Atlantic Area of the "Green Dairy" project group together contain 103,000 dairy holdings, i.e. 23% of the Community total (and representing 24% of dairy cow numbers).



Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 1: The weight of the « Green Dairy » regions in the dairy sector of the EU at 15

The relative contribution of each of the eleven regions differs quite markedly: those of Ireland and Brittany are considerably greater than those of the Basque Country, Scotland, Aquitaine or the north of Portugal (Graph 1).

To carry out relevant comparisons between regions, in particular on the question of production costs (costs per ton of milk), we focussed the analysis on specialized farms (i.e. on units whose value of dairy production represents more than 60% of the value of the total agricultural production, subsidies included). At the EU level, the 292,700 specialized units in the Green Dairy region (64% of the total numbers) account for 75% of EU dairy production. For the eleven regions studied, these units cover overall 73% of numbers for 81% of the dairy production. These holdings play a very significant role in

³ Accessibility to the data of the European FADN of 1999 to 2003 lies within the scope of work completed by the Institut de l'Elevage and the INRA on the theme of work productivity in dairy farms in the North of the EU (Chatellier, Perrot, You, 2006).

⁴ The farms are regarded as commercial since they employ more than 0.75 Agricultural Work Units (AWU) or their Standard Gross Margin (SGM) exceeds a minimal threshold, fixed by Member States. This threshold is 1 SGM in Portugal, 2 SGM in Spain and Ireland, 4 SGM in Northern Ireland, 8 SGM in France and in the United Kingdom. The introduction of an entry threshold, fixed at more than 5 cows per holding, makes it possible to give more homogeneity between areas.

the regions of the North and South of the EU, but they are proportionally less well represented in the three French regions (Table 1). A complementary separation was finally operated to identify the specialized dairy holdings with an annual milk production greater than 200,000 kg. At the Community level, this category is made up of 161,300 farms with 63% of the dairy production (compared with, respectively, 44,300 farms and 68% of the dairy production in the eleven "Green Dairy" regions). This last group is more homogeneous and removes the results of small structures from the analysis, some of which will probably not survive in the medium or long term.

Table 1: The number of dairy farms according to the « Green Dairy » regions (2003)

	Dairy farms (together)			Specialised dairy farms			Specialised dairy farms > 200 Tons of milk		
	Sample	All	% of milk	Sample	All	% of milk	Sample	All	% of milk
Ireland	500	25 600	100%	421	21 300	89%	274	11 900	69%
Northern Ireland	139	4 600	100%	120	3 800	92%	101	3 000	86%
Scotland	56	1 600	100%	47	1 300	88%	44	1 200	87%
Wales	161	3 100	100%	140	2 600	93%	132	2 200	91%
England (SW)	181	7 300	100%	149	6 200	87%	138	5 600	85%
Brittany	398	20 500	100%	237	14 200	70%	180	9 600	57%
Pays de la Loire	217	13 700	100%	106	7 700	61%	71	4 800	49%
Aquitaine	72	4 100	100%	44	2 300	64%	23	1 500	53%
Basque Country	200	800	100%	198	800	100%	128	400	80%
Galicía	338	15 800	100%	242	10 300	81%	83	2 500	40%
Portugal (North)	202	5 900	100%	182	5 100	96%	86	1 600	64%
Total 11 regions	2 464	103 000	100%	1 886	75 600	81%	1 260	44 300	68%
Regions North	737	34 500	100%	617	28 800	88%	456	18 700	78%
Regions France	687	38 200	100%	387	24 100	66%	274	15 900	54%
Regions South	740	22 600	100%	622	16 300	87%	297	4 500	50%
EU-15	13 586	457 700	100%	8 673	292 700	75%	1 027	161 300	63%

Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

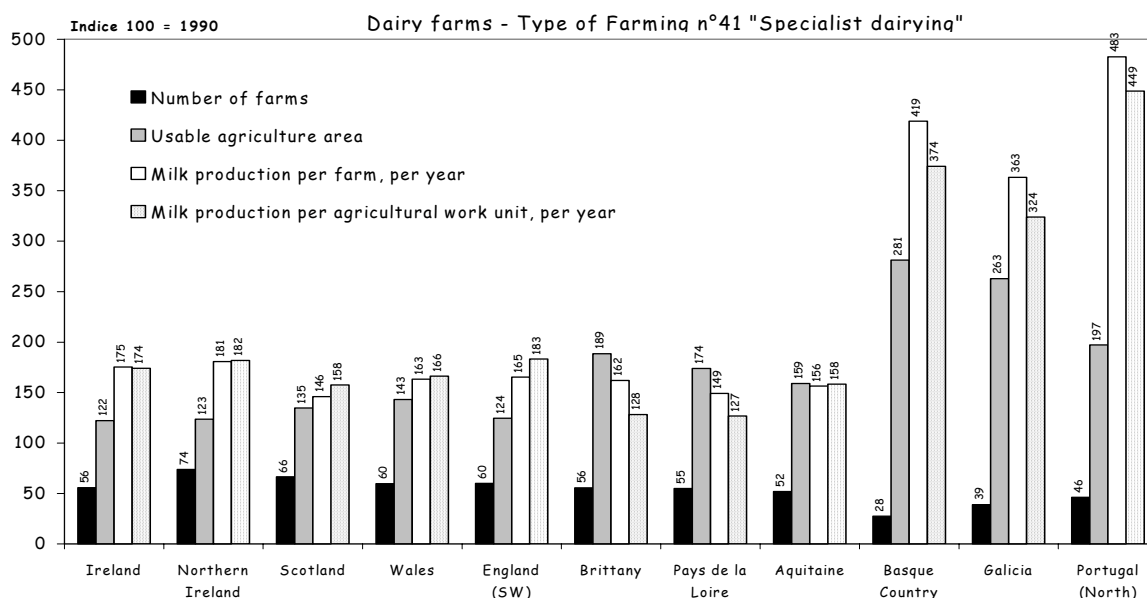
The FADN is a tool that is overall representative of dairy holdings, but the data selection requires prudence, especially for those groupings that comprise only a few observations. Thus, results for groups made up of less than 15 individuals are not presented here; this then affects the analysis of the disparity of economic results within each region (Aquitaine and the Basque Country are then excluded).

2. The dynamics of the structures, productivity and feeding systems

This second section concerns the structural characteristics of the dairy farms of the eleven regions studied and deals successively with two aspects: i) the reorganisation of the farms between 1990 and 2003 and the variations in work productivity, and ii) technical models and feeding systems.

2.1. The dynamics of the structures and labour productivity

The changes in dairy farms between 1990 and 2003 was analysed from standard FADN results and related to the Type of Farming n°41 "Specialist Dairying" (a very large majority of these farms come under the case of so-called "specialized" holdings).



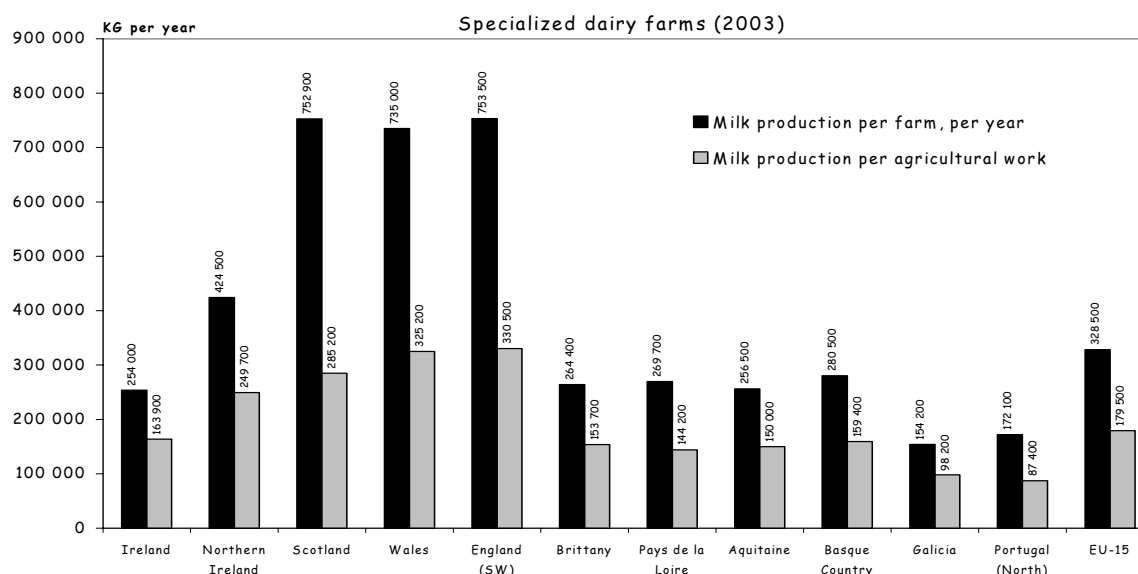
Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 2: The restructuring of dairy farms of the « Green Dairy » regions between 1990 and 2003

Between 1990 and 2003, the reduction in the number of dairy farms (based on an index of 100 at the beginning of the period) was significant in all the regions (Graph 2). Particularly strong in the two Spanish regions and in Portugal, it was more moderate in Northern Ireland. The intensity of restructuring of the farms must consider three principal points: the economic dimension of the farms in the south was particularly limited in 1990; the rise of associations of farms, in particular in France, meant that the reduction in employment was not proportional to the drop in farm numbers; the English farms had already benefited from a significant restructuring movement and, from the start, were significantly larger. Work productivity (production of milk per AWU and per year) more than tripled in the regions of the south and by 1.5 to 1.8 times in all the other regions. The average agricultural area of the farms also increased considerably.

The rate of restructuring of dairy holdings was influenced by the age pattern of the farmers, by possible opportunities for agricultural diversification, but also by the intervention methods of the national authorities (Ruas, 2002). This includes the measures taken under the national agricultural policy (subsidies for investments, financial incentives for the encouragement of young farmers, end-of-activity programmes, subsidies for farms located in zones with natural handicaps, etc.) and, in addition, the methods chosen for the application of Community regulations relating to the milk quota system. Unlike the United Kingdom (which prefers a relatively liberal approach), France opted for an administrative and territorial management of milk quotas (Boinon, 2000). This means that the quantities of milk released are not the subject of commercial competition, but are allocated free to farmers considered to be priority cases (Barthelemy et al., 2001). In the same way, production volumes are fixed at the department level, thus slowing down the process of geographical concentration of the supply in regions benefiting from comparative advantages (Daniel, 2002).

In 2003, and in spite of a considerable catching up in recent years, the average size of herds and the level of milk production per cow still remain very different between the dairy holdings of the regions of the South (Institut de l' Elevage, 2001) and those of the North. The average herd size was close to 30 cows in the three regions of the South (Table 3); about 40 in the three French regions, 45 in the Irish Republic, 60 in Northern Ireland and approximately 100 in the three other regions of the UK. Milk production per cow increased considerably in the Basque Country and Portugal. Although in the regions of the south, dairy production per holding is gradually approaching that of the French regions, the gap in production volume per holding remains very great when compared with that of the North (Graph 3).



Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

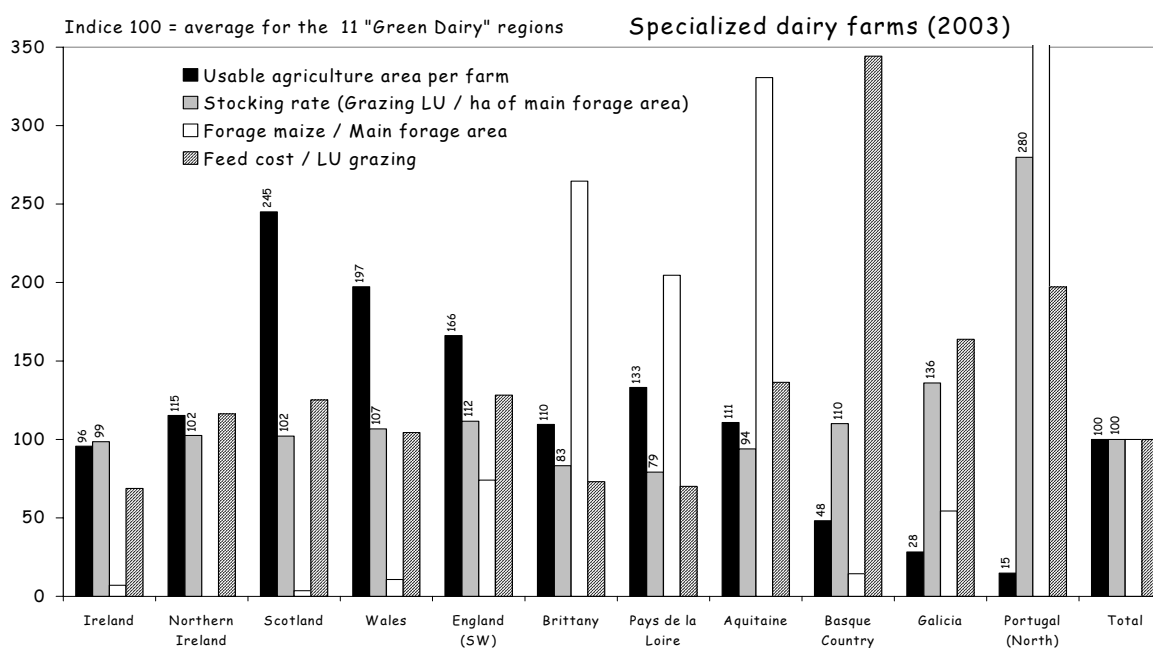
Graph 3: Annual milk production per specialised dairy farm and per AWU (2003)

The annual production of milk per specialized dairy farm, which is on average 313,400 kg for the eleven regions studied, varied in 2003 from 154,100 kg in Galicia to slightly more than 730,000 kg in SW England, Scotland and Wales. With a production of between 260,000 and 270,000 kg, the French regions occupy an intermediate position, comparable to that of the Basque Country. By comparing milk production to employment, hierarchies remain, but the variations are slightly closer (work productivity in the SW England is twice as great as in Brittany or Pays de Loire, three times more than in Galicia and four times more than in Portugal). The size of the workforce is, indeed, greater in the regions of the north, in particular because of more frequent recourse to paid employment (which represents approximately a third of the total workforce as compared with less than 10% in France). The size of the family workforce is quite stable from one region to another, with approximately 1.4 to 1.8 family Annual Working Unit (family AWU).

2.2. Feeding systems and land use

The average surface area of the farms in 2003 was about 8 ha in Portugal, 15 ha in Galicia and 25 ha in the Basque Country. In these regions, available land is still scarce and expensive. The fields are often very small and separated and rarely make grazing possible even in Galicia where grassland remains largely predominant. To compensate for the lack of area, livestock farmers buy large quantities of concentrate, and also of forage (alfalfa hay or maize silage). Due to total mixt ration (TMR), the 50% of concentrate in the diet does not seem to pose significant health problems and makes it possible to achieve to production close to 8,000 kg of milk per cow in the larger units. On the basis of irrigated area under maize forage and Italian ryegrass as a catch crop, the forage production can exceed 25 tons of dry matter per ha and per year and thus makes it possible to feed 5 cows per ha (even more in the Oporto region). In Galicia or in the Basque Country, where forage is still based mainly on grass silage, yields are limited and the stocking rates are 2.5 to 3 cows per ha. In the Basque Country, the average quantity of concentrate usually exceeds 3 tons per cow and per year and dairy performances are the highest not only in Spain but also in the whole of the "Green Dairy" regions. The area used for fodder surface is very limited, so opportunity to spread liquid manure is limited too. This is accentuated by the lack of slurry storage capacity, the priority of investments being given to increasing herds and material equipment. However, because of the low density of these modernized holdings and the significant role played by forests in the landscape, water pollution created by phosphorus or nitrogen surpluses does not seem to have resulted in a problem yet.

The situation is very different in the two regions of the West of France. Land is relatively cheap, which often makes it possible to have greater self-sufficiency in feed: forage production is frequently accompanied by a production of cereals for consumption on the farm, and there is a sufficient area for spreading slurry (except for certain holdings that have diversified towards pig production). The forage system is mainly based on maize forage (Graph 4) for the winter and interim periods and on grazed grass in spring and summer when the weather is not too dry. Temporary grassland containing perennial ryegrass is predominant and is integrated into the rotation which, with relatively low organic fertilisation, provide good maize or wheat yields. With these two good quality fodder crops (maize silage and grazed grass), the quantities of concentrate can be limited to less than one ton per cow and per year for a milk output near to 6,500 kg a year. With these relatively self contained autonomous feeding systems, mineral surpluses are fairly low. This fact is also due to the existence, for about ten years, of strong pressure from regulations (these zones were classified as nitrate vulnerable zones in 1994 in a context where concentrations of nitrate in waters sometimes exceed 40 mg/litre). This is more particularly the case in Brittany, a region which experienced a very significant development of housed pig and poultry units (+/-land less) until 2000 and which, consequently, had to set up a programme for the treatment of liquid manure surpluses.



Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 4: Agricultural area, intensification and purchases of feed in specialised holdings (2003)

In the regions of the North, it is mainly permanent grassland which supports grazing and silage production. Climate, structures and the land pattern are favourable enough to allow grazing for 6 to 8 months each year, even more in Southern Ireland. In this country, 85% of calvings are grouped at the end of the winter and the bulk of dairy production is during the grazing period with few concentrates required. For the other regions, autumn calvings are the norm and thus require more silage stock and concentrate input. With fertilizer rates of 200-250 kg N/ ha and a consumption of from 1.5 to 2 tons of concentrate per cow, the stocking rates are often more than two cows per ha and the N surpluses greater than 200 kg per ha. However, and in spite of liquid manure storage capacities still being insufficient, the nitrate contents of water remain satisfactory overall, at least in the zones with the most grassland.

Thus, with regard to the feeding systems, three large zones can be distinguished within the "Green Dairy" project: i) the regions of the South which are rapidly changing towards dairy systems that are very intensive in terms of the cow stocking rates in relation to the area involved, but in an overall environment that is not intensive, with a large proportion of forest; ii) regions of the West of France where, in spite of relatively well balanced and self contained systems, the quality of water is still below the required standard, mainly because of intensive pig and poultry units and the sensitivity of the environment; and iii) the rather intensive areas of the North, but with permanent grassland systems

that do not have obvious or immediate risks for water quality. This conclusion indicates that dairy farmers of W French, in spite of the efforts already made, have less room for manoeuvre to meet water quality constraints than those of the other zones studied.

3. The costs of milk production and the economic results

In the European context characterized by a fall in the institutional prices of butter and dried milk (compensated by the granting of direct payments per ton of quota), by an accelerated expansion of the markets (*via* the reduction in customs duties) and by the introduction of a system decoupling support measures from farm incomes (Chatellier, 2006), the question of the competitiveness of dairy farms becomes more urgent (Jamet, 2005). The comparative analysis, between zones, of the economic results of farms is therefore useful (IFCN, 2004), because these are located in the same competing zone, and they will be increasingly so in the future as the quota system could disappear. It also proves to be difficult insofar as the Member States do not all come under the same economic constraints (purchasing power parity, unemployment rates, costs of paid employment, etc.) and do not all apply identical rules as regards agricultural policy (management of milk quotas, incentive measures for establishing young farmers, agricultural profit tax rate, environmental regulations, etc.). Selected economic indicators (GFI, Family farm Income, etc.) correspond to those traditionally used in analyses made in France from the agricultural accounting plan. If the definitions are harmonized between countries, variations can nevertheless occur: depreciation times are not similar as the tax policies are different and they can influence the producers' investment strategies.

3.1. A comparative analysis of economic results between regions

The economic results between regions are compared here for dairy holdings having an annual milk production greater than 200,000 kg and for the financial year 2003 (Table 6). ⁵By limiting the discussion to this category, the impact of the "size" effect is partially removed and the calculation of the production cost brought to the ton of milk is not influenced by the costs inherent in other non-dairy activities on the farm.

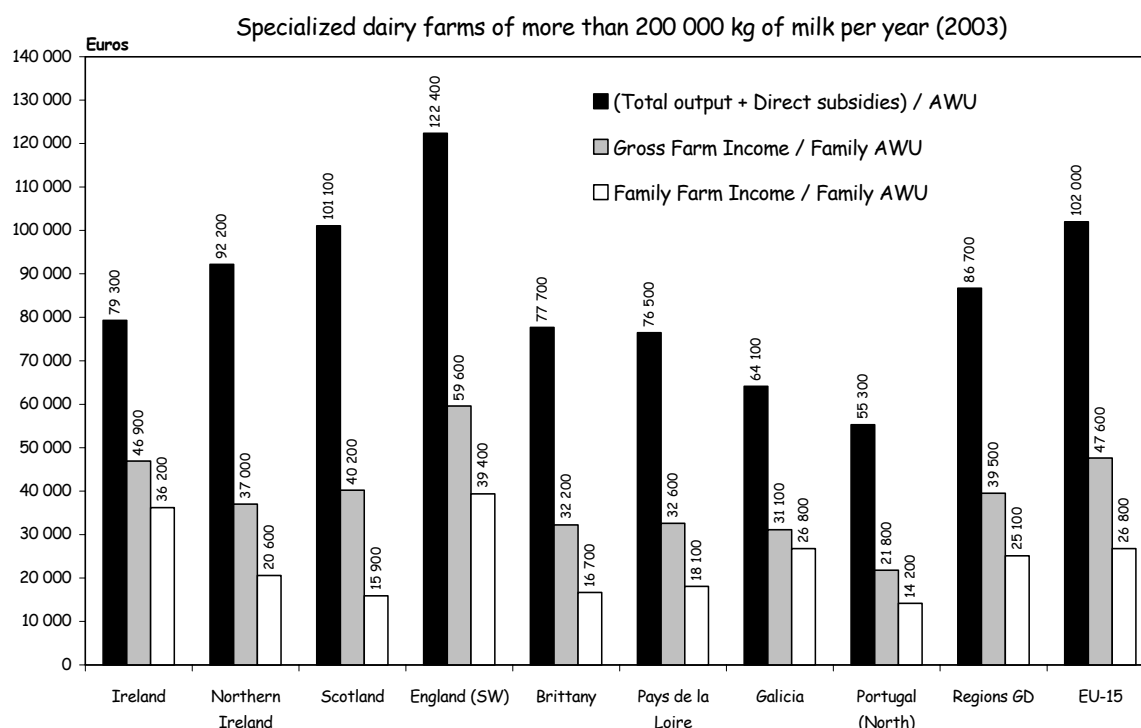
The average annual milk production per holding is between 300 000 and 360 000 kg for the two regions of the South, the two French regions and Southern Ireland. It rises to slightly more than 500 000 kg in Northern Ireland and slightly more than 800 000 kg in England and Scotland. In terms of work productivity (measured by milk production per worker or by the agricultural production value – including subsidies – per worker), the milk per AWU varies from one to two between the first group and the two regions with large structures in the United Kingdom.

The mean level of economic efficiency, measured by the ratio "Gross Farming Income ⁶ / Output + Subsidies" varies significantly between the regions studied. These variations are explained by an accumulation of factors (Allan, 1995): the price of milk, the amount of subsidies and, above all, the different costs (feed, fertiliser, rents, cost of paid workforce). It is lower in Scotland (28%) and in SW England (31%) than in the West of France (nearly 40%), Galicia (45%) or Northern Ireland (48%).

The English holdings, indeed, are penalised on this criterion by the existence of high labour costs. Because of these distinctly different efficiency levels, the regional variations observed are overall less significant at the level of the Gross Farming Income (GFI) than when they are compared at the level of production value (Graph 5).

⁵ Complementary tables (not included here) have the economic results for the specialised dairy farms (together) for the year 2003 (table 3) and for an average for 1999 to 2003 (Table 2).

⁶ GFI = Production of the financial year (excluding purchases of animals) - Intermediate consumptions (food, seeds, etc.) - Rents and other tenancy costs - Insurance + Reductions and rebates - Taxes - Costs of personnel + Refunding of VAT + farm subsidies + Insurance compensations.

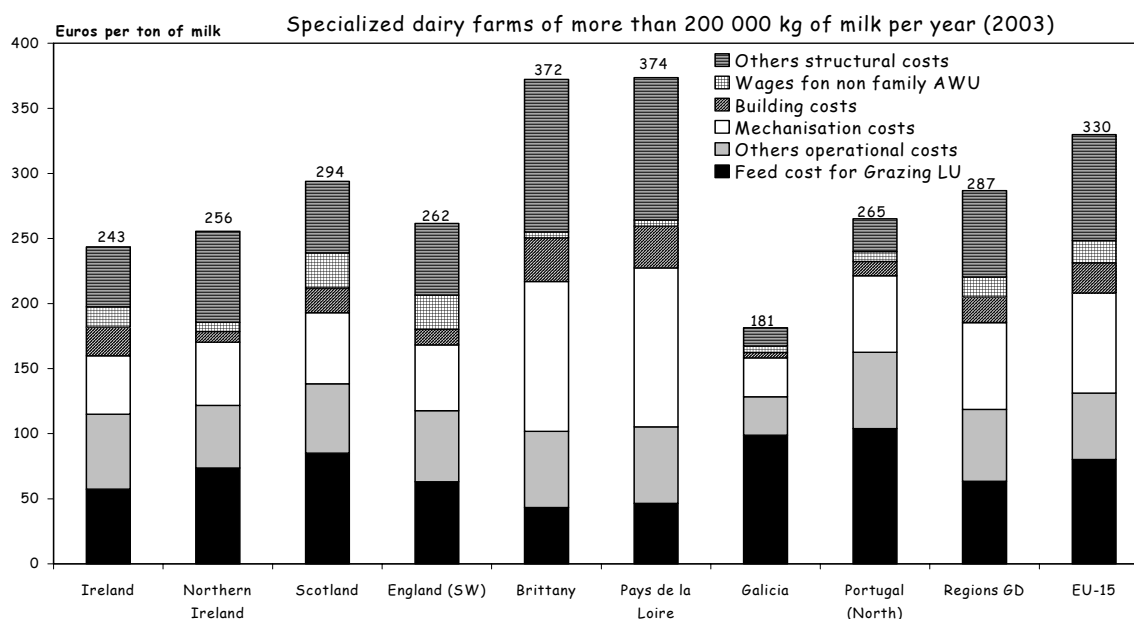


Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 5: Average economic results per worker (2003)

The Family Farm Income (FFI) per family AWU, which is sensitive to the effects of the current situation including price of milk, forage yields, etc., goes beyond the GFI indicator to take into account the costs associated with past and current investments (including depreciations and financial costs). It varies from 14 200 euros in Portugal to 39,400 euros in SW England (where the cost of living is quite higher). The dairy farms from the West of France give a farm income per family AWU similar to that of Scotland, where, however, the units produce twice as much milk (these results are validated by table 2 presenting averages over five years). In contrast, the holdings in England which have a similar herd and system to that of Scotland have twice the income per family worker. The good performance of the farms in the Irish Republic deserves to be underlined. They provide a farm income twice that of the French units, and with a labour productivity which is only slightly higher.

The analysis of production cost per ton of milk provides some figures that are useful to explain the disparity of the average economic results observed between regions (Butault et al., 1991). It must, however, be placed in relation to the price of milk (lower in Ireland and the UK than in France), the proportion of meat (as a dairy by-product) or cash crops and possible subsidies granted (also higher in France than in the UK). The total cost of production is divided into six headings: purchases of feed; other operational costs (fertilisers, seeds...); cost of mechanisation (depreciations in equipment, contract work, maintenance of equipment, fuel); costs of buildings (depreciations in buildings, upkeep); paid labour (wages and contributions); and other structural expenses.



Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 6: The amount of costs per ton of milk (euros, in 2003)

For specialised dairy farms with more than 200,000 kg, the production cost of a ton of milk rises, on average, for the 11 "Green Dairy" regions to 287 euros (Graph 6), i.e. 13% lower than the average calculated for EU 15 (this gap remains close when the calculation relates to the whole of the specialised units). This competitive advantage (Saha et al. , 2003) is still quite modest, however, insofar as the dairy farms in the "Green Dairy" regions receive a lower price for milk than that observed in other partner countries, such as Austria, Denmark, Italy or the Netherlands. With costs equivalent to 181 euros per ton of milk, Galicia has the best position among the eleven regions studied, in spite of high animal feed costs. The total costs are also low in Ireland (Thorne, Fingleton, 2005), namely 243 euros per ton of milk (including 115 euros of operational costs and 129 euros of structural costs). As had been highlighted from the FFI indicator per family AWU, the situation is less favourable for the West of France where the size of the farms is comparable to Ireland. These two French regions are penalized by high mechanisation costs (122 euros per ton of milk in the Pays de Loire or 115 euros in Brittany, compared with 50 euros in the south-west of England and 45 euros in Ireland). On the other hand, they have lower feed costs: the feed costs per grazing LU (except home-produced feed) represents about 45 euros per ton of milk in these two regions as against 57 euros in Ireland and 104 euros in the north of Portugal.

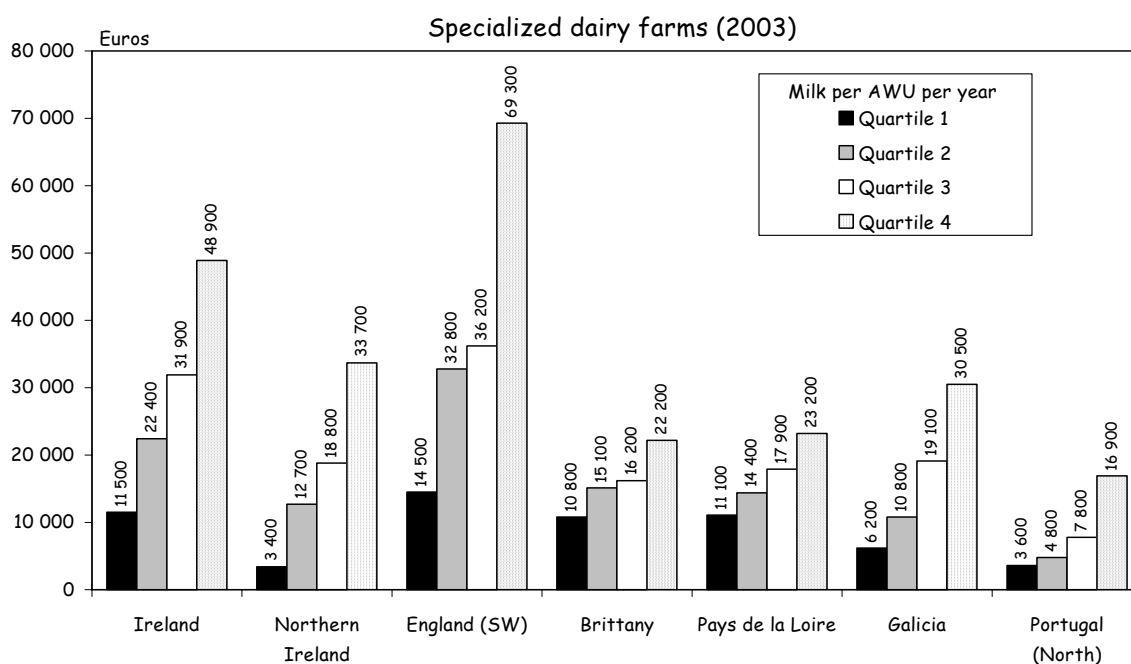
The comparison between regions of the financial situation of dairy holdings is difficult because of the diversity of the national contexts. This diversity relates to the price of land (very high in the British Isles and the regions of the South compared with the French regions), the way companies are financed or taking into account an accounting value for milk quotas (including if these were not bought). Thus, in specialised units with an annual dairy production higher than 200,000 kg, the amount of the recorded assets, when brought to the ton of milk produced, is three times higher in the Irish units than in the West of France. It has to be noted, however, that the financial costs per ton of quota is lower in Ireland than in Brittany (respectively, 11 and 20 euros per ton). This observation shows the existence of a more or less wide separation between countries in the estimated value of the assets (including land and milk quotas) and the financial costs of loans taken to acquire them. In the same way, the question of the method of transferring holdings to new owners or tenants is central to understanding the current financial situation of the farms (i.e. patrimonial *versus* economic approaches).

The farm debt rate is thus strongly influenced by the method of calculating the value of the assets. The amount of the debts per AWU is approximately five times higher in the French West, compared with the two regions of the South, which, as shown by the analysis carried out previously on restructuring between 1990 and 2003, have experienced fast growth in their production rates.

3.2. Significant disparities within each of the regions

The comparison of the results of the dairy holdings between European regions should not make us forget the existence of significant disparities within each region. So, to take account of this, FADN data for the year 2003 were processed in two ways for all the specialised dairy holdings: i) the first divided the farms according to four classifications determined on the basis of the value of each class of work productivity (measured by the milk production per AWU and per year); the second proceeds in a similar way for an indicator of economic efficiency (GFI/Output + Subsidies). The value of the four classes was then calculated within each zone considered.

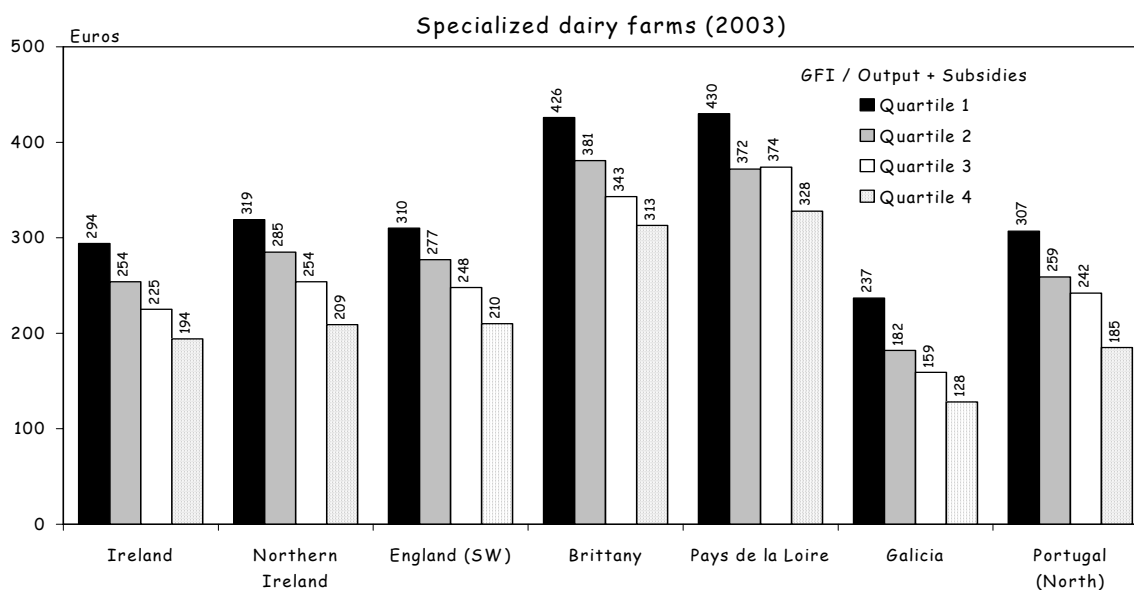
In all the regions studied, the holdings benefiting from the best work productivity (class 4) are also those which provided the best FFI per family AWU (Graph 7). The effect of work productivity on the level of income is more marked in Ireland and in the United Kingdom than in the regions of the south or in France. This is due to two principal reasons: i) the gaps in productivity between the two extreme classes are more accentuated in these zones where the national agricultural policy is less interventionist (in France, the control of structures leads to limiting the size of the largest holdings and thus in reducing differences between the two extreme classes); ii) the British and Irish holdings of class 4 are favoured by obtaining a better production cost per ton of milk than units of the other classes (this situation suggests the existence of a slight phenomenon of economy of scale is not found in the other regions studied). The holdings of class 4 are also, in all the regions, those which have most recourse to investments, whether in absolute value per year or *pro rata* of agricultural production (Table 4).



Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 7: The farm income per family AWU according to the quartiles of work productivity

This analysis, based on average results per class, does not mean that all the average size holdings are necessarily less profitable than the larger units. Some of them indeed manage to have better incomes because of increased economic efficiency. Obtaining better efficiency includes the cumulated effect of an overlapping set of factors: the technical skill of the farmer; the degree of autonomy of the feeding system; the price of milk (linked to its quality or its method of use) and the method of acquiring the means of production (individual purchases or in groups, externalisation of tasks, etc).



Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Graph 8: The production cost per ton of milk according to the quartiles of economic efficiency

In each region, significant differences in production costs are observed between dairy holdings (Graph 8 and Table 5). The differential is, in the various zones studied, nearly 100 euros per ton of milk between the two extreme classes (classes 1 and 4). The farms of Brittany or Pays de Loire in the best class of economic efficiency have a production cost higher than the lowest Irish class.

3.3. « The dairy environment » and the collective dynamic of the farmers

The analysis of the economic situation of milk producers must not be limited only to the observation of statistical data. These data do not always take account of "local dairy environments", namely the context (e.g. sociological, economic and political) on which these results depend. On the basis of work recently published by Institut de l'Elevage (2006) and information discussed with local experts, in particular those engaged in the "Green Dairy" project, several priority findings deserve to be emphasized for the principal zones studied.

In this analysis, English milk producers apparently have comfortable incomes compared with other regions, but their morale still seems to be fragile, especially after a difficult decade marked by several serious health crises (BSE, foot-and-mouth disease). For several years, the United Kingdom has not achieved the milk quota to which it is entitled, with an under-achievement of approximately 2% of the volume. This situation comes under a national context where the price of milk for producers is amongst the lowest in the EU (along with Ireland) and where the returns from the sale of beef and veal by-products have regularly decreased. In the same way, the right-to-produce or quota market does not seem very dynamic (contrary, for example, to that of Denmark), and this phenomenon has been accentuated since the application of total decoupling since 2005.

Unlike the situation in the two regions of the West of France, milk production in the UK and Ireland is not fixed within territories by the milk quota distributions. The effect of this is to discourage the least efficient producers and accelerate the process of geographical concentrations of the supply. Thus, considerable volumes of milk (4% of the quota of the United Kingdom) have left the East and South of England to go to Northern Ireland (McCluggage, 2005) (where production increased by almost a third between 1995 and 2005) and to a lesser extent Scotland and Wales (Livestock Institute, 2006). It is important, above all, to place the income of English milk producers in perspective in the economic context of the country: the average income of the working population is, on average, higher than in most of the other European regions (because of economic growth); prices are expressed here in euros

whereas it is the pound sterling⁷ which is applied; many holdings have limited their investments, which raises questions about the prospects for the long-term survival of farm structures that have not modernised their production methods, in particular to face up to the stricter application of the Nitrates Directive and the Water Framework Directive. This last remark is also true for the Irish Republic.

In spite of obtaining an excellent economic efficiency ratio and a high income per family AWU (compared with the other regions), it seems that many Irish milk producers hesitate to make the investments (e.g. slurry storage) required because of the classification in 2005 of the whole of the country as a nitrate vulnerable zone. Ireland, which produces approximately five times more milk than its domestic consumption, is very dependent on its competitiveness for export. The suppression of export subsidies and the drop in the institutional price of 'industrial' dairy products (butter and dried skimmed milk) are two facts that could have a negative effect on future prospects. As the economic situation in Ireland is very dynamic, with one of the lowest unemployment rates in the EU, this could have a negative influence on encouraging young people to remain in agriculture with other opportunities being available in trades considered to be less demanding. This evolution could, in addition, be reinforced by the fact that the price of land is very high thus, and in spite of historical cultural resistance to this, encouraging some farmers to sell their land.

The milk producers of the West of France, compared with the other regions of the Atlantic Arc, have had a slower increase in their work productivity⁸ and have currently higher production costs (per ton of milk). These can be partly explained by the modernisation of production systems (e.g. bringing livestock buildings up to standard) and by changing to agricultural contractors for harvesting maize forage. In this zone, tenant farming remains predominant and the principle of compensating the brothers and sisters applies when the working farm asset is taken over by one of the children. This mode of transfer is different from that practised in Ireland and Galicia where more than 80% of areas are in ownership and where the transfer of the land as an inheritance is carried out almost cost free to whoever takes over the succession: encouragement of the young is thus favoured and the take-over cost is minimal. The dairy sector in the West of France is, as in Ireland, weakened by the recent change in the Common Market Organisation (CMO) of milk and dairy products, insofar as nearly a third of its local production is used in the form of industrial products (Institut de l'Elevage, 2005). To face the challenges of tomorrow, the milk producers of Brittany and the Pays de Loire, however, benefit from several factors: the price paid for milk is higher than in the other zones studied; probably more room for manoeuvre to contract the level of costs; a high density of farms and processing companies (which makes it possible to limit collecting costs and stimulate a collective environment favourable to the organisation of livestock activities); a high single payment (which is explained by taking into account part of the subsidies to land under maize forage).

In the southern regions, mainly in Galicia (Maseda et al. , 2004), and taking into account the very fast rate of restructuring, the size of dairy farms could soon join those observed in the West of France and Ireland. This change should continue on the basis of family farms having a limited need for paid labour. In the Basque Country, the catching-up has been particularly spectacular in the past decade: the size of the herds has increased at the rate of two cows per year and the output per cow has progressed, each year, by 220 kg (as against only 80 kg per annum in the West of France, i.e. a considerably lower rate than the British situation). In Galicia, the production cost par ton of milk is low (Graph 6) and milk remains a major economic activity because the unemployment rate is high and has been accentuated by the reduction in fishing activities. As a result, installations are maintained and this area is even buying up quota from other regions or autonomies.

⁷ Expressed in pounds sterling, the price of milk dropped by 30% between 1995 and 2000; since then it has more or less stabilized.

⁸ In the analyses concerning the productivity (production of milk by AWU) and the remuneration of labour (FFI by family AWU), the unit of work must be interpreted with care. It often represents some 60 hours a week in Irish farms (with very few vacations) whereas in France the farmers expect a higher quality of life even if it means financing a replacement service. By way of illustration, the milk producers of the Pays de Loire, have noted that their incomes were similar to those of other animal producers whose routine work pattern very different, and consider that the priority must from now on be given to simplification, mechanisation and the organisation of work.

Conclusion: strengths and weaknesses resulting from future issues

To make predictions about the future of the European dairy sector in 2015 remains a difficult exercise as many uncertainties remain, in particular the choices which will be made as regards agricultural policy. Nevertheless, and without making excessive predictions, it appears that several notable developments could take place within ten years: the abandonment of the dairy quota system in the context of an accelerated expansion of the market resulting from reduced customs duties and the suppression of export refunds; the increase in the price of fossil energy; the strengthening of standards and environmental constraints, mainly those relating to water quality. Faced with these potential changes, what are the strengths and weaknesses of the dairy systems of the regions studied ?

Suppression of dairy quotas. This could lead to the geographical location of dairy production changing in every country, to either the benefit of the most competitive regions because of their available natural resources, their networks of food-processing enterprises, or their proximity to centres of consumption. The intensity of these movements would then depend primarily on the strategies adopted by the milk processing companies, whose role of directing the supply would be consolidated (to the detriment of the national authorities). The United Kingdom, in freeing the quota market, has already allowed migrations of dairy production from the East and Centre of England (and even from the South West) towards Northern Ireland and, to a lesser extent, towards Wales and Scotland. This geographical shift of production will continue in the next years, with or without the dismantling of milk quotas. The growth of production volumes in Northern Ireland will become more moderate because of the regulatory environmental constraints which will be apply. Southern Ireland could, for its part, accommodate much more milk production. The dairy sector uses only one third of the total grassland area . The other two third are used in extensive systems by beef and sheep production, which show some signs of declining since decoupling was set up in spite of a very favourable beef price. In Spain, the region of Galicia has already benefited from a positive transfer of milk quotas, but this has raised some political reactions from those regions adversely affected. In France, a suppression of milk quotas, which would result in a complete break in the link between land and milk production (Chatellier and Jacquerie, 2005), would have significant repercussions, in the medium term, on historical regional balances. Milk production could decline considerably in zones with a combination of unfavourable factors: low density of dairy cows to the square kilometre; individual small size holdings; modest commercial use of locally produced milk. The regions of the West of France which currently account for 45% of national milk production could then be consolidated in the measure, but where this growth in volume remains compatible with the environmental requirements (at the small agricultural region or catchment scale).

Increasing price of fossil energy. Such a prospect could generate a long-term increase in all energy sources and have a positive impact on the price of cereals. It would be potentially less penalising for dairy systems which are the most economical in mineral fertiliser, concentrate and mechanisation costs. This is in particular the case with the Irish systems, with the exception of the "fertilisation cost" item which could be reduced with further uptake of the use of white clover. Conversely dairy systems in the south of the EU are not so well positioned. As high consumers of concentrates, they could be encouraged (although in a difficult local market) to expand the farm size to increase fodder production and thus gradually become more self-sufficient. In the regions of the West of France, such a change is likely to stimulate collective approaches to reduce mechanisation expenses.

The strengthening of environmental constraints. Faced with the "Nitrates Directive", the dairy holdings of the French regions can take advantage of having a considerable advantage compared with their counterparts in the North and South, in particular with regard to the slurry storage capacities already constructed and depreciating (Le Gall et al., 2005). The situation is different in the Southern and Northern Ireland which have just declared, in 2005, the whole island as a nitrate vulnerable zone. Many Irish producers, for whom the slurry storage capacity is often less than two months, now realise that they must face up to the requirement for making significant investments. In addition, the principle of conditionality of subsidies reinforces the pressure on livestock farmers who are worried about current negotiations with the European Commission relating to obtaining a derogation for the authorized threshold of 170 kg N/ha, in organic manures. Among the regions of the South, only Galicia could accommodate more milk production because it has significant areas under grass, which

are still not used very intensively. This would probably suppose a return towards more grazing and a reduction or a slower increase in the performances per cow. But it is the "Water Framework" Directive which is the greatest unknown factor. This will require, between now and 2015, a good ecological status for all waters (surface, ground and coastal). This objective will result in placing greater emphasis on problems of eutrophication that happen at a much lower concentration of nitrate than that required for drinking water. Importantly, the thresholds of phosphorus surpluses could become more limiting than those of nitrogen.

The "Green Dairy" project which stimulated this investigation on the situation of the dairy holdings within the eleven European areas of the Atlantic arc has tried, through exchanges between researchers, company advisers and livestock farmers, to increase knowledge relevant to more sustainable European dairy systems. These systems must not only be adapted to the strengths and weaknesses of the local environments, but they must also be socially attractive and economically profitable.

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Table 2: Average characteristics of specialised dairy farms over 5 years -1999-2003

	Ireland	Northern Ireland	Scotland	Wales	SW England	Brittany	Pays de Loire	Aquitaine	Basque Country	Galicia	North Portugal	Total 11 regions	Regions North	Regions France	Regions South	EU-15 (total)
Number of holdings	22 220	4 220	1 430	2 980	6 710	14 100	8 240	2 220	1 070	12 450	4 860	80 490	30 360	24 560	18 380	323 810
Structural characteristics (jobs, areas, herd and intensification)																
Agricultural Work Unit (AWU)	1,57	1,69	2,69	2,17	2,29	1,64	1,73	1,62	1,68	1,55	2,07	1,74	1,78	1,67	1,70	1,78
AWU non family (paid) / AWU total (%)	12%	8%	32%	25%	37%	4%	3%	8%	3%	2%	14%	12%	20%	4%	6%	11%
Usable Agricultural Area (UAA)	47	58	128	91	85	54	64	52	23	13	8	49	59	57	12	49
Forage surface (FS) /UAA (%)	98%	98%	91%	96%	86%	72%	74%	64%	96%	98%	92%	86%	93%	72%	97%	80%
LU Grazing	84	104	216	180	153	61	73	55	40	32	39	79	106	64	34	72
LU Grazing / FS	1,8	1,8	1,9	2,1	2,1	1,6	1,5	1,7	1,9	2,6	5,2	1,9	1,9	1,6	2,9	1,9
Dairy cows	45	61	108	100	100	38	39	39	30	25	28	47	60	38	26	44
Milk production																
Milk production per holding (kg/year)	228 400	367 300	688 200	621 600	672 700	250 000	253 900	240 100	210 300	132 900	176 800	283 600	347 900	250 300	148 200	287 100
Milk production per AWU (kg per year)	145 500	217 100	255 600	287 000	294 300	152 000	146 800	148 400	124 900	85 600	85 500	163 100	195 700	149 900	87 400	161 300
Milk production per dairy cow (kg/year)	5 100	6 000	6 400	6 200	6 700	6 600	6 500	6 200	7 100	5 200	6 300	6 000	5 800	6 500	5 700	6 500
Milk production per ha of FS (kg/year)	5 000	6 500	5 900	7 100	9 300	6 400	5 400	7 300	9 700	10 700	23 800	6 700	6 300	6 100	12 800	7 300
Costs per ton of milk (euros)																
Total costs	263	276	344	276	295	349	364	401	257	166	270	294	284	359	206	335
Operational costs (not counting home-grown)	120	124	145	125	131	105	116	154	170	114	162	123	127	113	133	127
* Feed for grazing stock except home-grown)	57	71	86	68	69	40	50	69	145	84	106	64	65	46	95	73
Structural costs	143	152	198	151	164	244	248	247	87	53	109	171	157	246	73	208
* Mechanisation costs	51	56	61	56	57	109	117	123	30	29	62	69	55	113	40	85
* Building costs	27	9	16	19	15	27	25	25	14	8	11	20	21	26	9	24
* Tenant farming	16	17	11	12	18	23	28	19	4	1	2	17	17	24	1	20
* Farm taxes	1	2	4	0	0	6	5	6	1	0	0	2	1	6	0	4
* Wages for non family AWU	12	7	32	21	31	4	4	9	4	3	9	14	22	4	5	14
* Financial costs	12	12	16	18	17	18	17	9	5	2	6	14	14	17	3	19
* Other structural costs	24	49	59	25	25	58	52	56	30	10	19	35	28	56	15	41
Economic results																
Operational costs / output + subsidies	29%	35%	37%	35%	35%	22%	24%	33%	50%	28%	41%	30%	32%	24%	33%	28%
Structural costs / output + subsidies	34%	43%	50%	42%	44%	52%	50%	52%	25%	13%	27%	41%	40%	51%	18%	45%
Subsidies (€)	8 400	6 500	15 400	16 100	17 200	12 300	15 000	14 400	3 100	500	3 400	9 400	10 700	13 400	1 400	12 900
Subsidies / FFI (%)	26%	25%	56%	34%	40%	44%	49%	83%	17%	2%	26%	32%	31%	48%	7%	42%
Total output (€)	86 300	123 400	254 700	207 500	233 400	105 200	109 800	99 200	68 800	54 200	66 500	107 500	126 600	106 200	58 100	118 800
Milk production (%)	76%	82%	77%	82%	80%	74%	73%	75%	92%	73%	82%	77%	78%	74%	77%	77%
Gross Farming Income (€)	41 800	48 500	85 100	76 300	73 700	48 000	50 600	36 600	27 200	26 400	22 300	44 900	50 900	47 800	25 300	53 000
GFI / Output + subsidies	44%	37%	32%	34%	29%	41%	41%	32%	38%	48%	32%	38%	37%	40%	43%	40%
Family Farm Income (€)	32 000	26 200	27 700	47 000	43 300	28 200	30 600	17 300	18 100	23 200	13 400	29 100	34 200	28 000	20 200	30 500
FFI / Family AWU (€)	23 100	16 800	15 000	29 000	29 900	17 800	18 300	11 600	11 200	15 300	7 500	19 000	24 100	17 400	12 700	19 300
Assets and investments																
Total assets (€)	723 200	719 000	1 256 500	894 900	937 900	230 800	227 800	227 500	147 800	253 200	113 200	488 700	796 800	229 500	208 400	602 300
Total liabilities (€)	37 200	33 100	164 200	151 200	182 600	97 800	92 500	54 900	18 400	8 000	14 300	66 300	75 200	92 200	10 200	114 300
Gross investment / output + subsidies (%)	11%	15%	14%	15%	12%	15%	13%	14%	13%	9%	12%	13%	12%	14%	10%	17%
Gross investment (€)	10 900	20 000	36 900	32 900	28 800	17 200	16 700	16 100	9 100	4 900	8 200	14 800	16 000	16 900	6 000	21 900
* Agricultural lands, permanent crops (€)	900	0	2 300	5 300	3 200	1 600	1 200	1 000	1 800	200	200	1 200	1 500	1 400	200	3 000
* Quotas and acquisition costs (€)	2 800	4 400	2 100	8 100	7 400	0	100	0	-200	600	300	2 100	3 800	0	500	3 100
* Building (€)	3 400	0	4 600	6 300	5 100	5 600	5 100	4 400	4 000	1 300	1 500	3 600	3 800	5 300	1 400	6 300
* Equipment (€)	3 800	9 000	17 800	11 000	12 500	9 800	9 900	11 000	3 500	2 000	5 800	7 000	6 400	9 900	3 000	9 300

Sources: FADN UE, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Table 3: Average characteristics of specialised dairy holdings for 2003

	Ireland	Northern Ireland	Scotland	Wales	SW England	Brittany	Pays de Loire	Aquitaine	Basque Country	Galicia	North Portugal	Total 11 regions	Regions North	Regions France	Regions South	EU-15 (total)
Number of holdings	21 330	3 840	1 280	2 570	6 160	14 170	7 700	2 250	830	10 350	5 120	75 590	28 770	24 120	16 300	292 680
Structural characteristics (jobs, areas, herd and intensification)																
Agricultural Work Unit (AWU)	1,55	1,7	2,65	2,27	2,28	1,71	1,88	1,73	1,76	1,57	1,97	1,76	1,75	1,77	1,71	1,83
AWU non family (paid) / AWU total (%)	13%	8%	29%	29%	35%	4%	3%	13%	3%	3%	10%	12%	20%	5%	6%	14%
Usable Agricultural Area (UAA)	50	60	128	103	87	57	70	58	25	15	8	52	62	61	13	54
FS /UAA (%)	97%	98%	89%	96%	86%	73%	73%	60%	97%	99%	92%	86%	93%	72%	98%	79%
LU Grazing	89	113	217	197	156	64	75	61	50	37	37	84	109	67	38	80
LU Grazing / FS	1,8	1,9	1,9	2,0	2,1	1,5	1,5	1,7	2,0	2,5	5,2	1,9	1,9	1,5	2,9	1,9
Dairy cows	48	67	116	113	106	39	41	41	38	29	27	50	63	40	29	49
Milk production																
Milk production per holding (kg/year)	253 900	425 100	761 600	736 900	754 800	264 100	270 800	261 200	280 300	154 100	172 500	313 400	383 700	266 000	166 300	328 500
Milk production per AWU (kg per year)	163 800	250 100	287 400	324 600	331 100	154 500	144 000	151 000	159 300	98 100	87 500	178 000	219 300	150 300	97 200	179 500
Milk production per dairy cow (kg/year)	5 300	6 300	6 500	6 500	7 100	6 700	6 600	6 400	7 400	5 300	6 300	6 200	6 100	6 700	5 700	6 600
Milk production per ha of FS (kg/year)	5 200	7 200	6 600	7 400	10 000	6 300	5 300	7 500	11 500	10 500	24 100	7 000	6 700	6 000	13 000	7 800
Costs per ton of milk (euros)																
Total costs	244	261	295	261	263	364	370	447	256	176	260	283	256	373	210	333
Operational costs (not counting home-grown)	116	123	139	119	118	101	106	164	173	122	159	118	119	108	139	130
* Feed for grazing stock (except home-grown)	58	74	85	66	63	42	46	75	146	94	101	64	62	47	101	79
Structural costs	128	138	156	142	145	263	264	283	83	54	101	165	138	265	72	203
* Mechanisation costs	46	50	55	51	51	113	120	136	30	29	60	67	49	118	39	81
* Building costs	24	9	19	17	12	31	30	28	15	6	10	20	18	30	8	24
* Tenant farming	14	17	6	12	17	23	27	21	4	1	2	16	15	24	2	20
* Farm taxes	1	1	4	0	1	7	6	6	0	1	0	2	1	7	1	4
* Wages for non family AWU	13	7	27	22	26	4	4	16	3	3	7	13	20	5	4	15
* Financial costs	10	10	12	13	12	19	16	11	5	2	4	12	11	17	3	18
* Other structural costs	20	44	34	25	26	65	61	67	26	11	18	35	24	64	15	41
Economic results																
Operational costs / output + subsidies	29%	37%	41%	35%	33%	22%	22%	33%	52%	30%	40%	30%	32%	23%	34%	29%
Structural costs / output + subsidies	32%	42%	46%	42%	40%	56%	54%	58%	25%	13%	25%	41%	37%	56%	18%	45%
Subsidies (€)	9 900	6 400	16 900	21 500	18 600	14 200	16 300	19 200	4 700	1 000	3 100	11 000	12 100	15 400	1 800	15 100
Subsidies / FFI (%)	27%	23%	60%	42%	33%	55%	55%	177%	20%	4%	19%	35%	30%	60%	8%	46%
Total output (€)	90 200	134 200	242 500	229 900	251 200	108 800	115 700	108 700	89 400	62 500	66 400	114 100	131 400	111 000	65 100	133 500
Milk production (%)	76%	82%	77%	81%	78%	75%	73%	74%	92%	75%	81%	77%	77%	74%	78%	77%
Gross Farming Income (€)	48 400	49 900	71 400	80 200	84 300	48 100	52 300	35 000	34 300	29 200	23 300	48 300	57 100	48 200	27 600	57 400
GFI / Output + subsidies	48%	36%	28%	32%	31%	39%	40%	27%	36%	46%	34%	39%	40%	38%	41%	39%
Family Farm Income (€)	37 300	27 300	28 000	51 200	55 700	25 800	29 400	10 900	22 900	25 700	15 700	31 700	40 900	25 600	22 400	32 900
FFI / Family AWU (€)	27 700	17 500	15 000	31 800	37 400	15 600	16 300	7 200	13 400	16 900	8 800	20 400	29 200	15 100	13 900	20 800
Assets and investments																
Total assets (€)	764 000	712 500	1 369 500	870 900	981 000	249 000	240 900	244 200	182 600	304 300	106 800	513 800	837 300	245 900	236 000	672 300
Total liabilities (€)	40 800	72 300	164 000	169 300	181 400	108 900	99 800	65 100	23 100	10 200	9 800	73 300	76 400	101 900	10 700	134 700
Gross investment / output + subsidies (%)	9%	17%	18%	20%	16%	13%	13%	12%	9%	7%	8%	13%	13%	13%	7%	16%
Gross investment (€)	9 500	24 300	45 800	51 400	43 200	15 800	16 900	14 900	8 800	4 100	5 700	16 100	18 300	16 100	4 900	23 300
* Agricultural lands, permanent crops (€)	-600	0	2 200	5 100	8 300	1 600	900	1 700	1 900	0	200	1 200	1 400	1 400	200	2 400
* Quotas and acquisition costs (€)	2 700	9 600	0	20 000	14 100	0	100	0	-1 100	2 700	600	3 500	5 000	0	1 800	4 200
* Building (€)	3 000	0	13 500	10 800	5 300	4 900	5 100	2 200	4 100	500	700	3 600	4 000	4 700	800	6 900
* Equipment (€)	3 600	9 300	20 900	14 100	13 800	10 100	12 800	11 000	4 000	900	4 400	7 400	6 500	11 000	2 100	9 800

Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Table 4: Average characteristics of specialised dairy holdings according to the quartiles of milk production per AWU and per year during 2003

	Output / AWU	Ireland	Northern Ireland	SW England	Brittany	Pays de Loire	Galicia	North Portugal	Total 11 regions	Regions North	Regions France	Regions South	EU-15 (total)
Milk production / AWU (kg/year)	Quartile 1	70 600	96 100	143 900	98 000	89 600	38 300	27 300	64 100	79 100	95 700	34 700	59 700
	Quartile 2	131 400	175 100	251 500	135 200	126 400	68 800	46 500	123 100	148 700	131 700	62 500	115 600
	Quartile 3	180 200	257 400	351 700	168 800	160 500	99 400	82 600	175 900	215 600	165 800	96 900	177 200
	Quartile 4	272 800	430 800	558 300	239 000	217 200	177 500	159 200	331 200	384 900	232 800	180 400	347 600
	Together	163 900	249 700	330 500	153 700	144 200	98 200	87 400	178 100	219 400	150 400	97 400	179 500
Total costs / Ton of milk (euros)	Quartile 1	257	342	293	368	361	167	240	258	263	396	219	385
	Quartile 2	248	266	297	356	385	197	255	322	254	372	210	361
	Quartile 3	250	265	281	373	360	168	264	301	263	369	206	351
	Quartile 4	235	241	227	360	373	175	261	265	252	367	211	307
	Together	244	260	263	364	370	176	260	283	256	373	210	333
Operational costs / Ton of milk (euros)	Quartile 1	123	139	124	99	104	110	146	125	123	117	137	142
	Quartile 2	118	124	125	97	116	129	155	119	119	107	132	130
	Quartile 3	117	121	127	105	103	115	157	117	120	107	134	127
	Quartile 4	112	120	107	102	101	126	163	118	117	106	143	130
	Together	116	122	118	101	106	122	159	118	119	108	139	130
Structure costs / Ton of milk (euros)	Quartile 1	134	203	169	270	257	57	94	132	140	279	82	243
	Quartile 2	130	142	172	259	269	68	100	203	135	265	78	232
	Quartile 3	133	144	153	267	257	52	108	184	143	262	72	224
	Quartile 4	122	121	120	258	272	48	99	147	135	261	68	177
	Together	128	138	145	263	264	54	101	165	138	265	72	203
GFI / Output + Subsidies (%)	Quartile 1	49%	26%	30%	37%	38%	40%	39%	40%	46%	34%	37%	42%
	Quartile 2	48%	37%	33%	41%	39%	40%	34%	39%	46%	39%	39%	40%
	Quartile 3	48%	36%	27%	38%	41%	50%	32%	42%	41%	39%	43%	39%
	Quartile 4	49%	37%	33%	40%	40%	47%	34%	36%	35%	39%	42%	37%
	Together	48%	36%	31%	39%	40%	46%	34%	39%	40%	38%	41%	39%
Income / family AWU (euros)	Quartile 1	11 500	3 400	14 500	10 800	11 100	6 200	3 600	9 000	12 200	9 800	4 700	9 300
	Quartile 2	22 400	12 700	32 800	15 100	14 400	10 800	4 800	14 700	23 800	14 000	8 700	14 600
	Quartile 3	31 900	18 800	36 200	16 200	17 900	19 100	7 800	22 100	33 000	16 800	14 800	20 400
	Quartile 4	48 900	33 700	69 300	22 200	23 200	30 500	16 900	37 900	49 400	21 400	25 800	40 600
	Together	27 600	17 400	37 200	15 700	16 200	16 900	8 800	20 400	29 200	15 100	13 900	20 800
Gross investment / Output + Subsidies (%)	Quartile 1	0%	9%	12%	9%	14%	0%	0%	2%	3%	8%	0%	12%
	Quartile 2	8%	15%	16%	10%	7%	3%	3%	9%	11%	10%	4%	13%
	Quartile 3	14%	17%	10%	12%	11%	2%	6%	14%	12%	12%	3%	13%
	Quartile 4	9%	20%	21%	19%	19%	12%	12%	16%	16%	18%	12%	19%
	Together	9%	17%	16%	13%	13%	7%	8%	13%	13%	13%	7%	16%

Sources: FADN EU, European Commission DG AGRI-G3 / processed by INRA SAE2 Nantes and Institut de l'Elevage

Table 5: Average characteristics of specialised dairy farms according to the classes of economic efficiency (GFI / Output + Subsidies) in 2003

	GFI / Output + Subsidies	Ireland	Northern Ireland	SW England	Brittany	Pays de Loire	Galicia	North Portugal	Total 11 regions	Regions North	Regions France	Regions South	EU-15 (total)
Milk production / AWU (kg/year)	Quartile 1	162 700	197 600	295 700	149 000	134 000	81 200	86 900	198 900	269 700	141 300	88 500	194 400
	Quartile 2	166 300	254 700	355 800	156 700	135 800	107 900	99 900	182 300	233 200	147 600	106 700	187 700
	Quartile 3	164 100	264 300	338 200	161 800	156 100	98 600	102 000	170 100	183 400	158 900	105 300	175 900
	Quartile 4	164 500	279 800	333 800	147 800	149 600	107 400	46 500	153 400	163 900	152 900	89 800	155 100
	Together	163 900	249 700	330 500	153 700	144 200	98 200	87 400	178 100	219 400	150 400	97 400	179 500
Total costs / Ton of milk (euros)	Quartile 1	294	319	310	426	430	237	307	323	298	448	274	390
	Quartile 2	254	285	277	381	372	182	259	303	243	374	224	351
	Quartile 3	225	254	248	343	374	159	242	267	236	362	181	312
	Quartile 4	194	209	210	313	328	128	185	209	198	323	135	244
	Together	244	260	263	364	370	176	260	283	256	373	210	333
Operational costs / Ton of milk (euros)	Quartile 1	137	145	130	112	137	161	182	138	133	136	175	160
	Quartile 2	119	131	126	113	108	130	162	120	115	113	149	133
	Quartile 3	110	120	114	98	101	111	148	107	112	104	122	117
	Quartile 4	95	103	98	81	87	89	119	97	96	86	93	96
	Together	116	122	118	101	106	122	159	118	119	108	139	130
Structure costs / Ton of milk (euros)	Quartile 1	157	174	180	313	292	76	125	185	165	312	100	230
	Quartile 2	135	154	151	268	264	52	98	183	128	261	75	219
	Quartile 3	115	133	133	244	272	48	94	160	123	258	59	196
	Quartile 4	100	106	112	232	241	39	66	112	102	237	42	148
	Together	128	138	145	263	264	54	101	165	138	265	72	203
GFI / Output + Subsidies (%)	Quartile 1	34%	20%	15%	27%	28%	23%	21%	23%	24%	24%	22%	20%
	Quartile 2	46%	30%	27%	37%	36%	41%	32%	37%	41%	36%	37%	37%
	Quartile 3	53%	38%	36%	42%	40%	51%	41%	45%	50%	41%	48%	45%
	Quartile 4	62%	48%	48%	49%	49%	64%	53%	57%	60%	49%	63%	59%
	Together	48%	36%	31%	39%	40%	46%	34%	39%	40%	38%	41%	39%
Income / family AWU (euros)	Quartile 1	17 900	1 500	6 500	5 600	7 800	5 000	3 600	9 600	19 800	4 300	4 700	5 800
	Quartile 2	27 000	12 600	42 500	13 700	13 300	16 600	9 500	18 100	30 800	13 100	12 200	18 000
	Quartile 3	29 900	21 800	42 800	17 600	16 100	19 600	13 500	24 000	31 400	17 000	19 000	24 200
	Quartile 4	35 200	31 600	55 300	24 000	24 200	28 700	8 300	30 500	34 500	23 900	22 600	34 000
	Together	27 600	17 400	37 200	15 700	16 200	16 900	8 800	20 400	29 200	15 100	13 900	20 800
Gross investment / Output + Subsidies (%)	Quartile 1	6%	20%	19%	16%	14%	7%	8%	13%	14%	14%	4%	12%
	Quartile 2	9%	9%	12%	12%	10%	7%	7%	14%	15%	11%	11%	18%
	Quartile 3	12%	19%	23%	11%	12%	6%	12%	12%	11%	13%	6%	18%
	Quartile 4	11%	20%	9%	13%	15%	6%	0%	11%	10%	14%	8%	16%
	Together	9%	17%	16%	13%	13%	7%	8%	13%	13%	13%	7%	16%

Sources: FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Table 6: Average characteristics of specialised dairy holdings of more than 200,000 kg of milk per year during 2003

	Ireland	Northern Ireland	Scotland	SW England	Brittany	Pays de Loire	Galicia	North Portugal	Total 11 regions	Regions North	Regions France	Regions South	EU-15 (total)
Number of holdings	11 880	2 960	1 200	5 610	9 620	4 810	2 480	1 630	44 320	18 690	15 950	4 480	161 310
Structural characteristics (jobs, areas, herd and intensification)													
Agricultural Work Unit (AWU)	1,75	1,82	2,7	2,37	1,92	2,23	1,97	2,59	2,04	2	2,02	2,22	2,15
AWU non family (paid) / AWU total (%)	19%	10%	31%	36%	5%	4%	8%	17%	17%	26%	6%	12%	20%
Usable Agricultural Area (UAA)	62	68	133	92	69	84	23	13	71	75	73	20	73
FS /UAA (%)	96%	98%	89%	86%	72%	71%	100%	96%	85%	92%	70%	99%	77%
LU Grazing	119	133	227	165	76	90	69	74	115	140	80	72	116
LU Grazing / FS	2,0	2,0	1,9	2,1	1,6	1,5	3,0	6,0	1,9	2,0	1,6	3,6	2,0
Dairy cows	65	80	122	113	46	49	53	53	69	83	47	54	71
Milk production													
Milk production per holding (kg/year)	354 700	513 300	802 800	814 300	316 300	346 000	319 000	361 000	448 500	521 400	325 600	349 300	496 700
Milk production per AWU (kg per year)	202 700	282 100	297 300	343 600	164 700	155 200	161 900	139 400	219 800	260 700	161 200	157 400	231 000
Milk production per dairy cow (kg/year)	5 500	6 400	6 600	7 200	6 900	7 100	6 000	6 900	6 500	6 300	6 900	6 500	7 000
Milk production per ha of FS (kg/year)	5 900	7 600	6 800	10 300	6 400	5 800	13 900	29 300	7 500	7 500	6 300	17 500	8 800
Costs per ton of milk (euros)													
Total costs	243	256	294	262	372	374	181	265	287	257	381	222	330
Operational costs (not counting home-grown)	115	122	138	118	102	105	128	163	119	119	109	147	131
* Feed for grazing stock (except home-grown)	57	74	85	63	43	47	99	104	63	63	47	107	80
Structural costs	129	134	156	144	271	268	53	103	168	138	272	75	199
* Mechanisation costs	45	49	55	50	115	122	30	59	67	48	120	41	77
* Building costs	22	8	19	12	34	32	4	11	20	17	33	8	23
* Tenant farming	16	17	6	17	25	28	1	2	17	15	26	1	21
* Farm taxes	1	1	4	1	6	5	0	0	2	1	6	0	4
* Wages for non family AWU	16	7	27	26	4	5	5	8	15	22	6	6	17
* Financial costs	11	10	12	12	20	15	3	5	13	12	18	4	19
* Other structural costs	19	42	33	25	65	60	10	18	35	23	64	15	37
Economic results													
Operational costs / output + subsidies	29%	37%	41%	33%	22%	21%	32%	41%	30%	32%	23%	38%	30%
Structural costs / output + subsidies	33%	41%	46%	40%	57%	54%	13%	26%	43%	37%	56%	19%	45%
Subsidies (€)	12 000	7 300	17 600	19 700	17 200	20 800	1 200	5 200	15 000	14 700	19 000	3 100	19 200
Subsidies / FFI (%)	23%	22%	59%	33%	57%	54%	2%	17%	35%	28%	61%	8%	41%
Total output (€)	126 800	160 600	255 400	270 500	132 000	149 900	125 000	138 100	161 900	178 200	137 700	132 800	200 100
Milk production (%)	76%	83%	77%	78%	74%	72%	79%	83%	77%	77%	73%	82%	78%
Gross Farming Income (€)	66 700	60 700	75 200	90 600	58 600	69 300	56 600	46 600	67 100	74 400	60 400	53 300	82 400
GFI / Output + subsidies	48%	36%	28%	31%	39%	41%	45%	33%	38%	39%	39%	39%	38%
Family Farm Income (€)	51 400	33 700	29 700	60 000	30 400	38 500	48 800	30 400	42 700	52 600	31 100	41 500	46 400
FFI / Family AWU (€)	36 200	20 600	15 900	39 400	16 700	18 100	26 800	14 200	25 100	35 500	16 400	21 200	26 800
Assets and investments													
Total assets (€)	1 002 100	817 300	1 428 800	1 034 700	300 200	305 800	513 100	213 400	689 000	1 039 100	301 300	387 000	974 200
Total liabilities (€)	61 600	90 400	174 800	198 100	141 300	130 800	24 400	27 000	112 700	109 800	132 900	27 200	220 700
Gross investment / output + subsidies (%)	10%	18%	18%	16%	15%	14%	14%	11%	15%	14%	14%	13%	16%
Gross investment (€)	14 500	30 600	48 500	47 100	21 900	23 600	17 400	15 800	25 900	26 400	22 200	17 200	35 900
* Agricultural lands, permanent crops (€)	0	0	2 300	9 100	1 600	1 300	100	0	2 100	2 800	1 600	300	4 000
* Quotas and acquisition costs (€)	4 400	12 200	0	15 700	0	100	11 200	1 700	5 800	7 500	0	6 800	7 500
* Building (€)	3 500	0	14 500	5 800	6 900	6 600	1 100	1 900	5 200	4 900	6 300	2 000	10 000
* Equipment (€)	4 800	11 300	22 200	14 700	14 000	17 900	2 500	11 800	11 400	8 800	15 200	6 400	14 000

Sources : FADN EU, European Commission DG AGRI-G3 / Processed by INRA SAE2 Nantes and Institut de l'Elevage

Green Dairy: an ambitious and innovative project

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Abstract

Dairy production is a major economic activity in the Atlantic Area, providing a livelihood for 150,000 farmers and approximately 70,000 paid workers in the dairy industry. The dairy systems of the Atlantic Area, based on grassland and maize forage according to contexts, are rather intensive. The nitrogen surpluses observed at the scale of the dairy farm are often between 150 and 300 kg per hectare and contribute to water pollution by nitrates. Faced with increasingly restrictive environmental regulations and strong pressure from society, it appeared necessary to improve the coordination of the means of research and development to develop more sustainable dairy systems and specify the phosphorus and nitrogen flows in dairy farms. The project, called Green Dairy, was given ERDF financing within the framework of the Interreg IIIB programme. The Green Dairy project mobilised three different tools, two scales of study and three types of players. The project thus brought together nine experimental dairy farms in the Atlantic Area, nine networks of pilot farms and also called upon cartography to connect organic and mineral nitrogen pressures with the nitrate concentration. Two scales of studies were thus chosen: dairy farming and the hydrographic catchment area. This project mobilised researchers and engineers, development technicians and the farmers of the pilot farms. It stimulated many exchanges between the project partners and between livestock farmer groups, with several trips and seminars.

Introduction

Green Dairy is a European research and development project on dairy systems and the environment. It concerns eleven regions of the five countries of Atlantic Area: Ireland, the United Kingdom, France, Spain and Portugal. It has taken place over three years, from 2003 to 2006, based on a network of researchers, technicians and farmers, around experimental farms and pilot farms. It benefits from co-financing from the ERDF within the framework of an Interreg III B programme at the level of the Atlantic Area.

1. Context: intensive dairy production confronted by environmental questions

1.1. Dairy production in the Atlantic Area, a major economic activity

At European level, it can be considered that the location of dairy production is conditioned by four major forces: proximity of urban centres, a climate and soil situation favourable to forage production and the growth of grass, soils less easy to plough than in the cereal-growing plains and a fairly dense farming population. For these several reasons, dairy production is a major economic activity in the Atlantic Area. It mobilises more than 150,000 farmers and approximately 70,000 dairy industry employees. It also uses more than 40 % of the territory and provides the raw material for a powerful food-processing industry, aimed rather at industrial products. This dairy production also represents more than 20 % of the production recorded in the European Union at 15. The coastal zones of the Atlantic Area are also regions where tourism represents an increasing share of the regional economy alongside fishing and shellfish farming. In this context, conflicts of interest with intensive livestock farming systems have tended to multiply in recent years, in particular around environmental questions.

1.2. A climate under oceanic influence but contrasting climatic situations

All of the regions of the Atlantic Area are under oceanic influence but there are contrasts in the climatic situations. There are regions with heavy rainfall like the British Isles, hot regions with a marked lack of water in the summer such as the Pays de Loire and quite hot regions that nevertheless have regular rainfall

like the Basque Country and Galicia. A good proportion of the soils are of clay-loamy texture. This temperate climatic context with its relatively high rainfall is favourable to forage production, i.e. for grassland with more or less maize silage according to the latitude. Good grass growth can thus be seen in the British Isles and good productivity of maize forage in France as well as on the Cantabrian Corniche.

1.3. Fairly variable forage systems

The forage systems encountered the Atlantic Area are diversified with a variable proportion of grassland, maize forage and cereals, going from 100 % grassland to 100 % maize forage, according to contexts. Three main categories of dairy systems can be considered.

- *In the North West of Europe, grassland systems which maximise grazing*

In the South of Ireland, 10,000 litres of milk are produced per hectare of grass with spring calvings, 9 months of grazing, 250 kg of mineral nitrogen and 2.5 cows/ha. These are systems intensive per hectare but economical in concentrates (500 kg/cow) and investments, in particular for housing and storing forage and slurry. In Northern Ireland, Scotland and Wales and in the West of England, the calving period is more often centred on the autumn with more productive cows and larger infrastructures. Nevertheless, grassland remains predominant from spring to autumn.

- *In the south west of Europe, systems which give importance to maize forage and the complete ration*

In the South Aquitaine, in the Basque Country and in Galicia, maize silage takes over from grazed grass, in spite of rather good rainfall in summer. Indeed, maize forage yields are at least twice as high as grass yields, and this is in regions where land is rare and expensive. In the North-West of Portugal, dual maize-Italian rye grass cultivation is practised systematically with yields of from 25 to 30 tons of DM per hectare (two cuts of rye grass and one maize silage), making it possible to feed from 4 to 6 LU per hectare! In these different regions of the South and in particular in Spain, the complete ration with 2.5 to 3 tons of concentrate per cow is becoming generalised with increasing recourse to feed resources external to the farm.

- *Intermediary systems in the West of France*

In the West of France, intermediary dairy systems can be observed, based on temporary grassland for grazing and maize forage for stores. The proportion of maize silage is often between 20 and 30 % of the forage area, sometimes more in large dairy structures, which do not have a land pattern suitable for grazing. The stocking rate varies from 1.6 to 1.8 LU/ha FS. Milk production is between 6,000 and 8,000 litres per cow, with levels of concentrate which can be variable. Taking into account the rural density, the dairy farms are of average size, which has led to dairy specialisation, a certain intensification of dairy systems and sometimes to association with pigs or poultry (25 % of the dairy farms in Brittany).

1.4. Intensive dairy systems confronted by environmental problems

These dairy systems of the Atlantic Area are rather intensive because the stocking rate goes from 1.5 to 5 LU per hectare. This intensification has been made possible by recourse to mineral nitrogen and cattle feed over the whole of the Atlantic front and to maize silage in all the regions of the south of Europe. Farm manures have not always been well recycled and considerable use of mineral nitrogen has been involved. Under these conditions, several studies carried out in recent years in the regions of the Atlantic Area, showed that **nitrogen surpluses varied between 150 and 300 kg of nitrogen per hectare** in dairy farms in these regions (table 1). The nitrogen surpluses are even higher when milk production is associated with off-ground pig production, as is the case in Brittany. Moreover, the organic nitrogen pressure per spreadable hectare is close to the ceiling imposed by the European Union, under the Nitrate Directive. In this context, these systems present risks for water and air quality. The risks for water are probably exacerbated in forage crop systems, associating turn-over of grasslands, bare soils during the winter and the use of manure.

Table 1: Nitrogen surpluses in some dairy systems of the Atlantic Area during the decade 1990/2000

	England and Wales	Ireland South West	Brittany/ Pays Loire	Brittany	Brittany (milk + pigs)	Aquitaine
Source	Jarvis <i>et al.</i> , 1999	Humphreys <i>et al.</i> , 2003	Simon <i>et al.</i> , 2000	Le Gall, 2000	Le Gall, 2000	Le Gall, 2000
Years of studies	1999	1999-2001	1989-1994	1995-1996	1995-1996	1991
Number of farms	110	32	48	128	11	19
Crops (% AA)	0	0	12	19	15	42
Maize silage (% FA)	-	0	46	33	28	56
Stocking rate(LSU/ha FA)	1.4	2.6	1.8	1.8	1.8	2.6
Milk production (l/cow)	5 888	5444	6 900	6 600	5 800	6409
Concentrates (kg/cow)	-	615	1300	1 080	1 070	-
Milk (l/ha AA)	8260	8 704	6 400	5 650	5 800	6 396
Inputs (kg N.ha⁻¹ AA) :	-	318	276	196	471	282
Fertilisers	281	300	200	100	101	196
Concentrates	-	-	72	49	327	77
Fixation	-	-	0	27	29	0
Slurry	-	-	0	14	6	0
Others ¹	-	-	4	6	8	9
Outputs (kg N.ha⁻¹ AA) :	36	62	59	54	180	84
Milk	-	47	44	30	32	31
Meat	-	-	8	9	83	8
Crops	-	-	7	14	10	45
Slurry	-	-	0	1	55	0
Surplus (kg N.ha⁻¹ AA)	257	256	217	142	291	198
N organic loading (kg N.ha ⁻¹ AA)	-	221	135	124	362	128
Conversion rate (N output/N input)	-	19	28	30	32	30

1: including animals, straw, forage...

Nevertheless, these **dairy systems also have assets for the environment**. The landscape of grassland and hedges, organized into small hedged fields, contributes to the maintenance of a pleasant, open landscape. In addition, these grassland areas with more or less diversified flora also contribute to the biodiversity of the flora and fauna of the rural areas, even in the case of intensive management. This biodiversity is all the stronger because the proportion of long term grassland is considerable. It should also be pointed out that these Atlantic Area dairy systems which leave a considerable area for grazing are rather favourable to the wellbeing of dairy cows.

We also have to keep in mind that we should not only focus on the dairy farms, but also take into account the other agricultural activities in the regions (table 2).

Table 2 : Share of AA/TA, stocking rate, organic load and % of vulnerable zone in the Green Dairy regions

Region	% AA / total area	Stocking rate (LSU/ha AA)	N organic loading (kg N/ha AA)	% region in Vulnerable Area
Scotland	> 70 %	0.25-0,5	< 90	
South West England	> 70 %	1-1.5	90-120	10 %
South Ireland	40-60 %	1-1.5	90-120	100 %
Brittany	> 60 %	0.75-1	120-170	100 %
Pays de la Loire	> 60 %	0.75-1,5	60-120	80 %
Aquitaine	40-50 %	< 0.5	0 - 50	< 10 %
Basque Country	40-50 %	1-1.5	0 - 90	< 5 %
Galicie	30-40 %	> 1.5	170-210	< 5 %
North Portugal	10-20 %	Localement > 1.5	90-170	< 5 %

Source : Eurostat – structure census 2000 adapted by Institut de l'Elevage

1.5. An Atlantic coastal zone which has strong specific features of hydrology

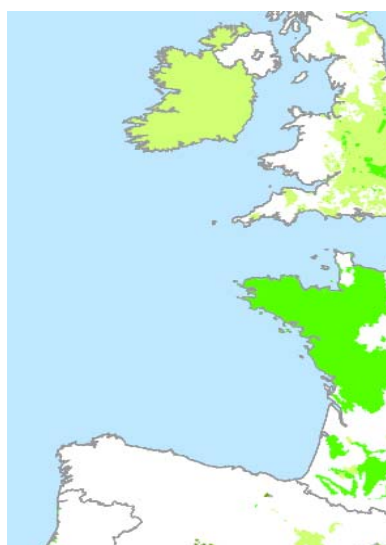
The majority of the regions of this coastal zone have little or no deep water tables, because the sub-soil is not very permeable (mainly on primary basement layer). Consequently the water circulates relatively quickly with a lower depollution rate. It is this surface water which provides most of the drinking water. In the same way, many rivers exit directly into the ocean, without a buffer area, wetlands or easily flooded land (except for the Marais Poitevin and Redon). However, if these rivers present few problems of eutrophication because of rather fast movement, they can on the other hand involve sufficient quantities of nitrogen and phosphorus to favour the development of algae and plant planktons, all along the coasts and in particular in the estuaries.

The two main sources for nitrates and phosphorus are agriculture and brown water from local communities. These communities should in a few years' time have treatment processes that considerably limit their discharges of nitrogen and phosphorus. The drop in the phosphorus content of river water is already very considerable, since the composition of detergents has been changed. Pig and poultry farming have to reduce their numbers or adopt expensive but essential treatment processes to be compliant with environmental legislation. In this context, society pressure risks becoming stronger on dairy farming because it is considered to be responsible for a significant part of the nitrates and phosphorus inputs in river and maritime waters.

1.6. Increasingly significant environmental regulations

In this context, dairy production in the Atlantic Area is subjected to increasingly significant environmental regulations, already discussed in the article by Aarts and Jarvis (2006, this work). The Nitrates Directive relating to drinking water has been effective in Europe in the vulnerable zones since 1991. The whole of the West of France has been classified as a vulnerable zone since 1992 and the farmers of this region have to comply with a certain number of constraints and regulations in relation to nitrogen management: organic nitrogen ceiling of 170 kg/ spreadable ha, spreading and fertilisation plan, winter cover for soils. Conversely, the other dairy regions of the Atlantic Area, until recently, were clearly less restricted by this directive. Indeed, only 10 % of the territory in Aquitaine, Portugal and Galicia is classified as a vulnerable zone. In the same way, the whole of Ireland was classified as a Vulnerable Zone in 2005.

Map 1: Location of the vulnerable zones on the Atlantic Area



The Water Framework Directive (2000/60 EC) bringing together the various regulations and aimed at obtaining by 2015 a good state of inland and marine waters will bring new constraints to bear on these livestock systems to limit pollution risks. This directive announces radical changes because the move is from

an obligation of means to an obligation of results and various polluting elements have to be integrated (nitrate, phosphorus, organic matter, pathogenic germs, pesticides) with action plans per large catchment area.

2. Issues and objectives of the Green Dairy project

The analysis of the context of dairy production, the possible impacts of agricultural activity on air and water pollution and the strengthening of the environmental regulatory context make it necessary to progress on the possible impacts of dairy systems on the environment, on directions for improvement at farm level as well as on mobilising the farmers and the various players. This feeling was shared by all the research and development structures concerning milk production in the Atlantic Area and it was easy to federate various partners around a joint project, called Green Dairy.

The project, worked out in 2003, had the following objective:

- To specify the impact of productive dairy systems of the Atlantic Area on nitrogen losses towards water and air. It also concerned assessing the risks of phosphorus transfer towards water, and the consumption of energy and pesticides, emerging themes about which there was not much documentation in 2003. In a context which has a great diversity of soil and climatic conditions, fodder systems and fertilisation management, the project also set out, for example, to specify the impact of forage level and animal intensification, type of fodder system and method of managing farm manures on nitrogen losses towards water and air. In other words, is the Irish dairy system with grazing for 10 months out of 12 and high nitrogen fertilisation, more or less aggressive for the environment than the dairy system of the West of France, associating sown grasslands, maize forage and cereals?

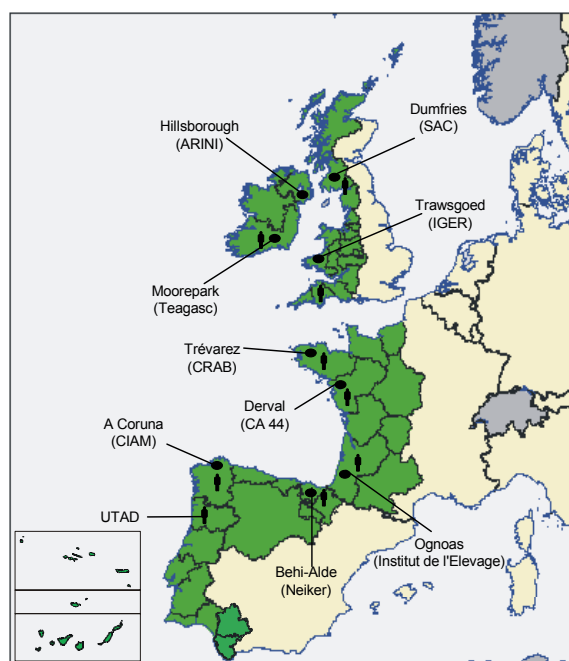
- to share and communicate our questioning on relations between dairy production and environment as well as our study structures (experimental farms, pilot farms, modelling) in order to bring faster and more reliable answers adapted to the diversity of environments. It also involved increasing relations between the researchers, technicians and livestock farmers of the Atlantic Area.

3. Green Dairy: four key actions in synergy

3.1. An original structure mobilising different sectors

To improve the study of phosphorus and nitrogen flows in dairy systems, the Green Dairy project mobilised three different tools, two scales of study and three types of players. The project thus brought together nine experimental dairy farms of the Atlantic Area, nine networks of pilot farm (map 2) and also called upon cartography to connect organic and mineral nitrogen pressures with nitrate concentration. Two scales of studies were chosen: dairy farming and the hydrographic catchment area. Lastly, this project mobilised researchers and engineers, development technicians and the farmers of the pilot farms. Green Dairy is an Interreg IIIB project, financed by ERDF within the framework of the Atlantic Area programme. The project budget was 3.8 million euros of which 2.2 million came from ERDF.

Map 2: Location of the experimental farms and the networks of pilot farms and bodies that are project partners



3.2. The networks of pilot farms to situate the nitrogen and phosphorus surpluses and identify the margins for progress

Within the framework of the project, nine networks of pilot farms were mobilised over the whole of the Atlantic Area (table 3), bringing together 139 dairy holdings. Their purpose was to situate the phosphorus and nitrogen surpluses, the consumption of energy and plant health products in dairy farms, linked to the composition of the forage system, the levels of forage and animal intensification and farming practices. It also involved identifying the margins for progress on nitrogen and phosphorus management in collaboration with the farmers then implementing them.

In Brittany, the Pays de Loire and Aquitaine, the farms come from the livestock farming networks or the networks monitoring technical and economic performances. In Ireland, Scotland and England, the farms also come from technical and economic performance study groups. For the regions of the South, the choice went towards the most intensive farms, representative of systems of tomorrow and not those which currently still form the regional agricultural landscape. These farms had not previously been integrated into a working group and thus did not benefit from previous participation in the monitoring.

Table 3 : Presentation of the pilot farm networks

Country	Region	Partner	Number of pilots farms	Contacts
United Kingdom	Scotland	SAC	10	P. Mardell
United Kingdom	South West England	IGER	13	E. Jewkes
Southern Ireland	Munster	TEAGASC	24	K. Mac Namara/M. Treacy
France	Brittany	CRAB	15	A. Bras
France	Pays de la Loire	Institut de l'Elevage	13	B. Rubin
France	Aquitaine	Inst. de l'El./CA 40 and 64	9	J.C Moreau
Spain	Basque Country	NEIKER	16	M. Pinto/O. del Hierro
Spain	Galicia	CIAM	18	J.F. Castro
Portugal	North	UTAD	21	D. Fangueiro/H. Trindade

In all the regions, the farms are managed by motivated farmers anxious for their system to evolve towards a better consideration of the environment. In addition, the farms were selected in order to integrate a variability of systems within each region. This network gives a photograph of some production systems but does not constitute a representative sample whose results could be extrapolated on a larger scale.

3.3. The experimental farms to specify the distribution of nitrogen losses to water and air

Nine experimental farms were mobilised within the framework of the Green Dairy project (table 4). It was a question of measuring nitrogen flows at a dairy system scale, measuring the surplus and especially understanding the distribution of this nitrogen surplus by evaluating the nitrogen losses towards water and air. Previous studies had been carried out on this theme but had often been confined to the assessment of nitric nitrogen losses, in relation to the nitrogen surplus. The originality of the approach consists of assessing flows and losses of nitrogen at the scale of a complete system, conducted in a real way, integrating all the constraints of a farm (climate, work...). This approach also makes it possible to integrate the various segments of the system (herds, farm manure storage facilities, fields) and carry out global and non sectional analyses, noting the possible transfers of pollution.

Within the framework of this project, the study concentrated on all of the experimental farms (Trévarez in Brittany, Derval in Pays de Loire, Ognoas in Aquitaine, Behi-Alde in the Basque Country and Mabegondo in Galicia) or on two or three systems placed in comparison (Hillsborough in Northern Ireland, Solohead in the Irish Republic, Dumfries in Scotland, Ty Gwyn in Wales).

Table 4 : Presentation of the experimental farms

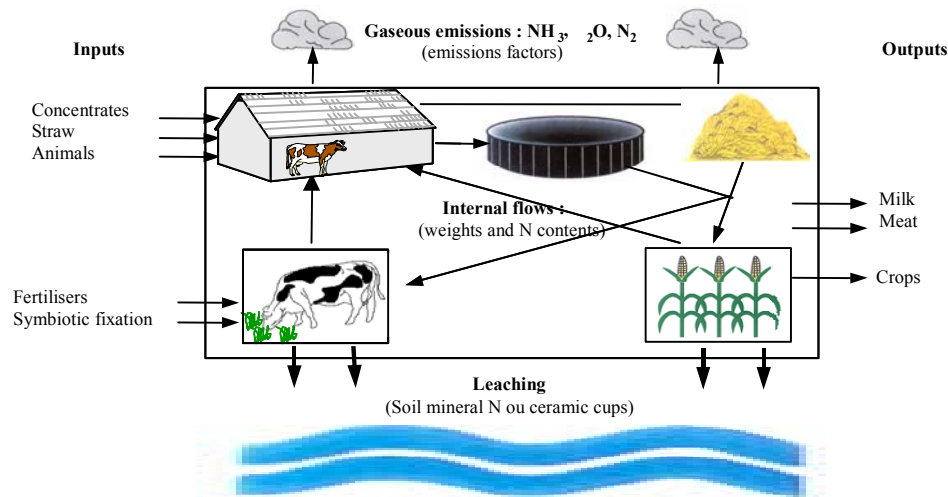
Experimental farm	Country	Region	Partner	Number of systems studied	Contacts
Dumfries	United Kingdom	Scotland	SAC	2	D. Romer
Hillsborough	United Kingdom	North Ireland	ARINI	2	C. Ferris
Solohead	Southern Ireland	Munster	TEAGASC	3	J. Humphreys
Ty Gwyn	United Kingdom	Pays de Galles	IGER	2	S. Cuttle
Trévarez	France	Brittany	CRAB	1	D. Le Meur/M.M. Cabaret
Derval	France	Pays de la Loire	CA 44	1	M. Fougère
Ognoas	France	Aquitaine	Institut de l'Elevage	1	J. Legarto
Behi-Alde	Spain	Basque Country	NEIKER	1	O. Del Hierro
Mabegondo	Spain	Galicia	CIAM	1	D. Baez Bernal

Unlike previous studies on dairy systems optimised at the level of nitrogen management (De Marke, Crécom, Ognoas, Bridgets), the systems studied are not necessarily optimised at the environmental level. The French experimental farms can point out efforts on the management of farm manures, reasoned fertilisation and the establishment of intermediate crops. On the other hand, in the experimental farms of the British Isles, high nitrogen fertilisation can be observed for some systems studied. In the Spanish Basque Country, the farm of Behi-Alde is a cooperative farm, not directly integrated into the research structure, with very liberal nitrogen management. This variability in the levels of optimisation was not an obstacle to the project because it was initially intended to analyse the distribution of the nitrogen surplus

The method for assessing nitrogen flows and losses implemented in the experimental farms is largely inspired from that implemented since 1992 at the farm of De Marke in the Netherlands (Aarts et al., 1992) then taken up in France at Crécom and Ognoas (Legarto and Le Gall, 1999; Le Gall and Cabaret, 2000) and in the United Kingdom at Bridgets (Peel et al., 1997). Nevertheless, the first year of the project consisted of harmonising the methods for measuring nitrate, the methods of calculating the different balances carried out at different levels, the emission factors selected to evaluate ammoniacal nitrogen and nitrogen protoxide losses. This harmonisation phase involved heavy investment because it takes time to be understood, to

compare points of view and to come to a consensus when everyone has worked separately for the past 20 years! The adoption of a common procedure (figure 1) to assess flows and losses of nitrogen at the scale of the dairy farm is not the least benefit of the project.

Figure 1: Methodology for assessing nitrogen flows and losses in the experimental farms



In a way complementary to this study in experimental farms, **modeling work** was carried out using the N-Gauge model, elaborated by IGER (Brown et al., 2005; Del Prado et al., 2006). This work consisted of testing this model on the experimental farms of Trévarez, Derval and Behi-Alde. After a phase of setting the model's parameters and integrating local climatic data, the model outputs were compared with the experimental setting results. This work showed rather good agreement between the model predictions and the experimental results. It also stressed the importance of the parameter setting for a wider use of this model at the European scale, worked out in the British context.

3.4. Cartography to assess the risks of water pollution by nitrates at the scale of the catchment area

The cartography made it possible to make a change of scale and know the nitrogen surpluses at catchment area and regional level. The livestock systems, organic and mineral nitrogen pressures, nitrogen and phosphorus surpluses, risks of erosion were charted and placed in relation with the nitrate concentration of the water per catchment area. This work required the provision of large data bases by the partners. It also made it possible to assess the contribution of dairy systems to water pollution by nitrates and simulate the impact of changes in dairy systems by 2014.

This cartographic work was crossed with that carried out in the experimental farms on nitrogen leaching and made it possible to consolidate the results obtained. The combination of the three study approaches (pilot farms, experimental farms, cartography) probably constitutes the originality of the project because it makes it possible to look at a complex theme from different viewpoints.

3.5. Many stimulating inter-regional exchanges and dialogues

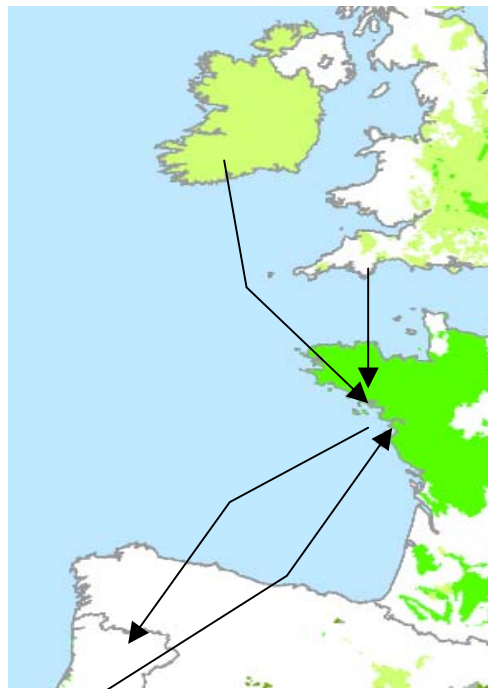
This project provided the opportunity for many exchanges to take place between researchers, technicians and farmers at the level of the Atlantic Area.

Several seminars and working meetings were organised to conduct the three study sectors of the project. Six plenary seminars took place successively at Wageningen (the Netherlands), at Edinburgh (Scotland), in Galicia and North Portugal, at Cork (Ireland), at North Wyke (England), at Paris (France) to give a progress report on the various actions, to harmonise procedures, to present and validate the first results. Other meetings specific to the groups of experimental farms or pilot farms were also held. The plenary seminars,

carried out in the various regions of the project, were the opportunity to discover the experimental farm involved in the project and visit two to three pilot farms, to become familiar with the conditions of the country's dairy production. These exchanges always took place in the friendliest of atmospheres, each partner making it a point of honour to receive the project partners. These meetings, the high spots of the project, stimulated exchanges between researchers, technicians and farmers and enabled very different dairy systems to be observed. These cross-disciplinary discoveries and observations enabled all sides to look at their own situation and take stock of the dairy systems in their own region.

The exchanges between groups of farmers made it possible to associate them more actively in the project and in thinking about the development of more environmentally-friendly dairy systems. So Irish, English and Portuguese farmers converged on Brittany and the Pays de Loire. The farmers from the Pays de Loire set off to discover Ireland whereas the Breton farmers headed south to Saint Jacques de Compostella (map 3). During these trips, the farmers visited pilot farms and the experimental farm involved in the project. They were able to discuss with their colleagues the dairy production conditions, environmental questions, the CAP reform and the price of milk... It was also the opportunity for deeper dialogue between the farmers of a same region, participating in the trip.

Map 3: Exchanges between farmer groups



3.6. Well-structured technical and scientific organisation

The technical and scientific organisation of the project was at three levels, with:

- **A leadership group** composed of Institut de l'Elevage engineers, under the responsibility of Andre Pflimlin. It carried out the day to day technical, administrative and financial coordination of the project. The engineers in charge of the project collected information from the various partners, checked the consistency and validity of the information and wrote the combined reports.

- **A scientific committee** composed of European experts and researchers with widely recognised experience in the environmental field, in dairy production and the systemic approach (table 5). This committee, chaired by Steve Jarvis, the manager of the North Wyke station at the IGER, in England, validated the methods and procedures implemented then discussed the relevance of the results. This committee thus took part in all of the project seminars.

Table 5 : Composition of the Green Dairy project scientific committee

Name	Position	Country
Steve Jarvis	Scientist, IGER, Head of the North Wyke Station	United Kingdom
Frans Aarts	Scientist, PRI, Wageningen University	Netherlands
Pat Dillon	Scientist, Head of the Station of Moorepark, Teagasc	South Ireland
David Leaver	Principal of the Royal College of Cirencister	United Kingdom
Jean-Louis Peyraud	Scientist, Head of the Dairy Production Research Unit, INRA Rennes St-Gilles	France
Gilles Lemaire	Scientist, in charge of the Praiterre program, INRA Lusignan	France
Francis Trocherie	Ingeneer, French Institute of Environment	France
David Scholefield	Scientist, IGER, North Wyke Station	United-Kingdom

In addition, INRA researchers were associated with this project, in particular for precise points of procedure: T. Morvan, F. Vertès, L. Delaby, P. Durand.

- **A steering committee**, in charge of monitoring the progress of the project and the financial aspects. It was chaired by Jean Luc Fossé, a milk producer from Brittany, the President of the "Applied Research" committee of the Regional Chamber of Agriculture of Brittany. It brought together the various partners of the project.

Conclusion

The Green Dairy project brought together some 50 technicians and researchers and 150 farmers for three years at the level of the Atlantic Area. The various sections of the project increased knowledge on nitrogen and phosphorus flows and losses in the dairy systems of the Atlantic Area and provided information for the development of more sustainable dairy systems. It was also a wonderful human adventure, made of exchanges between researchers, technicians and farmers in the various regions and countries of this Atlantic Area. Listening and understanding enabled everybody to develop, to discover that they were more partners than competitors, thus contributing to forging a European identity.

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Optimisation of environmental practices in a network of dairy farms of the Atlantic Area

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Abstract

For 3 years, 139 pilot farms distributed over 9 regions of the Atlantic Area were studied within the framework of the EU Interreg Green Dairy project. Each year, the nitrogen (N) and phosphorus (P) balances and the fertiliser practices were analysed. This was followed up by an examination of energy consumption and plant health products. The objective was to identify possible margins for progress to reduce mineral surpluses and to propose more environmentally-friendly systems.

In the North, the systems were based on grazing and harvested grass was stored and used in winter. The stocking rate was 1.6 to 2.2 LU/ha. The mineral fertiliser rate was generally higher than 200 kg N, but inputs by feed were more moderate, in particular in Ireland (580 kg concentrates/cow). The surpluses were close to 200 kg N/ha AA (agricultural area) and 20 kg P₂O₅/ha AA. The mineral N inputs have decreased for three years, but remain high. However, insufficient storage capacities limit the use of the organic manures and therefore the reduction of mineral N.

In the South, the systems studied were very intensive, from 3 to 6 LU/ha AA and consumed large quantities of inputs to ensure a production of from 10,000 to 30,000 L milk/ha. The ration was based on maize produced on the farm supplemented by more than 3 tons of concentrates. The mineral fertiliser rate was high, 200 kg N/ha and 100 kg of P₂O₅/ha, with other inputs coming from farm manure and the supplies from the soils. In spite of high exports in milk, the N and P balances were from 250 to 500 kg N/ha AA and from 100 to 180 kg P₂O₅/ha AA. Although progress was visible and will continue in reducing fertiliser rates, the reduction in purchases of feed is more difficult and more costly given the scarcity and cost of land. The low manures storage capacities slow down the reductions in mineral fertiliser.

In the regions of the West of France, the systems were undoubtedly the most improved, especially in Brittany and Pays de Loire. The balances there were close to 100 kg N/ha AA, with low inputs by mineral fertiliser and concentrates. However, it is in these areas that the problems of water quality are the most serious. In Aquitaine, the proportion of cash crops contributed favourably to the balance. Mineral fertiliser was still high and could be decreased by 50 kg N/ha AA. The surpluses of the N balance could be reduced to 100 kg N/ha without penalising yields.

Several years of study are necessary to follow the changes and measure their benefits. The first visible improvements were encouraged by the dialogues between livestock farmers from the same region but also from one country to another.

Introduction

Agricultural activities consume inputs in the form of fertilisers and cattle feed to ensure their production. The use of these inputs often leads to P and N surpluses which disperse into the environment and contribute to the deterioration of water (contamination by nitrate, eutrophication, etc.) and air (N₂O, NH₃ emissions, etc.). In dairy farms, surplus levels are very variable. The reduction of inputs and the search for better efficiency are therefore necessary, not only for environmental, but also for economic reasons. To decrease the impact of farming activities on water, a succession of regulatory texts have been issued since the beginning of the 1990s: the Nitrates Directive (91/676/EC), the Water Framework Directive (2000/60/EC) and the conditionality of CAP subsidies (regulation 1728/2003/EC). For dairy farmers, the issue for the years to come thus consists of producing milk while adapting to market trends, and at the same time respecting the

environment. Modifications of practices and investments are necessary to achieve this goal. However, these adaptations must be adapted according to the type of system and the local context.

Within the framework of the Green Dairy project, monitoring the pilot farms (action B) aims at proposing solutions for optimising environmental practices in order to reduce P and N surpluses. The study is based on the monitoring of a network of 139 pilot farms, covering a wide diversity of systems, located in nine regions of the Atlantic Area. In these farms, N and P balances and fertilisation practices are analysed annually in order to identify the targets of optimisation. This analysis is supplemented by consumption of energy and plant health products.

The present synthesis gives a progress report on the 3 years of monitoring. First of all, the systems will be presented through the analysis of nutrient surpluses, fertiliser practices, consumption of energy and plant health products. Then, actions to optimise practices will be identified and the results observed within the framework of the project will be presented.

1. Methodology and progress of the "pilot farms" action

1.1. Constitution of the pilot farm network

The 139 pilot farms studied are located in 9 regions of the Atlantic Area (between 10 and 24 farms per region). They are commercial farms, specialised for the most part in dairy production. In Brittany, Pays de Loire and Aquitaine, the holdings are from livestock farming networks (Réseaux d'élevage bovin lait⁹) or networks monitoring technical and economic performances. In Ireland and Scotland, the Green Dairy farms are also integrated in follow-ups of technical and economic performance analyses. For the regions of the south (Spain and Portugal), the choice was for modernised and intensive farms, which pose environmental problems, representative of the systems of tomorrow and not necessarily of those which make up the majority of holdings. They were integrated into no monitoring group. In all the regions, farms are managed by motivated farmers anxious to develop their system, and taking more account of the environment. In addition, the farms were selected so as to integrate variability of systems in the very heart of each region. This network gives a snapshot of some production systems but does not form a representative sample of current dairy production, but is more representative of that of tomorrow. The farms of the Green Dairy network are often larger than the regional average, this is particularly the case in the regions of the south (Table 1).

Table 1: Comparison of the number of dairy cows in the Green Dairy holdings compared with the regional average

Region	Regional average	Green Dairy average
Scotland	88	162
Southern Ireland	54	82
South West England	81	156
Brittany	34	45
Pays de la Loire	35	56
Aquitaine	25	53
Basque country	13	99
Galiccia	12	74
North Portugal	10	86

Source RA 2000 - Eurostat

1.2. Data collected

The monitoring carried out in the Green Dairy network, was largely inspired by the method implemented for 25 years in livestock farming networks by the Institut de l'Élevage and the Chambers of Agriculture in France. The information collected relates to the description of the systems (livestock, dairy production,

⁹ : Réseaux d'élevage bovin lait : network with around 500 dairy farms, coordinated by Institut de l'Élevage in link with the Chambres d'Agriculture.

rotation etc). In addition, information was collected which was necessary for calculating the various indicators presented below. These data were collected for the three years of the project.

1.2.1. Nitrogen pressure

Organic N pressure refers to the N produced by livestock, related to the agriculture area (AA) of the farm. The quantity of N produced is corrected from exports from the farm and imports coming from other holdings. It therefore includes organic N that is spread mechanically (slurry or manure) and the excretions from animals at grazing.

$$\text{Pressure of organic N (kgN/ha AA)} = \frac{[\text{Organic N produced on the farm (kg N)} - \text{exports (kg N)} + \text{imports (kg N)}]}{AA}$$

- *Production of organic nitrogen on the farm:*

The quantity of N produced on the farm is determined from the excretions of animals of each category. The excretions from dairy cows were calculated by applying the following formula:

Excretion Dairy cow (kg N/year) = $9.6351 \times \text{total N in the ration \%} - 39.114$ (for a production of 6000 L with adjustment on the dairy production) (Vérité et Delaby, 1998).

The losses by gases are fixed at 10 % of the emissions at grazing and 30% of the emissions in the buildings. This calculation method gives a more precise assessment of the excretions from cows than the regulatory standards of each country (Pflimlin et al., 2006 same volume).

On the other hand, there was no adjustment of the same type for the other categories of animals. For heifers, the usual French standards were used: 53 kg N/year for a heifer of more than 2 years, 42 kg/year for a heifer from 1 to 2 years, and 25 kg/year for a heifer of less than one year (Corpen 2001). For the other categories, the French references were also used (Other cattle: Corpen 2001 ; Pigs: Corpen 96 ; Poultry: Corpen 97). The excretion rates are multiplied by the number of animals of each category present on the farm.

The mineral N pressure refers to the inputs of mineral N per hectare of AA.

The total N pressure is the sum of organic and mineral N inputs per hectare of AA.

1.2.2. The nitrogen and phosphorus balance at farm scale

The apparent balance is carried out at the scale of the farm according to a common method for all the regions. This method is also used in the experimental farms monitored in action A of the project and is more extensively described by Bossuet et al. (2006, same volume).

The difference between the N and P inputs on the holding (in the form of mineral and organic fertilisers, feed and animals) and the outputs (milk, meat, cash crops, animal excretions) gives a surplus or deficit.. Common references for the N and P contents of fertilisers, feed, milk, cash crops were used (outputs by meat: 24 kg N and 16 kg P₂O₅/ton of live weight; outputs by milk sold: (protein%/6.06) kg N and 2.17 kg P₂O₅/1,000 L of milk).

The N balance also takes account of symbiotic fixation by leguminous plants as an input. It relates mainly to the farms of the West of France and the Basque Country and was estimated by applying the following formula:

$$\text{Fixed nitrogen} = \text{yield of grasslands} \times \% \text{ clover} \times 30 \text{ kgN/tDM clover}.$$

The balance is expressed in kg/ha AA but can also be expressed per unit of production (1,000 L milk). The balances of minerals were supplemented by an analysis of the fertiliser practices.

1.2.3. The energy consumption

The calculation method of energy consumptions was that developed and used by the Institute de l'Elevage (Charrouin et al, 2006) in the networks of French milk and beef cattle farms. Two types of energy were identified: **direct energy and indirect energy**. Direct energy comes from fuel and other petroleum by-products, electricity and other fuels (wood, coal, etc.). The energy associated with work carried out by third parties (CUMA, contractors) is also included. Indirect energy is allocated to the manufacture, processing and transport of inputs (fertilisers, concentrates, forage bought in etc...). Energy associated with buildings, farm equipment, plant health products and plastics were excluded from the calculation. The estimates carried out by the Planet group (Risoud et al., 2002). on French farms, show that they represent less than 20 % of total energy consumption on a farm. The unit used is the Fuel Equivalent (FEQ), and the references chosen by Planet were applied (Risoud et al., 2002). Consumption of energy was quite stable from one year to the other in the same dairy system, and was assessed only in the second year.

1.2.4. The use of pesticides

Consumption of plant health products was examined during the second year of the project. Taking into account the multiplicity of commercial products and active materials on the market, it was difficult to make an exhaustive inventory within the framework of this project. The information collected was thus centred on the number of treatments made per crop, distinguishing weed killer, fungicide and insecticide treatments. The quantities applied are approached by a coefficient of use load factor compared to the approved amount (e.g.: 0.8 = application of the product at 80 % of the approved amount).

1.2.5. The margin on feed and fertilisers

Each country has its own accounting and management rules and items such as depreciation and social security contributions are integrated differently. It was therefore essential to go back to the basic accounting data to obtain comparable information. The common economic approach adopted consists of evaluating a margin on costs of feed and fertilisers at the scale of the "**dairy cows unit**" only. The margin is calculated in the following way:

$$\begin{aligned} \text{Margin} &= \text{products} - \text{costs with} \\ \text{Products} &= \text{Price of milk} * (\text{quantity sold} + \text{milk to calves}) \\ \text{Costs} &= \text{Fertilisers (N, P}_2\text{O}_4 \text{ and K}_2\text{O)} + \text{feed bought in} \end{aligned}$$

This margin has the advantage of translating directly into monetary units the savings in mineral fertilisers and concentrates, even if these two items represent a variable proportion of all of the costs (Chatellier and Pflimlin, 2006, same volume).

1.3. The improvement project

From a diagnosis of the initial situation, the projected asked that the farmers implement actions to optimise their practices and to reduce surpluses. The farmers themselves defined the short and medium term objectives in collaboration with their advisers but were under no obligation to do that. The initial consideration was based on the mineral balance and the analysis of practices. It also incorporated the strengths and weaknesses of the whole holding (buildings, land pattern, workforce, economic situation etc.). The farmer could therefore work out an improvement plan adapted to his production system which related particularly to organic and mineral fertiliser practices and to the management of feed with the aim of reducing surpluses of mineral N and P inputs by better use of farm manures, etc...

1.4. Progress of the project

The first two years of monitoring made it possible to set up the farmers' groups, to characterise the holdings and make a diagnosis of the initial situation by analysing P and N balances and management practices. One to three meetings with visits to holdings were organised among farmers of a same region around themes of

the control of N and P surpluses, improvement of agronomic and feed practices and economic efficiency. The objectives were specific for each farm, however, During the second or third year, depending on farms the farmers applied their improvement plan. These improvements relate to the management of manures the use of mineral fertilisers and concentrated feed. Interregional dialogues were also organised with the aim of discovering the agriculture and practices of another region.

2. Description of dairy systems in the Green Dairy network

Table 2 shows the average characteristics of the farms monitored. The systems were in 3 groups: grassland systems located in the North (the United Kingdom and Southern Ireland), intermediate systems located in Western France, based on grass and maize in variable proportions, and the very intensive systems of the south (Galicia, the Basque Country and Portugal), with a large proportion of preserved forage and high levels of concentrates.

2.1. The pilot farms of the North (Scotland, South West England and Southern Ireland) : grass-based with often high rates of mineral fertiliser

In North, the climate is very favourable to the growth of grass but sometimes limits the grazing period in spring and autumn. The yields were close to 10 t DM/ha. The stocking rate was high, ranging between 1.6 and 2.2 LU per hectare. In the holdings in Southern Ireland, with spring calving, the dairy production per cow was the lowest at 5,680 litres/cow. The level of concentrates was also low with 106 g /litre of milk. These systems were representative of the dairy farms of the south of Ireland. The English and Scottish farms are the biggest, more than 150 cows on average, more than 100 ha of AA and an average quota of 1,000,000 L (6,500 to 7,500 L and more than 1.6 tons of concentrates/cow). These structures react very quickly in size and animal intensification to economic drivers. The reform of the CAP and the free movements of quotas favour enlargement and lead to intensification Investment on farm building was quite moderate in most parts of the United Kingdom during the 90s as shown by the FADN¹⁰ data. Nevertheless in Scotland, 95% of the farm buildings respect the Assurance regulation applied to dairy farms. But more storage capacity for slurry will often be necessary to make the best use of the manure especially when the quota is increasing. In Southern Ireland, as the grazing period is considerably longer, farmers need less investment and storage but seem also to be reluctant for new investments (Chatellier and Pflimlin 2006). In England and Scotland, there are farms similar to the "typical" regional farm, but also more balance systems with levels of concentrates similar to those of Irish pilot farms.

2.2. The pilot farms of Western of France : balanced dairy management systems

In Brittany and the Pays de Loire, the dairy systems monitored were diversified, with farms of grassland only and those with more than 30 % of maize in the forage area (FA). This diversity is explained by climatic conditions unfavourable to the growth of grass in drier areas, but also by the inclination of the farmers. The holdings in the network had, on average, 50 cows and used 56 to 80 hectares of agriculture area (AA). The stocking rate was moderate compared with other regions at 1.8 LU/ha AA. Concentrates levels were low in the Breton network (926 kg/cow) and a little higher in Pays de Loire (1,500 kg/cow). Nearly all of the holdings are in a vulnerable zone and they all complied with the local restrictions (sufficient manure storage capacities, complying with the load of 170 kg organic N/ha NDA¹¹). There were 5 mixed milk + housed animal. These systems are frequent in Brittany in particular, where 25 % of the dairy farms also have a pig unit. Several farms in these regions produce meat (fattening of young bulls or suckler cow production) in addition to milk. On average, beef production represented less than 7 % of the total ruminant LUs. The farms studied were characteristic of regional production systems, were of a size close to the regional average and are all committed to optimising practices, which meant that these holdings were the most optimised in the Green Dairy network at the start of the study.

¹⁰: Farm Accountancy Data Network of the European Union

¹¹:Nitrates Directive Area = spreadable area + grazed area not spreadable.

In the South Aquitaine, dairy farms were mixed and produce grain maize intended for sale on approximately half of the AA. The forage system was 40 % grass and 60 % maize silage, which was usually irrigated. The stocking rate per hectare of AA was low because of the proportion of cash crops, but reached 2.6 LU/ha FA. The level of concentrates was close to 1.8 t/cow for a production close to 7,900 L milk sold/cow and an average quota of 388,400 litres, i.e. twice as much as the regional average (182,000 litres).

2.3. Pilot farms in the Basque Country, Galicia and in North Portugal: intensive production

The selected farms were characteristic of the modernised dairy systems which will become more common in the future and which currently pose environmental problems because of their level of intensification. These farms are therefore representative of the type of holdings that will be present in these regions in a few years but which have to have a intensive management production to meet the environmental standards. At present, dairy production is being completely restructured and small-scale farms are disappearing to the advantage of farms that double their quota and their area in return for significant investments. The network therefore brings together farms with more than 70 cows, with quotas higher than 600,000 litres, on restricted areas, whereas the regional average is 10 to 15 cows per holding . The Green Dairy pilot farms are 5 to 6 times bigger than the regional average of the RA 2000. This development is illustrated and discussed by Chatellier and Pflimlin (2006, same volume).

In the Basque Country the size of the pilot farms was 58 ha with production of close to 15,300 litres of milk per hectare AA. There is still a good amount of grassland (88 %), but the proportion of maize is increasing quickly. Galicia and North Portugal are characterised by very small farms (22). Land is rare and expensive (from 15,000 to 40,000 €/ha) and farming activities are in competition with urbanisation. In this context, holdings increase their quota without taking on more land. The stocking rate levels varied from 3 LU/ha AA in Galicia to more than 6 LU/ha in Portugal. However, in Portugal, one irrigated hectare can produce up to 30 T DM/year (20 tons of maize silage and 8-10 tons of ryegrass as a catch crop). This practice of double cropping is also widespread in Galicia. The ration was based on silage associated with levels of concentrates higher than 3 T/cow for an average production higher than 8,500 L milk sold/cow. The maize silage included that produced on the farm as well as external purchases. The cows were permanent housed, with a complete ration supplied in Portugal and also more and more in Galicia, in spite of 60 % of grassland in the AA in this region.

3. The environmental indicators in the Green Dairy pilot farms

3.1. The nitrogen pressure varies greatly between systems

- *Nitrogen emissions from dairy cows*

The calculation of N excretion from dairy cows integrates the rate of total N content in the ration and the level of dairy production and includes losses by volatilisation which were fixed at 30 % of N emissions in the buildings and 10 % at grazing. According to these calculations, the waste from dairy cows varied from 82 kg N/cow/year in Aquitaine and Galicia to 115 kg N/cow/year in Northern Ireland (Table 3). It is in the grasslands systems that the excretion from cows was highest. The ration based on grass has a high total n content (approximately 20%) and the losses by volatilisation are moderate since the animals spend on average more than 60% of their time at grazing. In the other regions, the rations have lower N contents and the animals spend more time inside. The overall N losses per cow are therefore lower, but the ammonia emissions higher.

Table 3 : Average nitrogen excretion dairy cows (after volatilisation) in the Green Dairy pilot farms

	Scotland	Southern Ireland	South West England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicia	North Portugal
N excretions from dairy cows (kg N/cow/year)	105	115	115	88	82	91	102	82	90

Table 2 : Characteristics of the Green Dairy pilot farms

	Scotland	South Ireland	South West England	Brittany ¹	Pays de la Loire ¹	Aquitaine	Basque country	Galicia	North Portugal
Number of farms	10	24	13	15	13	9	16	18	21
Main characteristics	Grazing system	Intensive grazing		Grazing and maize forage Optimised system of West of France		Mixed system Milk + grain maize	Very intensive High level of concentrates	Very intensive Complete ration No grazing	
Climate	Wet and cold 1 000 mm	Wet 1 000 mm	Wet 1 000 mm	700 to 1 100 mm Dry summer	800 mm - water deficit June - September	800 to 1 500 mm Moisture deficit	> 1 200 mm		
Forage calendar	Autumn calving Grass silage winter	Group calving maximized calving	Autumn calving Winter grass silage	Grazing March-November Low concentrates levels	Reduced grazing > 50 % maize	< 10 % grazing large part of maize	100 % indoor Complete ration		
Grassland and forage crops	Permanent grassland	Permanent grassland	Permanent grassland	Temporary grassland (< 5 years) + Maize	Temporary grassland (< 5 years) + Maize	Temporary grassland + Monoculture of maize forage	Maize forage + temporary grassland		Maize forage IRG (double crops)
Grassland management	Grazing + cutting	Grazing + cutting	Grazing + cutting	Grazing + cutting		Cutting + grazing (heifers)			Cutting
AA (ha)	167	58	110	57	82	69	58	32	22
FA/AA (%)	99	100	92	79	74	52	99	100	100
Grassland / FA (%)	94	100	84	70	65	39	88	58	0
Maize / FA (%)	6 ²	0	16 ²	30	35	61	12	42	100
Number of cows	159	82	165	45	56	53	99	74	88
Quota (l)	1 163 000	438 600	846 400	288 000	380 600	388 400	908 000	659 600	712 000
Milk sold (l/cow)	7 515	5 487	6 565	6 733	7 084	7 881	8 966	8 529	8 690
Milk sold (l/ha AA)	7 155	7 757	9 847	5 315	4 837	6 053	15 304	19 723	34 760
Concentrates (kg/cow)	2 175	580	1 605	926	1 494	1 772	3 922	3 584	3 339
Concentrates (g/l sold milk)	289	106	244	138	225	225	437	420	384
% LU milk / LU herbivores	64	100	97	95	93	100	100	100	100
LU/ha AA ⁴	1.6 ⁽²⁾	2.1	2.2	1.4	1.3	1.2	2.7	3	6.1
LU/ha FA ⁵	1.6 ⁽²⁾	2.1	2.3	1.8	1.8	2.5	2.7	3	6.1
N mineral/ha AA	114	269	234	57	66	147	28	136	212
P ₂ O ₅ mineral/ha AA	30	25	30	10	13	54	23	80	68

¹Brittany: with 4 mixed farms (milk + pig : 3 farms ; milk + poultry : 1 farm) ; Pays de la Loire : with 1 mixed farm (milk + poultry)

²Maize + others forage crops

³including others LU ruminant – in average 97 beefs /farm

⁴AA = Agriculture Area

⁵FA = Forage Area = Area used for the milk production

- *Pressure of organic, mineral and total nitrogen*

The pressures of organic N presented in Table 4 correspond to the quantity of organic N produced by the animals on the farm expressed per ha of agricultural area. The organic N pressures varied from 100 kg N in Aquitaine to 448 kg N/ha AA in Portugal. And are directly linked with the stocking rate. Thus, the farms in Aquitaine had low pressures (close to 100 kg/ha AA) since the proportion of cash crops was high which results in a dilution of organic N produced over the whole area i.e 2.5 LU/ha FA, but 1.5 LU/ha AA). In Brittany and in the Pays de la Loire, the organic N pressure is limited to 170 kg organic N/ha NDA¹² since the application of the Nitrates Directive. In these regions, the organic N pressure was lower than 130 kgN/ha AA (i.e. equivalent to less than 155 kg organic N /ha NDA). In the South, the systems produced between 270 and 448 kgN/ha AA. This N is mainly produced in the buildings and generates considerable need for manure storage. In the grassland systems, the herd produced 170 to 245 kg N/ha and between 50 and 70 % of this nitrogen was excreted at grazing.

Table 4 : Average pressure of organic and mineral N in the Green Dairy pilot farms

	Scotland	Southern Ireland	South West England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicia	North Portugal
LU/ha AA	1.6	2.1	2.2	1.4	1.3	1.2	2.7	3	6.1
N organic (kg N total org /ha AA)	170	229	213	130	97	94	270	267	448
N mineral (kg N min/ha AA)	114	269	234	57	66	147	28	136	212
Pressure total N (kg (N total org + N min) / ha AA)	284	498	447	187	163	241	298	403	660
Time spent inside by dairy cows (%) (typical case)	50	30	50	50 to 60	60	80	100	100	100

* : including milking time

The total N pressures were moderate in Pays de La Loire and Brittany i.e. 163 to 187 kg N/ha AA, including about 60 kg of mineral N. Elsewhere, the pressures were high, i.e. from 241 to 660 kg (organic + mineral) N/ha AA (Tble 4).

3.2. Variability of N surpluses from region to region

- *Distribution of the N balance*

In the Green Dairy farms, the average N surpluses per group varied from 93 to 502 kg N/ha AA. Table 5 details the inputs and outputs of this balance. In the grassland systems of the North, more than 60 % of the inputs come from mineral fertilisers, which represented 114 kg/ha in Scotland and more than 234 kg N/ha in Ireland and South West England. The inputs in feed represented only 32 kg N/ha AA in Southern Ireland, where the systems have low concentrate use (580 kg/cow/year). In Scotland and South West England, inputs from concentrates are 2 to 2.5 times as high. In the West of France, fertilisers were the principal input and this rises to 70% when fixation and imports of manure are added (these were between 92 kg/ha in Brittany and 147 kg/ha in Aquitaine). In Brittany, imports by feed also included that used in the pig or poultry units present on the holding. Thus, the overall feed item was 85 kg N/ha whereas the concentrates supplied to the y cows was 138 g/litre of milk. In the intensive systems of the South, inputs ranged from 352 to 754 kg N/ha. More than two thirds of the inputs came from feed which resulted in a total amount ranging from 315 kg N/ha in the Basque Country to 524 kg N/ha in Portugal. Inputs from fertilisers were 136 kg N/ha in Galicia and 212 kg N/ha in Portugal.

¹² : In France, this pressure is calculated by applying the national standards of animal excretions (Corpen standard: 85 kg dairy cows etc). The Nitrates Directive Area = spreadable area + grazed area not spreadable. In the dairy systems of the West of France, Nitrate Directive Area = 100 % area in grazed grassland + 70 % of the area under crops

Table 5 : Nitrogen balances in the Green Dairy dairy farms (average of 3 years)

	Scotland ⁽¹⁾	Southern Ireland	South West England	Brittany ⁽²⁾	Pays de la Loire ⁽²⁾	Aquitaine	Basque country	Galicia	North Portugal
<i>Mineral fertiliser</i>	114	269	234	57	66	147	28	136	212
<i>Fixation</i>	1	0	1	22	14	0	7	0	0
<i>Animal manures (purchased)</i>	0	0	0	21	12	0	0	0	0
<i>Feeds</i>	63	32	82	85	59	81	315	319	524
<i>Others (animals, straw)</i>	3	0	13	8	3	10	4	2	18
Total inputs (kg N/ha AA)	181	301	330	193	154	238	352	457	754
<i>Milk</i>	43	47	54	31	27	30	86	98	180
<i>Meat</i>	4	14	6	25	7	5	7	10	22
<i>Crops</i>	0	0	4	16	27	48	0	0	10
<i>Animal wastes</i>	0	0	0	4	0	0	2	0	40
Total outputs (kg N/ha AA)	47	61	64	76	61	83	95	108	252
Surplus with fixation (kg/ha AA)	134	240	266	117	93	155	257	349	502
<i>Surplus with fixation (kg/1,000 l milk)</i>	16	28	27	22	19	26	14	18	15
<i>Conversion rate (%) (Inputs/outputs)</i>	26	20	19	39	40	35	27	24	33

⁽¹⁾ the N balance is made on the basis of dairy cow units per total AA. It does not include other cattle).⁽²⁾ not counting the milk + housed animal units, the surplus = 75 kg N/ha in Brittany and 69 kg/ha in Pays de Loire.

Milk constituted more than 90 % of the N exports except in systems with cash crops or other associated activities. So, in French regions, only 45% of the N exports came from sales of milk, the remainder was composed of cash crops and outputs in meat. Exports in milk thus ranged between 27 and 54 kg N/ha AA in France, the UK and Southern Ireland. In the South, N exports in milk were 2 to 4 times higher because of the intensive managements (i.e from 15,000 to 35,000 litres milk/ha AA). In all the regions, N outputs were substantially lower than the inputs. Between 19% and 40% of the exports left the holding in the form of milk and meat, the rest is then available for loss to the environment..

- *Relation between the surplus and dairy production per hectare of AA*

The N surplus/ha AA increased with the level of intensification expressed litre milk/ha AA (Figure 1). The systems of the West of France, fairly economical in inputs, had a surplus lower than 150 kg for a production of 5,000 l/ha AA. The farms of Southern Ireland and England had a surplus ranging from 150 to 350 kg/ha AA for a production of 7,000 to 10,000 L. In the systems of the South, the average surpluses were between 257 and 502 kg/ha AA but the production per hectare was from two to three times higher (20,000 to more than 40,000 l/ha AA). For the same level of dairy production, the surplus can vary between one to two times. This difference comes from the dispersion of practices, the agronomic potential of the soils and the proportion of crop sales. In the Aquitaine region, for example, sale of crops made it possible to export more than 48 kg N/ha, i.e. 60% of the total N exports and improve the total balance compared with a balance carried out in the milk unit alone.

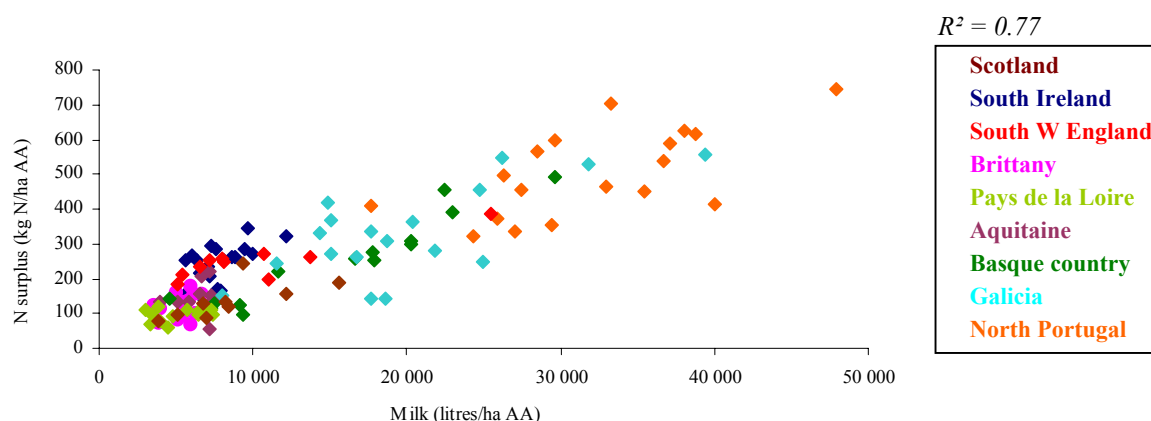


Figure 1 : Relation between N surplus (kg/ha AA) and dairy production (litres/ha AA)

As we have just seen, the N inputs on the farm were much higher than exports in milk, meat and crops. Figure 2 illustrates the correlation between N surplus and the level of inputs consumed on the farm. Generally speaking, the holdings whose surplus was lower than 100 kg/ha AA, on the whole import less than 150 kg N in feed and fertiliser.

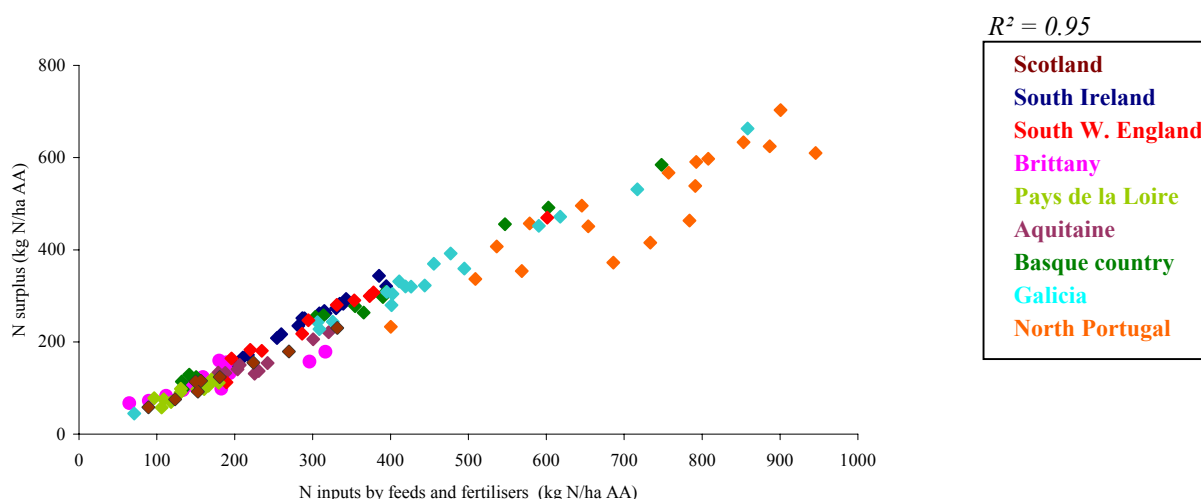
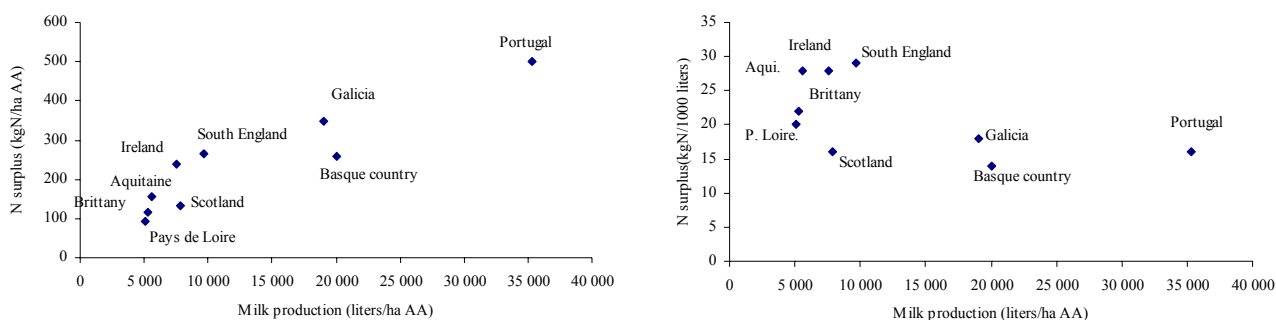


Figure 2 : Relation between the N surplus and inputs by fertiliser and feed (kgN/ha AA) in the 139 pilot farms

- Which units for N surplus?

When the N surpluses were expressed per 1,000 l milk, the hierarchy between the regions is very different from that obtained with the balances expressed per ha of AA (Figs 3 and 4). The balances varied from 15 to 28 kg/1,000 L of milk (Table 5). In the South, more than 15,000 L milk/ha were produced and consequently, the surpluses which were the highest per ha AA, were among the lowest per 1,000 l milk. This comparison raises the question of which unit to express the surplus. Since the N surplus defines the quantity of N which can be dispersed into the environment, surplus per ha AA is more suitable, in particular for water quality. However, the analysis of N balances at the territory scale must not be dissociated from other factors such as the proportion of agricultural area in the total area and the proportion of forests, etc. Indeed, the work carried out in this project shows that the N balance

alone does not make it possible to prejudge the quantity of N lost by leaching or volatilisation nor the direct impact on the environment (Bossuet et al, 2006, same vol.) and (Pflimlin et al, 2006, same vol.). However, it is an important tool to help improve the environmental impact of dairy production systems.



Figures 3 and 4 : Relation between the N surplus balance expressed in kgN/ha (Figure 3) and in kg N/1,000 l milk (Figure 4) and dairy production (l milk/ha AA)

3.3. Wide ranges in P₂O₅ surplus

The P inputs on the farm were very different between regions. In the British Isles and the West of France, the pilot farms used approximately 30 kg P₂O₅ / ha as fertilisers (mineral and organic) and between 16 and 39 kg P₂O₅/ha in feeds. In the three regions of the south, the P inputs were between 129 and 222 kg P₂O₅/ha AA of which more than two thirds came from feed. As found for N, the outputs of P in products from the farm were lower than the inputs and surpluses varied from 18 to 116 kg P₂O₅/ha. These surpluses accumulate in soils over of time and the soil P contents increases because of its immobility.

Table 6 : Phosphorus balance in the Green Dairy farms (average of 3 years)

(Kg P ₂ O ₅ /ha AA)	Scotland*	Southern Ireland	South West England	Brittany**	Pays de la Loire**	Aquitaine	Basque country	Galicia	North Portugal
Mineral fertiliser	30	25	30	10	13	54	23	80	68
Animal manures	0	6	0	18	12	0	0	0	0
Feeds	29	16	27	39	23	30	103	130	150
Others (animals, straw)	1		6	2	1	4	3	4	4
Total inputs (kg P ₂ O ₅ /ha AA)	60	47	63	69	49	88	129	214	222
Total outputs (kg P ₂ O ₅ /ha AA)									
including milk	20	29	28	33	28	38	45	51	106
	18	17	22	12	11	13	37	41	73
Surplus (kg P₂O₅/ha SAU)	40	18	35	36	22	49	84	163	116
Surplus (kg P₂O₅/1,000l milk)	5	2	3	5	4	8	5	8	3
Conversion rate (%) (Inputs/outputs)	33	62	44	48	57	43	35	24	48

* the nitrogen balance is carried out only on the dairy cow unit brought to the total AA. It does not include the other herbivores (beef cattle).

** not counting the milk + housed animal units, the surplus = 38 kg P₂O₅/ha in Brittany and 19 kg P₂O₅/ha in Pays de Loire.

Figure 5 presents the P₂O₅ surpluses calculated for the 139 pilot farms. Variations are significant between regions but also within the regions themselves. These differences, as we observed for N, show that there are some opportunities for progress.

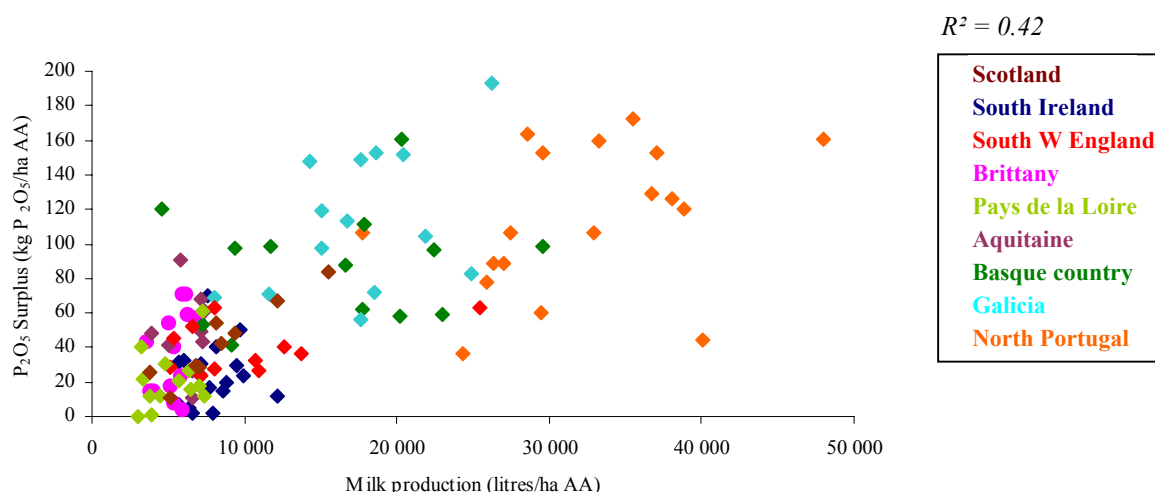


Figure 5 : Relation between the phosphorus surplus (kg P₂O₅/ha AA) and the dairy production (litres/ha AA)

Southern Ireland and the Pays de Loire have a conversion rate (outputs/inputs) of 63 % and 56 % respectively. The low levels of inputs and in particular the low use of mineral P made it possible for these systems to be the most efficient on the P use. The systems of the south, which were less autonomous, bring in a much feed to ensure a high production level (> 20,000 litres of milk/ha). However, in these farms, the balance could be improved if fertiliser purchase was reduced by making better use of the slurry produced.

3.4. Similarity in energy consumption per 1000 litres of milk

Table 7 : Energy consumptions in different production systems (year 2)

Type of system	Permanent grassland	Grassland + maize	Intensive
Regions	Scotland and South England	Brittany and Pays de la Loire*	Galicia and North Portugal
Number of farms	10	19	30
AA	132	67	26
% FA/AA	96	78	100
Stocking rate LU/ha AA	2.6	1.7	5.2
% maize/FA	0	32	90
Milk (l/ha AA)	8 274	5 296	26 700
Energy consumption			
FEQ	91 742	31 934	61 783
FEQ/1 000 milk	84	90	89
FEQ/ha AA	695	476	2 376
% direct energy	35	56	25
% indirect energy	65	44	75

* not counting milk + off-ground mixed farms.

Consumptions of energy were not recorded in Ireland and in the Basque Country as the data were not available. The other regions were assembled into three groups according to the type of management system. The permanent grassland systems (Scotland and England), the grassland + maize systems (Brittany and Pays de la Loire, (not including housed animal units) and intensive systems (Galicia and Portugal). The farms of South Aquitaine are not presented here since the energy consumptions were recorded for all production (i.e milk + crops), without isolating that related to dairy production alone.

Energy consumption per 1,000 l of milk produced was very similar between the three groups (Table 7), but the distribution between direct and indirect energies was variable and very much related

to the system (Fig. 6). In the intensive systems of the South, three quarters of energy consumption were as indirect energy, 80 % of which came from feed. This is energy associated with the production of raw material, and its processing and transport. In grassland systems, the indirect energy of feed and fertilisers also dominated. In the intermediate "grass + maize", systems, direct and indirect energy consumption was similar. The results obtained in the grassland and "grass + maize" systems, are consistent with those obtained in the French livestock networks by Charroin et al. (2006).

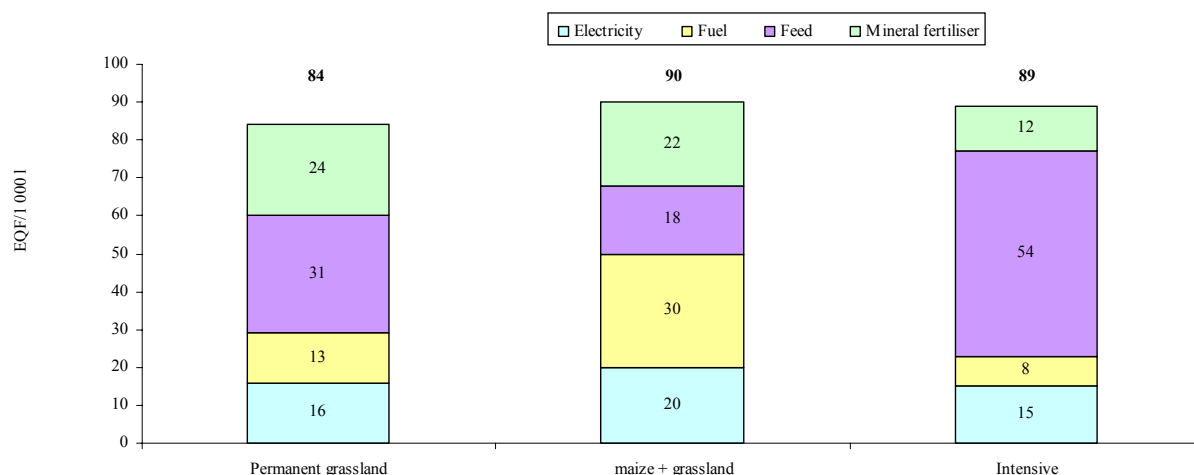


Figure 6 : Distribution of the different items of energy consumption

The analysis of the "direct energy" category shows a similar consumption of electricity between the systems, between 15 and 20 FEQ/1,000 l milk. Fuel consumption was lower in the grassland systems where permanent grassland occupies more than 85 % of the total area. The use of agricultural machines was primarily related to fertiliser inputs and harvesting. In the other regions, the forage farming system required more use of machinery and intervention, in particular in the south, where two crops follow one another in the same year. Fuel consumption per ha AA, thus varied from 120 FEQ/ha AA in Scotland to 213 FEQ/ha AA in the intensive systems of the south (Table 8).

Table 8 : Comparison of energy consumption (FEQ- equivalent fuel) associated with the farm crops

System	Land use	Fuel FEQ/ha AA	Fertilisers FEQ/ha AA
Permanent grassland	Permanent grassland for grazing and silage	120	222
Maize + grassland	53 % temporary grassland 47 % maize + crops for sale	159	116
Intensive	< 10 % temporary grassland > 90 % Maize (+ IRG)	213	320

On average, feed represented between 50 % and 80 % of indirect energy. Consumption per 1,000 litres of milk was, respectively, 18 FEQ/1,000 L and 31 FEQ/1,000 L milk in the "maize + grass" groups of Brittany and Pays de Loire and "grasslands of the North". The farms of the south were more dependent on purchases of feed and used, on average, 54 FEQ/1,000 L. The other major indirect energy item, fertilisers, generated between 116 and 320 FEQ/ha AA and depended on the rates of application.

3.5. Consumption of pesticides products associated with rotation

The areas treated with pesticides etc was correlated negatively with the grass area (Fig.7).In conventional farms, grasslands are very rarely treated except for some post-sowing weed killer. On the other hand, spraying against insects and weeds was systematic on maize with, on average, 1.8 to 2 treatments per year. Grain crops, present only in the farms of the south of England, Brittany and the

Pays de la Loire, were treated between 2.5 and 7 times on 70% to 100% of the area. Amounts applied have been reduced only in the French regions.

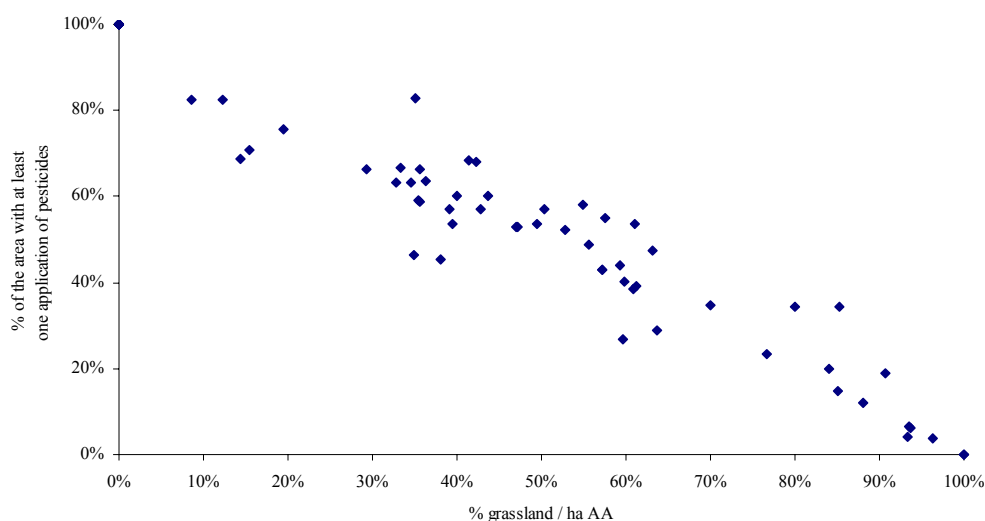


Figure 7 : Relation between the area receiving at least one pesticide treatment per year (excluding organic farms) and the proportion of grass in the AA

3.6. Integration of all the environmental factors

The environmental approach relates in this case to the management of N and P, energy consumption and plant health products. All these items have an environmental impact which is still to be totally quantified and whose ranking is not yet possible. The research conducted in experimental farms within the framework of the Green Dairy project (Action A : Bossuet et al., this volume) will in particular shed light on the possible future development of practices to reduce N surplus in the environment in various soil and climate contexts. The synthesis of the data gathered in the pilot farms is presented in Table 9.

Table 9 : Principal environmental factors of pilot farms in the Green Dairy network

	Scotland	Southern Ireland	South West England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicie	North Portugal
% grassland/AA	95	100	85	53	48	20	88	58	0
N organic (kg N /ha AA)	170	245	230	130	97	94	270	267	448
N mineral (kg/ha AA) with fixation	114	269	234	57	66	147	28	136	212
<i>N* Surplus (kg/ha AA)</i>	<i>134</i>	<i>240</i>	<i>266</i>	<i>117</i>	<i>93</i>	<i>155</i>	<i>257</i>	<i>349</i>	<i>502</i>
P ₂ O ₅ mineral kg/ha AA	30	25	30	10	13	54	23	80	68
<i>P₂O₅ Surplus* (kg P₂O₅/ha AA)</i>	<i>40</i>	<i>18</i>	<i>35</i>	<i>36</i>	<i>21</i>	<i>50</i>	<i>84</i>	<i>163</i>	<i>116</i>
<i>Energy consumption (EQF/1 000 l)</i>	<i>85</i>	-	<i>85</i>	<i>93</i>	<i>100</i>	<i>148</i>	-	<i>101</i>	<i>73</i>
% AA with at least one pesticide treatment	10	-	15	49	52	80	-	48	100
Storage capacity (month)	<3	3	<3	6	6	>6	<3	<3	<3

*: Surplus at the farm scale

- : missing data

The following are the major broad conclusions arising from the pilot farms:

- Grassland farms in the British Isles used little or no plant health products. Mineral fertiliser inputs remained high, with more than 150 kg N/ha AA and balance surpluses exceeded 150 to 200 kg N/hectare. The farm manure storage capacities were often insufficient to cover the winter period and to allow application to land at the recommended times. The margins for progress related primarily to fertiliser practices.

- Forage farming systems were very diverse and had N balances close to 100 kg/ha AA. Mineral fertilisation seem to be well adjusted in Brittany and Pays de la Loire. The fertiliser plans that have been made obligatory by the Nitrates Directive have already shown their effectiveness. Fertiliser rates remain high in Aquitaine where a low percentage of the region is classified as being in vulnerable zone. Improvements were also possible for P fertiliser use. The use of plant health products depended on the proportion of maize (2 treatments per year on average), but more especially on the proportion of winter cereals (2.5 to 7 treatments).

- In the systems of the South, 20,000 to 30,000 litres of milk/ha were produced were very demanding in inputs. The P and N balances were greater than 350 kg N/ha AA and 120 kg P₂O₅/ha AA, respectively. In these systems, improved use of farm manures would make it possible to reduce considerably the inputs of mineral fertiliser and improve economic returns. Manure storage capacities were in relation to needs. Construction of new buildings included storage capacity for more than 6 months. Capacity for the majority of farms was still insufficient.

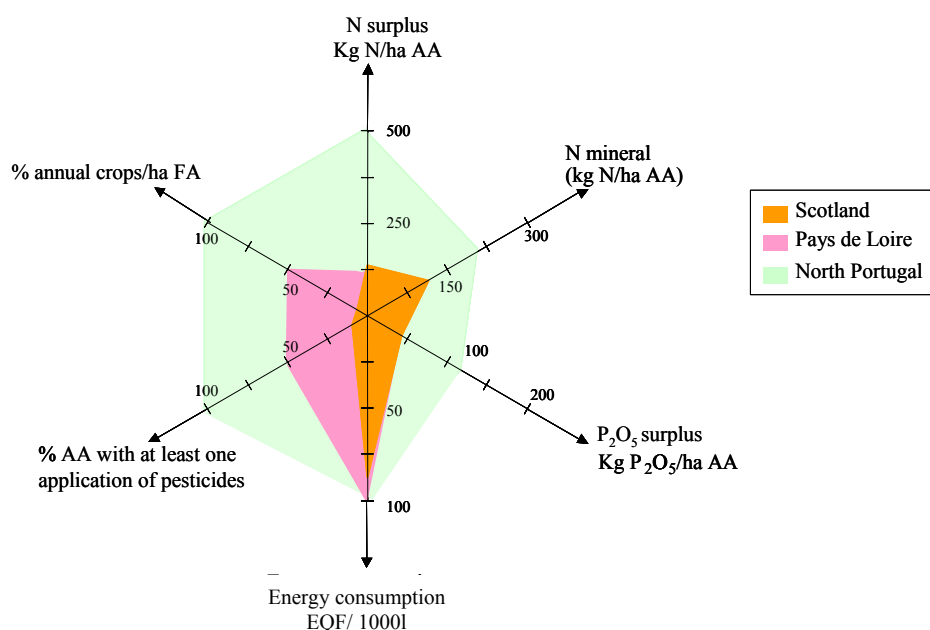


Figure 8 : Presentation of different indicators in 3 contrasting systems of the Green Dairy Atlantic Area

Figure 8 shows the principal indicators studied in 3 contrasting pilot farms of the Green Dairy project. Significant variations can be observed which are consistent with the type of system and farmers' practices. This type of analysis will be helpful to farmers to identify their scope for improvement. It will be a question of defining environmental objectives that can be reconciled with the production requirements systems and the context in which they are set.

4. Financial margins on feed and fertilisers at the dairy cow unit scale

4.1. Ranges in the price of milk

The milk prices presented here corresponds to the milk sold to dairies as well as to direct sales and were calculated with economic data provided by the farmers. The milk price in the pilot farms varied from 263 €/1,000 L milk in Scotland to 342 €/1,000 l in Galicia, i.e. a greater than 20 % difference . Pilot farms in the North (England, Scotland and Ireland) had the lowest prices. In France and in the Basque Country, prices were maintained at around 320 €/1,000 L.

Table 10 : Average price of milk (€/1,000 l) in the pilot farms of the Green Dairy network

	Scotland	Southern Ireland	South West England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicia	North Portugal
Year 1	-	282	264	331	323	325	310	330	300
Year 2	263	283	268	325	314	322	323	342	300
Year 3	273	298	-	315	304	320	323	340	300

- : Missing data

4.2. Costs associated with feed and fertilisers

The "costs" items taken into account correspond to the costs of bought feed (forage and concentrates) and to mineral fertilisers (N, P₂O₅ and K₂O), associated with milk production.

Table 11 : Costs of feed and fertilisers, milk produced and financial margin (average of 3 years)

		Scotland	Southern Ireland	Southern England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicia	North Portugal
Cost	Feeds (€/1,000 l)	53	28	43	32	48	60	113	117	110
	Fertilisers (€/1,000 l)	13	17	15	7	10	14	5	9	6
Milk produce (€/1,000 l)		268	288	266	324	314	322	319	337	300
Margin (€/1,000 l)		202	243	208	285	256	248	201	211	184

Fertilisers accounted for 5 €/1,000 L milk in the Basque Country and 15 €/1,000 L milk in England. The most intensive systems had the lowest expenditure related to fertilisers per litre of milk produced, but were among the highest per hectare. Fertiliser costs fell from more than 150 €/ha, in the South, to approximately 110 €/ha in grassland systems and 65 €/ha in Brittany. There were also differences in relation to feeds. In Ireland, the systems used, on average 580 kg of concentrates per cow for an average cost of 28 €/1,000 l milk: these were the lowest feed costs. In regions importing 1,500 to 2,000 kg of concentrates per cow and forage, the cost of feed was between 45 and 60 €/1,000 l milk. In the north of Spain and Portugal, the costs were greater than 110 €/1,000 l milk. A significant variation in costs according to systems is to be expected to be noted. The grassland systems of Ireland, with low use of concentrates, spend 45 €/1,000 l of milk for feed and fertilisers whilst the intensive systems of the South require more than 118 €/1,000 l milk.

4.3. Regional differences in financial margins and balances with production volumes

The calculated margin corresponds to the difference between the milk product and the cost of fertiliser and feed for the dairy unit and varied from 184 €/1,000 l in Portugal to 285€/1,000 l in Brittany. In Southern Ireland, the price of milk was low but was partly compensated for by good control of feed costs, making possible a margin of 243 €/1,000 l milk. In West of France, the margin was maintained at around 245-290 €/1,000 l milk . In the farms of the South, feed and fertilisers represented 60 % of

the cost of milk production. In the other regions, the levels of inputs represented between 15 and 30 % of the milk production costs. In Galicia and in the Basque Country, although the milk prices were the highest, the margin was one of the lowest. These costs are a heavy burden for these systems, and contrast with the farms of the West of France which were more self-sufficient with respect to inputs. Figure 9 shows that the margin was maintained at around 250 €/1,000 l milk when the N surpluses were moderate (i.e. lower than 150 kg N/ha AA in those farms which had a good efficiency of N use).

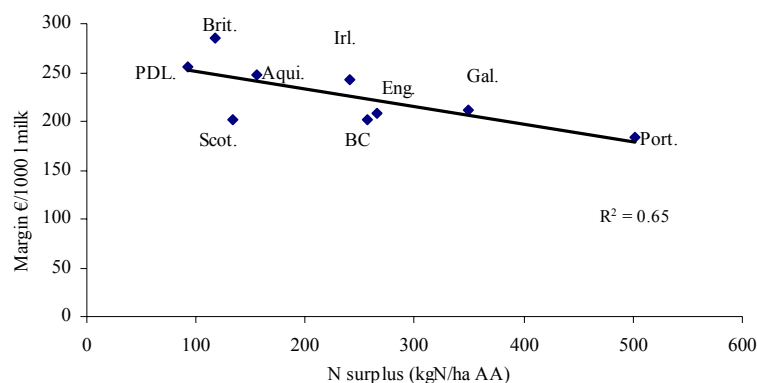


Figure 9 : Relation between the financial margin on fertilisers and feed (€/1,000 L) and N surplus (kg N/ha AA)

However, the margin does not include the other costs such as investments for buildings, storage works and equipment. The farms of Brittany and Pays de Loire have been brought up to standard in the past few years and are still currently undergoing this investment. The farms studied in the South recently increased their quota and had to invest in new buildings. In the British Isles, many buildings are in rather a poor condition and are generally depreciated (Chatellier and Pflimlin, 2006, same volume).

5. Implementation and assessment of environmental improvement

The global approach to the production system, to environmental constraints and the structural and the cultural contexts makes it possible to work out coherent proposals for action within the farm organisation and operation (Fig.10) and the objectives of the farmer (Chambaut et al, 2005) and must be coupled with the analysis of various environmental indicators. At the end of this phase, the opportunities for progress are identified by integrating soil and climatic factors, and the structural and cultural context. The principal targets for optimisation identified during the project primarily relate to the management of organic and mineral nutrients and the control of feed.

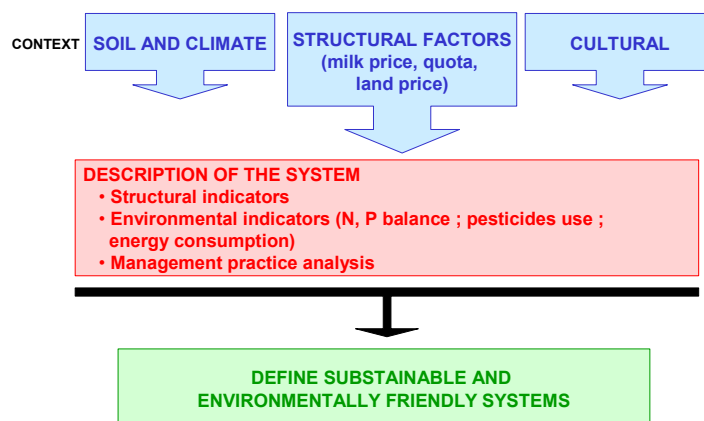


Figure 10 : A conceptual approach to the definition of environmentally-friendly dairy systems

5.1. Optimising organic and mineral fertilisers: an accessible tool for all farmers

To analyse more precisely the fertiliser practices and the opportunities progress, the N and P agronomic balance was calculated. This balance applies to the field scale and takes account of the inputs in organic fertiliser (manure spreading and excretion at grazing) and the mineral fertilisers and removals in crops and the grassland. This balance should not be used to make overall analyses between regions.

In Southern Ireland and South West England, the field agronomic N balances were between 182 and 233 kg N/ha. However, in these systems, this analysis is not very relevant because more than 60 % of the organic N inputs take place at grazing and is used inefficiently over the short and medium term, because of the timing of these returns, their heterogeneity and forms of N. Additional N inputs are therefore necessary, either as mineral fertiliser, or with the introduction of white clover. However, even if the calculation of the agronomic balance gives significant weighting to organic inputs it is possible to reduce fertiliser inputs without prejudicing yields. Humphrey, 2006 (same volume) in his comparison of systems showed that it is possible to decrease mineral N inputs by 134 kg/ha with the introduction of white clover without penalising production.

In the pilot farms of Brittany and Pays de la Loire, the agronomic N balance appeared to be well balanced (-2 kg N/ha in Pays de Loire and 30 kg N/ha in Brittany). For several years, local regulations have meant that N inputs must be determined by the exports in the crops. The P inputs are also well controlled.

In the South, the field agronomic N balance resulted in a surplus of 83 to 170 kg N/ha which was quite similar to the level of mineral fertiliser additions. If these farms had adequate slurry storage capacity to be able to carry out spreading at the periods when crops are able to make best use of the nutrients it supplies, the mineral N fertiliser inputs could be clearly reduced. The organic and mineral P inputs were also higher than the exports in crops. Surplus P additions during the last decade have resulted in an increase in the P content of the soils, and in many farms, a reduction or indeed a removal of mineral P inputs without risk for the crops seems possible.

Table 12 : Agronomic nutrient balances in the pilot farms

	Scotland	Southern Ireland	South West England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicia	North Portugal
N organic total /ha AA*	170	245	230	130	97	94	270	267	448
N min/ha AA	114	269	234	57	66	147	28	136	212
(N org total + N min) / ha AA	274	514	464	187	163	241	298	403	660
Yield									
Grassland (t MS/ha)	11	10,5	11	8	6,5	7	8	9-10	-
Maize (t MS/ha)	-	-	-	12	10	15	14	15	21 **
Removal in crops***									
kg N/ha AA	269	329	235	165	165	180	215	250	490
Nitrogen agronomic balance (inputs-removals)	5	185	229	22	-2	61	83	153	170
P₂O₅ agronomic balance (inputs-removals)	2	12	24	8	0	0	68	89	57

* Organic nitrogen = N produced by the herd – exports N + Imports.

** + Italian ryegrass 8-10 t DM/ha

*** Exports = 24 kg N/t DM mown grass; 32 kg N/t DM grazed grass; 12.5 kg N/tDM maize ; 1.5 kg N/quintal grain maize.

In these farming systems, reduction in mineral fertilisers first of all means good use of organic fertilisers. Mineral fertilisers should be considered as a complement to organic inputs. For this to be effective, the analysis of manures, the calculation of inputs according to the needs of plants, the nature of excretal patterns and inputs at optimum periods for agronomic responses are necessary. These considerations for optimising fertiliser are already being applied in French nitrate vulnerable zones. Since 1988, mineral N consumption has decreased by 22 % in Brittany and 14 % in Pays de la Loire (UNIFA, 2005).

However, in some regions storage capacities were sometimes insufficient and do not make it possible to align organic N inputs to the needs of the plants. The storage needs of a farm are defined by the time animals spend indoors, the crops in the rotation and the periods when spreading is possible. In the North of Europe, the requirements would be at least 4 months (taking into account 4 months in the buildings in winter). In the South, 6 to 9 months would be needed. In France, the storage cost is between 160 and 230 €/cow/month (storage of slurry + effluent from the milking parlour). On the basis of this reference point, the cost of 6 months of storage varies from 120 to 168 €/cow/year (5% loan over 10 years). The increase of the storage capacities provides a better manure management and increase their efficacy and it is thus possible to reduce the amount of mineral fertilisers. It would generate a saving. This saving, however, is lower than the storage cost and is not sufficient to encourage the farmers if government aid to investment is not available.

In the very intensive farms of the south, on a small agricultural area, the manure produced on the farm are sometimes more than the needs of the crops. In this case, possibilities are either to increase the spreadable area (taking over land or resorting to land lease) or to treat the excess. The land pressure and the few available limit the first solution and manure treatment requires significant investment which at the present time would not benefit from any subsidy in these regions.

5.2. The risk of concentrate adjustment for farmers of the South

The management of feed also makes it possible to optimise the nutrient balance surplus. The improvements can relate both to the quantities and the protein content of concentrates as well as the P content of the diet. The quantity of concentrates must be adjusted according to the level of dairy production and the forage resources available. Where these are possible, the inputs of concentrates can be reduced significantly as has been shown by several studies carried out in Europe (Brocard et al. 1999). Conversely, in the farms of the South, forage resources in the farms are limited and they have recourse to purchases of concentrates from outside, which the farmers consider it difficult to reduce.

It is often necessary to aim for a total N content of the total ration of 14 to 16 % for winter diets based on maize silage. During grazing, with young grass whose total N matter content is high (often more than 18 %) the concentrates based on cereals or residues are completely appropriate as shown by European research.

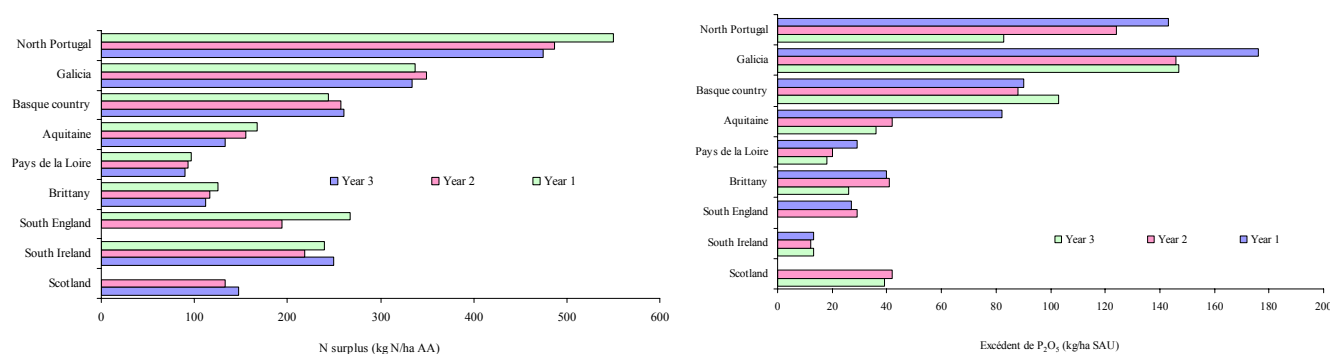
6. Changes in practices during the project: reduction in fertiliser use

Each year of the project, N and P balances were constructed and Table 13 shows the changes between year 1 and year 3 in the consumption of mineral fertiliser. These are the average evolutions which hide disparities between the farms of a same region. Generally speaking, it is observed that the mineral N inputs decreased by 5 to 60 kg N/ha AA without any consequence on yields. The inputs remained quite stable in Brittany and Pays de la Loire where the practices were already optimised but progress was recorded for P. Thus, in Aquitaine, the inputs decreased by 43 kg P₂O₅ / ha AA, a reduction of 50 %. A more modest reduction was also observed in other regions (Table 13). In North Portugal, there is a large reduction in N and P fertilisers use. This progress was made possible through better knowledge of the fertiliser value of farm manures. Indeed, in the majority of the farms, liquid manure was analysed during the project. In the same way, analyses of the P contents of soils were carried out in several farms in Galicia, the Basque Country and Portugal. The work carried out in the experimental farms involved in this project (Bossuet et al., this volume) was also used to raise the awareness of the farmers of available options to reduce environmental impact.

Table 13 : Changes in consumption of mineral N and P fertilisers between year 1 and year 3 of the Green Dairy project

	Scotland	Southern Ireland	South West England	Brittany	Pays de la Loire	Aquitaine	Basque country	Galicie	North Portugal
Mineral N year 1 (kgN/ha AA)	134	269	234	58	73	148	35	106	224
Trend in mineral N use between year 1 and 3 (kg/ha AA)	stable	- 40	- 60	stable	-5	- 20	- 10	stable	-60
P ₂ O ₅ mineral year 1 (kg P ₂ O ₅ /ha AA)	32	30	38	11	15	83	32	79	77
Trend in mineral P ₂ O ₅ use between year 1 and 3 (kg P ₂ O ₅ /ha AA)	stable	stable	-15	stable	-5	- 45	-15	stable	- 20

During the 3 years of the project, the average changes in the nutrient balances were contrasting (Figs 11 and 12) in the different regions, even though progress has been recorded on the use of mineral fertilisers. The N surplus decreased in Portugal, in England and in the regions of the West of France. The most significant progress relates to the P balance which decreased considerably in Portugal and in Aquitaine because of the reduction of inputs in fertilisers. The P balance was also improved in many of the other regions. However, prudence is advisable on these first results based on only 3 years of study. The N and P balances also incorporate changes in outputs by dairy production, meat and cash crops which can vary from year to year. The climatic year also has an important influence on farm production. Inter-annual variations on the balance outputs can thus disguise effects related to increases or reductions in inputs. A follow-up over a longer period of time is necessary to reveal progress more clearly.



Figures 11 and 12 : Changes in the N and P surplus during the project

7. Prospective changes in practices and impact on balances

Although a reduction in fertiliser use has been started, the inputs of concentrates and feed have remained stable. However, the project has made farmers aware of the progress possible. If the monitoring of the farms continues beyond the project, significant change can be expected. Scenarios of possible change in practice were applied in each region and the associated changes in N and P balances estimated (Table 14).

The scenarios are based on the adjustment of mineral N and P fertilisation. The levels of fertiliser use are determined from the analysis of fertiliser practices and agronomic balances. In addition, the storage capacities works are assumed to be sufficient.

In the grassland systems, the mineral N inputs were fixed at 100 kg N/ha. For Ireland, fertiliser use was based on a system studied on the experimental station of Solohead in part A of the project (see Bossuet et al., this volume) studies of N flows in experimental stations: i.e 90 kg of mineral N and 10 kg N/ha from fixation. For French farms, mineral N fertiliser, already quite well adjusted, was reduced by a few units. The inputs of P₂O₅ were also appreciably reduced. For Aquitaine, the

proposed inputs of mineral N were based on the application of a forward fertiliser plan. Inputs were completely eliminated in Galicia and in the Basque Country. In Portugal, taking into account the yield potential, mineral N inputs were fixed at 50 kg/ha, but P inputs were not allowed.

Table 14 : Impact of adjustment of fertiliser use on nutrient, balance surpluses and costs

	N mineral (kg N/ha AA)		N surplus (kg N/ha AA)		P ₂ O ₅ mineral (kg P ₂ O ₅ /ha AA)		P ₂ O ₅ surplus (kg N/ha AA)		Reduction of fertilisers costs** (Euro)	
	IS*	Project	IS*	Project	IS*	Project	IS*	Project	/ha AA	/ 1,000 litres
Scotland	114	100	134	120	30	15	40	25	16.6	2.3
Southern Ireland	269	90	240	161	25	15	18	8	129.8	16.7
South West England	234	150	266	132	30	15	35	20	65.6	6.7
Brittany	57	50	117	110	10	5	36	31	7.2	1.3
Pays de la Loire	66	60	93	87	13	5	21	13	7.8	1.6
Aquitaine	147	90	155	98	54	10	50	6	59.7	9.9
Basque country	28	0	257	229	23	0	84	61	30.0	2.0
Galicia	136	0	349	213	80	0	163	83	131.2	6.7
North Portugal	212	50	502	340	68	0	116	48	144.0	4.1

*SI = average initial situation year 1 to 3.

** With costs of 1 kg N and 1 kg P₂O₅ identical between regions.

According to this evaluation, fertiliser adjustment made it possible to reduce N surpluses by 7 % to more than 50 % (in England). In the South of Spain and Portugal, in spite of a significant reduction in fertilisers surpluses remained high. This demonstrates the need for adjusting the feed as close as possible to needs to continue the reduction in surplus. From an economic point of view, the reduction of fertiliser use would bring economies of up to 144 €/ha in Portugal, i.e. approximately 4 €/1,000 litres. However, this estimate does not integrate the construction or enlargement of manure storage capacity. In the Basque Country, Galicia and Portugal, the balances after adjustment of fertiliser remain higher than 260 kg N/ha AA and 104 kg P₂O₅/ha AA. To reduce the surplus more, it would be necessary to reduce the use of concentrates. However, there is little room for manoeuvre in this respect if dairy production is maintained at the current level.

Conclusion

The Green Dairy project began in October 2003 with the constitution of regional groups of farmers. Even though the project was centred on farmers motivated by environmental questions, they were not all at the same stage of thinking at the beginning of the project. In the West of France (Brittany and Pays de Loire), the water quality was very poor and it is the centre of attention from all concerned. The farmers are very much aware of environmental questions since they have been subject to the requirements of the nitrate directive since 1996 and for several years, they have been committed to a progressive approach which aims at reducing synthetic fertilisers and to improving the use of concentrates. In the other regions, water quality has been maintained. However, current production systems have significant P and N surpluses which should be controlled to reduce their environmental impact, and also to increase economic efficiency. The Green Dairy project thus constitutes for many farmers a first step towards environmental optimisation.

The project allowed not only exchanges between the farmers of the same region, but also between those of different regions and many regional exchanges have taken place (Table 14). The farmers have discovered other production systems and become aware of the economic and structural constraints to which their counterparts of the Atlantic Area are subjected. They have also had concrete illustrations of actions already undertaken by some of their colleagues.

Table 15 : Study trips organised in the Green Dairy regions

Green Dairy group	Southern Ireland	South West England	Brittany	Pays de la Loire	North Portugal	Scotland
Visited regions	Brittany Pays de la Loire	Brittany Pays de la Loire	North Portugal Galicia	Ireland	Brittany Pays de la Loire	Netherlands

The results observed at the end of 3 years of monitoring already show significant change in practices. Many farmers took advice and decided to reduce mineral fertilisers. These first steps had no effect on production and thus are motivating the farmers to continue. The British Isles, the North of Spain and North Portugal are now at stage 1 of the optimisation curve defined by Aarts and Jarvis , 2006 (same volume). This stage is defined as the "key" phase to optimisation whereby the farmer decides to commit himself to change his practices. The first results then will encourage them to continue. The farmers of the West of France have already taken this step and placed themselves in a dynamic phase of evolution and change in practices.

The progression towards stages 2 then 3 of the optimisation curve is only possible if the farmers benefit from advice and adopt the experimentation results to help them to think of the various actions in which they can engage. Many farmers involved in the Green Dairy project would like to continue to hold meetings and exchanges with the other farmers. The continuation of this network seems significant not only for the farmers already committed, but also for other producers in each area. The pilot farms provide a very valuable means to communicate options at the local scale.

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Study of the distribution of nitrogen surplus in experimental dairy farms of the Atlantic Area

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Abstract

Agricultural activity contributes to the production of nitrate but also to gaseous nitrogen emissions, i.e. ammonia, nitrous oxide, nitric oxide and nitrogen gas. To study the environmental impact of intensive dairy systems of the Atlantic Area on water, air and soil, the partners of the Green Dairy European project selected 9 experimental farms representative of each region concerned: Southern and Northern Ireland, Scotland, Wales, Brittany, Pays de Loire, Aquitaine, Spanish Basque Country and Galicia. In these experimental stations, a study of flows and losses of phosphorus (P) and nitrogen (N) was carried out over the years 2004 and 2005 at different scales: farm, field, animal, and housing and storage, following a common protocol. The results thus make it possible to compare N emissions to water and the air according to the production system and the local soil and climate environment. In intensive grassland systems with more than 2 LU/ha FA (forage area) and producing more than 10,000 kg milk/ha AA (agricultural area), the N surplus at farm level was high, near to 200 kg N/ha/year. In spite of this, mineral N residues at start of drainage were lower than 50 kg N/ha and the losses by leaching low (15 to 40 kg NO₃-N/ha). On the other hand, the calculated gaseous anthropic emissions (N₂O + NO + NH₃ + N₂) were considerable from 70 to 90 kg N/ha for a stocking rate of 2 to 2.8 LU/ha FA. In the annual forage crop systems (corn and temporary grassland), the field and herd balance surplus was lower, approximately 100 kg N/ha. However, soil mineral N at the beginning of drainage was around 80 kg N/ha and the losses by leaching varied from 40 with 80 kg N/ha. As the drainage water flows were lower in these systems, the nitrate concentrations fluctuated widely depending on the year's winter rainfall. The calculated gas emissions were lower than those obtained in intensive grassland systems. The Green Dairy project has made it possible to highlight the diversity of situations and create an important data base concerning N flows at the farm scale. These conclusions would have to be consolidated by continuing the environmental assessment of these farms over further years and looking in more detail at P losses.

Introduction

The West Atlantic Area is characterised by its abundant rainfall and its mild temperatures. This allows intensive dairy production, based primarily on grass in the North part and more on maize silage in the South, with a decreasing gradient according to the latitude. The Green Dairy project studied the impact of these productive dairy systems on water and air quality. The "pilot farm" part of the project gives an image of the diversity of the production systems present and the levels of N and P balances observed in commercial farms (Raison and Pflimlin, same volume).

All in all, intensive grassland dairy systems of the North have considerable recourse to mineral N fertilisers with high N balance surpluses. In France and in the South of Europe, the introduction of maize silage into the systems and the rotation of grasslands results in lower surpluses but raises other questions for N management, such as the management of inter-crops after maize or cultivating grasslands. Thus, even if N surpluses in the farm are lower, the risks of leakage can still be significant.

For a better understanding of the inter-year and inter-site diversity of N surpluses in dairy farms, the "experimental farm" part of the Green Dairy project aimed at characterising precisely the N balance of the farms and analysing changes in the surplus. Physical flows (movements of animals, feeding plans, crop interventions, purchases/sales...) are thus recorded and the P and N contents of the products were

listed or analysed. These made it possible to quantify P and N flows between the various parts of the farm and estimate the losses to water and air in order to compare them with N balance and surplus. After a rapid description of the experimental stations selected and the methodology employed, we present the managements of the dairy systems studied, and then analyse the variability of N flows for each site and from one year to another on the same site. Lastly, we detail the distribution of the N surplus obtained in Green Dairy by major type of forage system and compare these with others in the literature.

1. The experimental farm structure

1.1. Location of the experimental farms

The "experimental farm" study of Green Dairy groups together nine stations situated in four countries: the United Kingdom, the Irish Republic, France and Spain. The dairy systems studied include dairy cows and the replacement herd as well as the crops, except on the Dumfries site, where it was not possible to include the replacement herd. The analysis was therefore not carried out just on the main forage area (FA) but at the scale of the system as a whole in order to establish more easily the link with the results obtained in commercial farms ("pilot farms" study) and with the water quality observed at regional level. Thus, on Trévarez, Derval, Ognoas, Behi-Alde and Mabegondo experimental sites, it was the total farm which was studied. In Ognoas, the cash crop unit accounted for approximately 40% of the agricultural area (AA) and was integrated into the results because it is representative of the systems of its region. However, the results are not directly comparable with the other specialized milk stations and are the subject of a specific analysis.

The degree of optimisation of practices from an environmental point of view is variable according to sites and depending on the research themes being investigated. Thus in France for example, before the Green Dairy project, the sites had begun work on reducing inputs by better management of farm manures and the establishment of an intermediate crop. The systems presented are therefore relatively well optimised. At the other sites (Hillsborough, Solohead, Dumfries, Ty Gwyn) two or three systems were compared. The objective was then to carry out a comparative analysis between herds managed with different degrees of intensification or self-sufficiency in feed, some being more self contained than others with their inputs. The variability of optimisation levels was not an obstacle to the project as the first objective was to analyse the distribution of the N surpluses in given environments.

Table 1: Location and soil and climatic conditions of the 9 experimental stations

	Country	Region	Partner	Number of systems	Altitude (m)	%O.M. on 0-30 cm	Texture of soil	Average on 20 years		
								Annual rain mm	Drainage mm	T°C
Dumfries	United Kingdom	Scotland	SAC	2	10	5.5	Sandy loam	1050	327	9
Hillsborough	United Kingdom	Northern Ireland	ARINI	2	110 to 170	10.3	Loamy clay	892	400	9.1
Solohead	Southern Ireland	Munster	TEAGASC	3	103	16.7	Clay loam	995	550	10.5
Ty Gwyn	United Kingdom	Wales	IGER	2	50 to 110	9.5	Clay loam	1202	750	9.3
Trévarez	France	Brittany	CRAB	1	75 to 250	6.8	Loamy clay	1263	500	11.4
Derval	France	Pays de la Loire	CA 44	1	43	3.4	Loamy clay	774	250	11.7
Ognoas	France	Aquitaine	Inst. de l'Elevage	1	97	1.4	Sandy loam	932	254	12.8
Behi-Alde	Spain	Basque country	NEIKER	1	640	10	Clay loam	1335	800	10.5
Mabegondo	Spain	Galicia	CIAM	1	97	5.4	Loamy	1038	422	12.9

⁽¹⁾ : average of the region

The stations were at altitudes varying from 10 to 640 m above sea level (Table 1). They benefited from a moderate oceanic climate, favourable to the growth of grass. Annual rainfall was relatively high and the temperatures mild. However, in spite of similar climatic trends, great disparities existed in the

study years between the sites. The annual rainfall varied between one to two times between the sites with the least (Derval) and most rain (Ty Gwyn, Trévarez, Behi-Alde). On average, 50% of the annual rainfall fell from October to February. The drainage water flow was overall high, more than 400 mm, except at Derval and Ognoas with 250 mm. The soils were mainly of a loamy texture with more or less clay. Only Ognoas and Dumfries soils had a sandy texture. The soils at the Northern sites, based on permanent grasslands, were rich in organic matter, with more than 10% on the 0-30 cm horizon. Soils of the systems with forage crops had lower and more variable organic matter rates.

1.2. Diverse systems

The size of the systems studied in experimental stations ranged from ca.10 to more than 200 ha and the number of animals studied has the same range of variation (from 22 to 521 cows). We can identify 3 major types of management (Table 2):

- *Grassland systems with permanent grasslands managed more or less intensively*

In this group, we can classify the two systems at Hillsborough and the three systems at Solohead made up only of grasslands managed intensively (i.e more than 10,000 kg milk /ha grass). The grasslands were of long duration and primarily grazed. The systems were based on relatively low concentrate use (330 kg DM concentrates/cow/year at Solohead, 1100kg at Hillsborough) and the production per cow was moderate (from 5,500 to 6,500 kg milk/cow/year, respectively).

The two systems at Ty Gwyn, which had a lower stocking rate and less than 6,500 kg milk/ha, can also be integrated into this category. These two systems are managed under organic farming rules, one permitting purchases of feed, the other having reduced the stocking rate to be more self-sufficient. Both systems made extensive use of clover swards and did not use mineral fertilisers.

Lastly, the remaining systems with dominant grassland can always be classified in this category, but had a moderate inclusion of maize silage (less than 15 % of the FA). The two systems at Mabegondo and Dumfries High Forage belong to this group with respective dairy productivities of 7,000 and 12,000 kg milk/ha; They have very different levels of mineral and organic N input. In both cases, the inputs of concentrates are relatively high (1.5 T DM/cow/year). The average dairy production per animal was also higher than in the former group, with respectively, 7,500 and 8,800 kg milk/cow/year.

- *Forage crops based on maize silage and temporary grasslands in rotation.*

This group included the three French stations with more than 30% of maize FA. Rotation also comprised more or less cash crops: Trévarez and Derval had less than 10% of crops in the AA but Ognoas had 40 %. Dairy production per animal was quite high but remained moderate per ha AA because of intermediate stocking rates (Trévarez and Derval) or the presence of areas under cash crops (Ognoas). At Ognoas, dairy production reached 9,300 kg/ha FA. The level of concentrates was ca. 1.5 T DM/cow/year in Derval and Ognoas but much lower at Trévarez, the consequence of careful management.

- *Intensive “semi” housed systems with high levels of bought-in concentrates*

These include Behi-Alde and Dumfries Low Forage. The stocking rates were high and the concentrate input exceeded 3 tons of DM/cow/year producing more than 20,000 kg milk/ha AA. The Behi Alde site was a "commercial farm" with co-operative status in which field monitoring of P and N flows had been set up prior to the Green Dairy project.

Table 2: General characteristics of the 9 experimental stations (average for 2004 and 2005)

	% SFP /AA	% maize /FA	% grassland /FA	Stocking rate LSU/ha FA	Milk kg/ha AA	Concentrates kg DM/cow	Milk kg/cow/year	N fertilizer kg/ha	Organic N spread kg/ha	N fixation kg/ha
Hillsborough High N	100	0	100	2.8	12 019	1 094	5 525	262	160	0
Hillsborough Low N	100	0	100	2.8	12 180	1 094	5 599	226	160	0
Solohead Ferti N-230	100	0	100	2.2	11 500	330	6 469	221	55	27
Solohead WC-90	100	0	100	2.2	11 566	330	6 506	87	55	100
Solohead WC-REPS	100	0	100	2.0	10 534	330	6 474	100	50	56
Ty Gwyn self-sufficient	87	0	100	1.3	4 367	551	5 322	0	74	81
Ty Gwyn purchased feed	100	0	100	1.5	6 555	1 401	6 098	0	73	86
Dumfries High forage	100	13	77	1.5	11 978	1 375	8 758	187	97	0
Mabegondo	100	4	96	1.8	7 165	1 440	7 438	50	20	73
Trévarez	91	31	69	1.5	5 933	482	6 618	49	69	22
Derval	86	38	62	1.4	7 150	1 560	8 352	31	56	25
Ognoas	44	34	66	2.2	4 079	1 312	7 707	119	61	0
Dumfries Low forage	100	16	72	2.1	20 678	3 376	10 741	177	100	0
Behi-Alde	100	11	89	3.7	23 307	3 945	9 901	31	293	16

2. Method of assessing N flows and losses

Nitrogen flows and losses were assessed according to a common protocol after comparison of the procedures of each country. The evaluation method was largely based on those implemented in previous studies on complete systems (Aarts, 1999; Le Gall and Cabaret, 2000; Peel et al., 1997). However, for certain components there were some methodological variations, due either to the disparity of the research being conducted at the different sites, or for environmental reasons (methods of measuring losses by leaching for example).

The N flows were assessed at several levels: animal, buildings, fields, and at the scale of the whole farm. The difference between inputs and outputs provided a N surplus at the various scales, which is a first indicator of risk of losses towards the environment in the short or medium term. The second stage of the work then consisted of evaluating the losses to water and air by direct measurements and/or calculation. The N balance observed for the experimental system also provided the link with surpluses observed in pilot farms (Raison and Pflimlin; same volume).

2.1. Calculation of N flows and losses

2.1.1. Calculation of balances and flows of nitrogen

At the animal and herd level. A balance makes it possible to estimate excretions before losses by volatilisation. Calculations were carried out by grouping the animals into batches, i.e. animals having same ration and same management (housing/grazing). Flows were evaluated for the dairy cows and also for the heifers. The difference between the inputs in feed and the outputs in products represented the quantities excreted by the animals and herds.

Feed provides the only N entering the flow into the animal. The stored feed (preserved forage, concentrates, mineral supplement) was weighed as were the refusals. To estimate intake at grazing, various methods were used, either based on the needs of the animals evaluated by energy balance or balance associated with the intake capacity at the French and Behi Alde sites, or measurements of quantity of grass in swards pre and post grazed by herd at the other sites. Regular analyses made it possible to know the N content of each feed and therefore to estimate precisely the quantities of N ingested. Nitrogen is exported in milk and meat. The quantities of milk were recorded and using local

analyses and published information, N removed in milk was calculated. Calf cull cow weights were used to quantify the live meat produced by the dairy unit in the year. Weight gain by the heifers was recorded and common published data were used by all partners to estimate N outputs in meat. The division of excretion between the buildings and in the field during grazing was calculated according to the time spent by animals in or outside. This calculation made it possible to estimate appreciate the total and spreadable organic N pressure on the land and also made it possible to calculate gaseous N emissions from these flows.

At the field scale, N surpluses were estimated on an agronomic balance basis i.e. by summing all the inputs to the soil and subtracting all the outputs/removal in crops. The field balances were then combined to provide a total balance for the whole AA. For the crop fields (including maize forage), the N inputs considered were total mineral and organic fertilisers together with atmospheric deposition. The outputs correspond to the quantities of N exported in crops, calculated from production data and crop N contents.

For the grasslands, inputs to the soil were from mineral and organic fertilisers, excretal deposition at grazing, the symbiotic N₂ fixation by legumes and atmospheric deposition. Outputs correspond to the quantities of N either consumed at grazing or in conserved forage. Analyses of the N content of the grass, spread fertilisers and manures, and measurements of clover content, made it possible to quantify N flows in the grasslands. To take account N₂ fixation the following formula, established from measurements of fixation by white clover carried out in the United Kingdom and in Brittany (F Vertès, 2004, personal communication) was used:

$$\text{kg N fixed/ha} = \text{yield grasslands (t DM/ha)} * \% \text{ clover} * 35 \text{ kg N fixed/t DM} * 1.3$$

The white clover content of the pastures was measured at different times of the year, either by sorting and weighing, or by visual assessment to provide a weighted contribution to forage production.

At the farm scale, the apparent N balance or farm gate balance was calculated by considering the farm as a "black box" where N enters and leaves and whose quantities are counted, internal flows not being considered. The inputs can be in the form of mineral fertilisers, imported manure, N₂ fixation, cattle feed or atmospheric depositions. The outputs consist of all the animal products (milk, meat) and plants (crops and forage sold) which leave the farm, as well as any animal manure sold. The difference between inputs and outputs per ha AA was used as the apparent farm N balance/surplus.

The distribution of the N surplus in the environment was also determined and we quantified the proportion of the surplus lost as nitrate in water, into the air by volatilisation or denitrification and the fraction immobilised in the soil and thus increase the organic N pool. After mineralization this pool will be available for uptake by plants or create an additional risk of leaching.

2.1.2. Assessment of N losses to water and air

- *Assessment of N losses to water*

Nitrate losses by horizontal transport (run-off) were not considered because in the grassland systems studied, water movements were limited by the presence of winter cover. Significant run-off is however observed in Behi-Alde, because of steep slopes and the high clay contents. Nitrogen losses by run-off or leaching was not be measured at this site.

The leached N were calculated as the product of the drainage flow and the nitrate concentration of the drainage water. Each site had its own assessment method depending on the local soil and climate conditions and the tools/equipment already established because of previous studies (see Table 3).

Table 3: Methods of assessing nitrate leaching and concentrations on the experimental sites

	Nitrates concentration (mg NO ₃ -/l)	Drainage (mm)	Nitrogen leaching (kg N/ha AA)
Hillsborough	Dipwells	Water balance	Conc. nitrates * drainage
Solohead	Piesometers + drains	Water balance (+ drains)	Conc. nitrates * drainage
Ty Gwyn	Ceramic cups	Lysimeters	Conc. nitrates * drainage
Ognoas	Drains + lysimeters	Lysimeters	Conc. nitrates * drainage
Trévez	SNM* + LIXIM model	Water balance	SNM + LIXIM model
Derval	SNM + LIXIM model	Water balance	SNM + LIXIM model
Mabegondo	SNM + LIXIM model	Water balance	SNM + LIXIM model
Dumfries	leaching N/drainage	Water balance	SNM + model

* SNM : Soil neutrogen mineral

At Hillsborough, Solohead, Ty Gwyn and Ognoas, nitrate concentration was measured in the fields by various sampling methods: sampling water in dipwells, drains, lysimeters or ceramic cups. The drainage volume was estimated by a hydrological balance or lysimeter measurement.

At Trévez, Derval, Mabegondo and Dumfries, a thorough assessment of soil mineral N carried out for the drainage period to determine changes in N content of the soil (and moisture content) during the drainage period. Soil samples were taken at three depths (0-30, 30-60, and 60-90 cm), at a rate of 15 samples per field. These samples were taken just before the resumption of drainage then every 100 mm of water and/or every month, in order to monitor accurately the movement of nitrate in the soil. At start of drainage this was conducted on 60 to 100 % of the fields followed by measurements on 30 to 50 % of the fields. The quantities of leached N and the nitrate contents were then calculated by using the LIXIM model developed by INRA (Mary et al., 1999). Drainage volume was estimated by a hydrological balance (rain – evapotranspiration).

In all the dairy systems studied, N residues in the soil profile were measured at the resumption of drainage (on 60 to 100 % of the fields) in order to have a common measurement for all the sites.

- *Assessment of N losses to the air*

Losses as ammonia (NH₃-N), nitric oxide (NO -N), nitrous oxide (N₂O-N) and N₂ were assessed. These gas emissions can occur in the housing, during the storage of manures, when the animals are grazing and when spreading manure. They were estimated from coefficients taken from the literature, regressive models and by considering time the animals spent indoors etc (N excreted – N collected for spreading) (appendix 1). Indirect losses of N₂O can also occur as the result of leaching or after the deposition of NH₃ and factors for these were taken from the literature as were those of direct N₂O losses from the soil. (Appendix 1)

The selected emission factors take into account, as accurately as possible, the diversity of the soil and climatic conditions at each site but could not include all possibilities. Appendix 1 shows the different emission coefficients chosen for the Green Dairy project.

3. Management and technical performances of the systems

3.1. Soil and climatic conditions of the study years

In 2004, in spite of a recorded annual rainfall close to the average, on all the sites there was a deficit of 10 to 45% of winter rainfall (from 1st October 2004 to February 28, 2005). In 2005, a deficit was observed for the year as well as for the winter of 2005-2006. The average drainage observed over the two years of study was thus lower by about 20% than the average at all sites (Figure 1). The deficits were very marked at Derval and Trevarez, and present to a lesser degree at Ty Gwyn, Solohead and Ognoas. At the other sites, the drainage water flows were normal, with an excess at Mabegondo. Consequently, the leaching losses measured over the two years correspond for two out of three sites following winters with much less rainfall than normal.

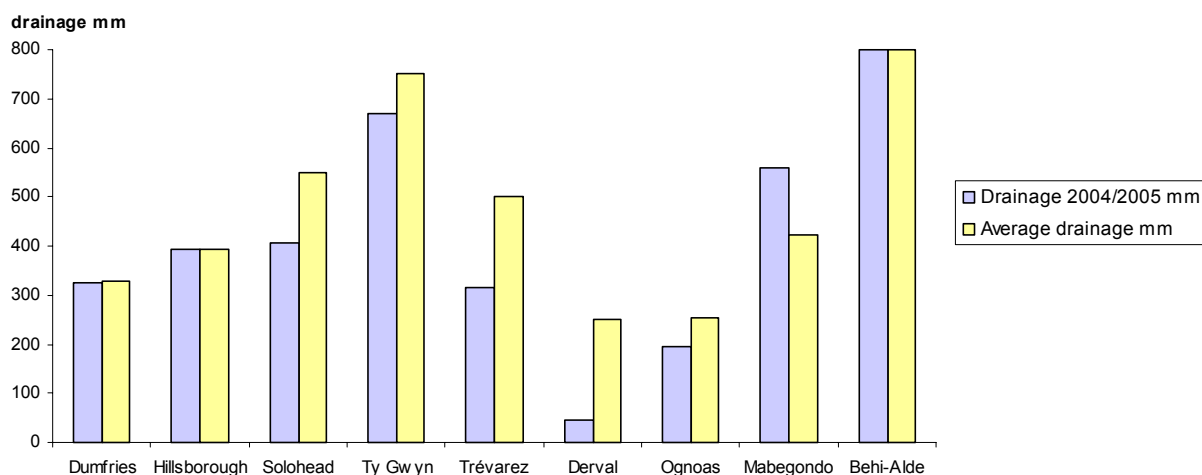


Figure 1: Comparison of the average drainage during the two years of monitoring (winter 2004-2005 and winter 2005-2006) and average over 20 years at the 9 experimental farm sites

3.2. Feeding the herd and associated N excretion

3.2.1. Place of grass in the feed

Cut and grazed grass represented more than 75% of the total ration (integrating concentrates) at Solohead and Hillsborough and 60% at Dumfries and Mabegondo. It represented less than 40% of the ration for the other systems based on forage crops and very intensive (Table 4). The place of grazed grass in the rations was very variable (from 0 to 70% of total intake) and varied from 40 to 70% in the grassland sites, and from 10 to 40 % for those using maize. Finally, the content of total N in the diet was greatest and close to 20% at the grassland sites, close to 15% at the sites that incorporated a significant proportion of maize silage and intermediate at Ty Gwyn.

Table 4: Herd feed management and production of farm manure (average for 2004 and 2005)

	Milk kg/cow	Concentrates kg DM/cow	g conc. /L milk	% grass /ration	% grazed grass /ration	CP ration %	Kg N excreted /cow ⁽¹⁾	% excreted in building	Type of manure ⁽²⁾
Hillsborough High N	5 525	1 094	192	79	43	19.1	124	55	slurry
Hillsborough Low N	5 599	1 094	189	79	43	18.6	120	55	slurry
Solohead Ferti N-230	6 469	330	49	94	70	19.8	129	21	slurry
Solohead WC-90	6 506	330	49	94	70	19.7	129	21	slurry
Solohead WC-REPS	6 474	330	49	94	70	19.7	129	21	slurry
Ty Gwyn self-sufficient	5 322	551	100	90	46	16.5	109	45	slurry
Ty Gwyn purchased feed	6 098	1 401	222	77	41	17.4	132	51	slurry
Dumfries High forage	8 758	1 375	162	58	18	15.8	139	65	slurry
Mabegondo	7 438	1 440	187	63	52	13.6	98	14	mixed
Trévarez	6 618	482	71	44	36	15.4	110	58	mixed
Derval	8 352	1 560	181	26	11	15.4	132	63	mixed
Ognoas	7 707	1 312	165	26	16	14.5	115	70	mixed
Dumfries Low forage	10 741	3 376	325	36	0	16.5	141	100	slurry
Behi-Alde	9 901	3 945	386	27	14	13.7	132	70	slurry

⁽¹⁾ : volatilisation in housing, buldings and other losses are not deduced

⁽²⁾ : mixed = FYM and slurry produced in the housing; slurry = mainly liquid effluent

3.2.2. N Excretion by the animals

Before deducting the gaseous N losses, the N excretion calculated per cow varied between 95 and 140 kg N/cow/year at the different experimental stations. These figure are representative of particular situation and can't be compared with level of emission taken in NitrateVulnerable Plan (excretion after air losses). Taking into account the productivity of the animals in the systems, the output per cow was 20 to 22 kg N/t milk produced in the mainly grassland systems (more than 75% grass in feed), ca. 16 kg/t milk in forage crop systems and grassland systems that incorporate a little maize forage, and 13 kg/t milk at the most intensive stations with cows ca 10,000 kg milk/year. These differences result from the level of production and the total N of the rations.

3.3. Nitrogen fertilisation and forage production

The intensive grassland systems of the North of the Atlantic Area use, on average, more than 200 kg mineral N ha (Table 5). Average yields were close to 11t DM/ha of grass and the days spent grazing were high (400 – 500 days/ha). The forage crop systems of Western France and Spain had more moderate mineral fertiliser use at ca. 50 kg mineral N/ha for grasslands because of lower yield, use of manures partly on grass and greater dependence on symbiotic fixation. Grassland yields were ca. 7t DM/ha with days spent grazing averaging ca.300-400 days/ha.

With maize, organic fertilisation represented from 70 to 100 % of the N inputs, mainly manure in the French stations and slurry elsewhere. The Ognoas station used more synthetic fertiliser for grain maize. The maize yields were variable and in conformity with regional potential: nearly 10t DM/ha at Dumfries, Derval and Mabegondo; nearly 12t DM/ha at Trévarez and Behi-Alde and 15t DM/ha at Ognoas with irrigation. The input/output balance was close to 100kg N/ha except at Behi-Alde where inputs of slurry were clearly surplus to requirements.

Overall, at the farm scale, mineral fertiliser covered a wide range, from 0 (Ty Gwyn, organic management) to 262 kg N/ha AA (Hillsborough) (Table 5). The annual inputs of manure and slurry produced by the animals (not counting manure excreted during grazing) were also variable: very high at Behi-Alde (293 kg/ha with input of pig slurry), high at Hillsborough (160 kg/ha) and less than 100 kg/ha for all other sites where they varied between 20 and 75 kg/ha. Symbiotic fixation was inversely proportional to the organic and mineral fertilisation and ranged between 20 and 100 kg N/ha AA.

**Table 5: Fertiliser use, yields and rotation at the system scale in kg N/ha AA
(average for 2004 and 2005)**

	Kg N fertilizer/ha AA	Kg N organic spread /ha AA**	Kg N fixation/ha AA	% grassland /FA	grazing days 24h/ha***	% new swards	yield of grassland t DM/ha
Hillsborough High N	262	160	0	100	413	0	11.4
Hillsborough Low N	226	160	0	100	413	0	11.4
Solohead Ferti N-230	221	55	27	100	507*	0	11.0
Solohead WC-90	87	55	100	100	507*	0	10.3
Solohead WC-REPS	100	50	56	100	461*	0	10.3
Ty Gwyn self-sufficient	0	74	81	100	196	11	7.9
Ty Gwyn purchased feed	0	73	86	100	226	11	8.0
Dumfries High forage	187	97	0	77	158*	0	8.6
Mabegondo	50	20	73	96	309	19	7.6
Trévarez	49	69	22	69	416	12	6.9
Derval	31	56	25	62	349	18	5.4
Ognoas	119	61	0	66	578	0	7.9
Dumfries Low forage	177	100	0	72	0	0	7.7
Behi-Alde	31	293	16	89	701*	5	7.2

* Estimation from grazing dates and stocking rate

**total organic nitrogen spread mechanically: productions from animals in housing +/- manure coming from outside

*** one day spent grazing corresponds to the round-the-clock presence of one LU on one hectare of grass. For example, a cow which only consumes grazed grass and stays for 20 hours in the field because of two daily milkings counts for 0.83 day spent grazing. On the other hand, this presence indicator does not take into account any other inputs of feed supplied to the animals over the period considered in the fields.

4. Nitrogen balances at farm scale

4.1. Nitrogen balances at farm level

The surpluses of *the apparent N balance measured* in 2004 and 2005 varied from 70 to 463 kg N/ha AA, with little inter-annual variations on the same site (Table 6). The N surplus is above all very closely connected to the total N entering the farm ($N \text{ surplus kg N/ha AA} = -14.7 + 0.76 N \text{ inputs kg N/ha AA}$, $r^2 = 0.97$). The N conversion rates, showing the efficiency of N use within the system, varied from 20 to 40% and were greater than 30 % in the most optimised and productive systems (i.e. Solohead 90 and REPS, Trévarez, Derval).

Table 6: Nitrogen balances at system level (average for 2004 and 2005)

	Hillsborough		Solohead			Ty Gwyn		Mabegondo	Trévarez	Derval	Ognoas	Behi-Alde
	High N	Low N	Ferti N-230	WC-90	WC-REPS	Self-sufficient	Purchased feed					
System	Milk + heifers	Milk + heifers	Milk + heifers	Milk + heifers	Milk + heifers	Milk + heifers + crops	Milk + heifers	Milk + heifers	Milk + heifers + crops	Milk + heifers + crops	Milk + heifers + crops	Milk + heifers
Fertilizers	262	226	221	87	100	0	0	50	48	30	119	31
Animal manure	0	0	0	0	0	0	0	7	16	0	0	22
Fixation	0	0	27	100	55	81	86	70	22	24	0	16
Total fertilization	262	226	248	186	155	81	86	126	86	55	119	68
Concentrates	83	83	25	25	23	5	48	39	37	63	44	256
Forages + straw	0	0	0	0	0	1	4	0	6	15	19	233
Animals	0	0	0	0	0	0	0	0	0	1	0	0
Deposition	12	12	8	8	8	6	6	10	15	11	5	33
Others	0	0	1	1	1	0	0	0	0	0	0	0
Total inputs kg N/ha	357	321	282	221	187	93	143	176	144	144	186	590
Fertilization (% inputs)	73%	71%	88%	84%	83%	87%	60%	72%	59%	38%	64%	12%
Feeds (% inputs)	23%	26%	9%	11%	12%	7%	36%	22%	30%	54%	34%	83%
Milk	63	62	64	64	59	18	28	36	30	36	21	117
Meat	9	9	9	9	8	2	3	5	7	5	2	10
Crops	0	0	0	0	0	1	0	0	1	7	68	0
Manure	13	8	0	0	0	0	0	0	4	0	0	0
Others	0	0	0	0	0	2	3	0	0	0	0	0
Total outputs kg N/ha	85	80	73	73	67	23	34	41	42	48	90	127
Nitrogen surplus kg N/ha	272	241	209	148	120	70	110	135	102	95	96	463
Nitrogen surplus kg N/1,000 L	23	20	19	13	12	17	17	19	18	14	24	21
Conversion rate %	24%	25%	26%	33%	36%	25%	24%	23%	29%	34%	48%	22%

The N surplus/ha AA appeared to be related to expressed per ha AA, which combines the effects of the level of intensification of both area and animal management (Figure 2, $r^2 = 0.89$). There were still, however, considerable variations in N when expressed per unit of dairy production per ha AA, which highlights available room for manoeuvre.

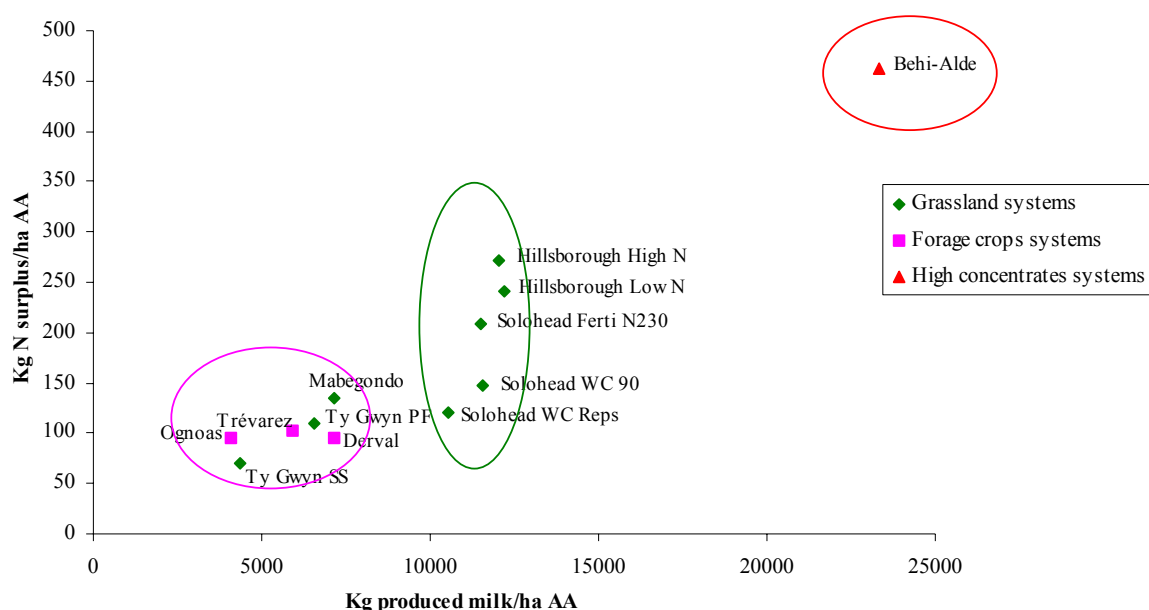


Figure 2: Relation between dairy production per hectare and N surplus (kg N/ha) on the Green Dairy experimental farm sites (average of 2004 and 2005)

The agronomic (field /herd) balance was also calculated at all the sites in order to take account of the diversity of inputs and outputs in the analysis of risks when considering the AA (Figure 3). The agronomic balance was closely correlated with the apparent N balance surplus for the farm ($\text{agronomic balance surplus} = 0.87 \text{ N apparent farm balance surplus} - 47$, $r^2 = 0.92$). These two indicators followed the same trends but a priori, the agronomic balance gives a better definition of the risk of surplus likely to be leached from any particular field.

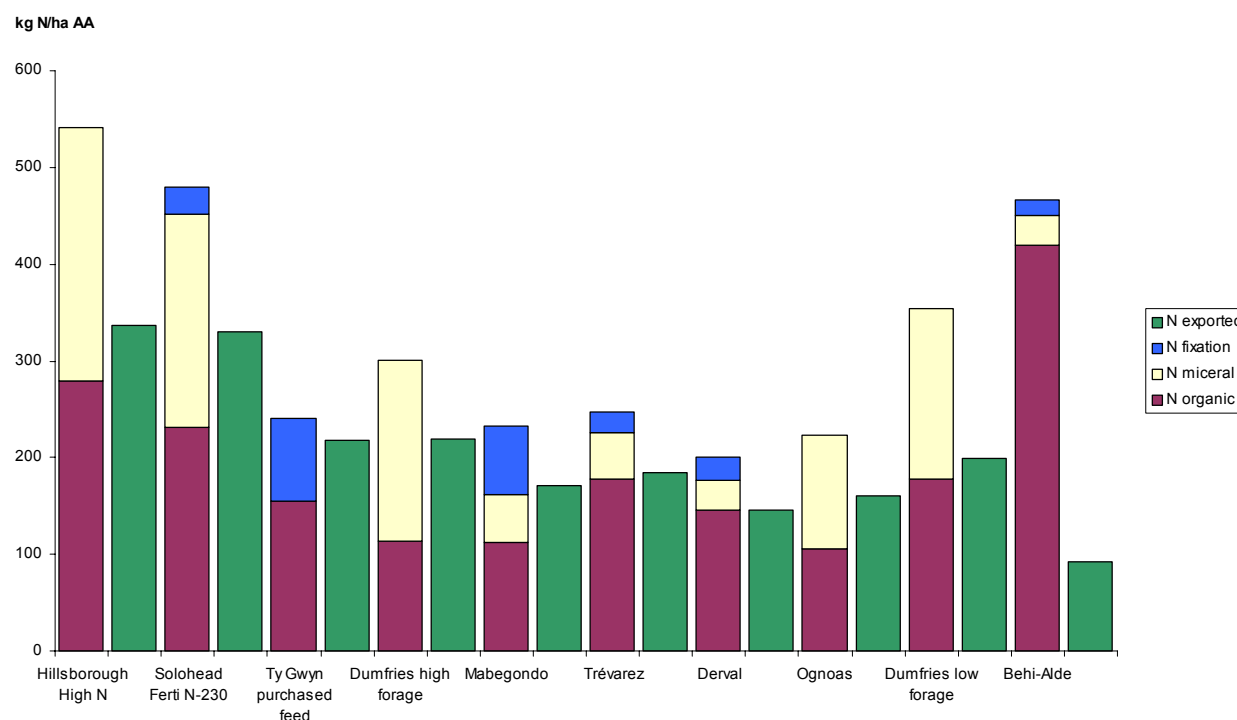


Figure 3: Difference between N inputs and outputs in crop production in kg N/ha AA (average for 2004/2005)

4.2. Nitrogen surpluses in grassland systems

In the predominantly grassland systems producing between 10,000 and 12,000 kg milk/ha (Hillsborough, Solohead), the apparent N balance surpluses varied from 120 to 270 kg N/ha AA for mineral fertiliser inputs from 100 to 260 kg N/ha AA. Nitrogen inputs from all sources (mineral, imported organic and fixation) corresponded to more than 70% of the inputs whereas concentrates accounted for only 10 to 20%. In the pilot farms, N surpluses were on average 234 kg N/ha AA (Raison et al, this volume), i.e. at a similar level to the highest N surpluses of the intensive grassland group of the experimental farms. More careful fertiliser managements in comparative tests at Solohead and Hillsborough show that there are significant margins for improvement at similar levels of production. For example, research at Solohead showed that it is possible to maintain the production of 11,500 kg milk/ha by reducing the N surplus by 25% compared with current practices in the region (Ferti N 230). By reducing production/ha by 10% it was possible to reduce the surplus by 40%. Work undertaken in New Zealand in an intensive system also shows similar effects (Ledgard et al, 2004).

In the less intensive grassland systems at Mabegondo (7,100 kg milk/ha AA) and Ty Gwyn in organic farming (4,000 to 6,500 kg milk/ha) the balances ranged between 70 and 135 kgN/ha AA. The N inputs in mineral fertilisers, imported organic manures and fixation) varied between 81 and 126 kg N/ha AA whereas they were between 155 and 262 kg N/ha AA in the more intensive systems. The fertiliser inputs to the soil, all forms included, were closer in this case to the level of outputs in crops as shown by the agronomic balance (Figure 3).

However, it must be noted that the system at Mabegondo aims to demonstrate the potential that it might be possible to achieve in this region if additional land was available close to the housing and farmers were willing to have animals graze. In the network of pilot farms in Galicia, the N surpluses were, on average, 349 kg N/ha AA and their profiles were close to that of Behi-Alde, i.e. with high inputs in concentrates and forage. The Mabegondo experimental system thus contrasts from local the farmer network because of a significant proportion of grazed grassland in the system.

4.3. N surplus in forage crop systems

In the three French stations with forage crops, the farm gate N balances were close to 100 kg N/ha AA, i.e. close to those observed in the pilot farms. The inputs from mineral fertilisers were reduced (45 kg N/ha on average) and the N needs of the grasslands partly satisfied by grass and white clover mixtures. The total N fertiliser inputs (mineral fertiliser + imported organic N + fixation) represented 85 kg N/ha AA, i.e. 60 % of the inputs of the farm balance. The agronomic balances were, in general, related to outputs (Figure 3). Nitrogen flows in these systems had the same profile as those of the commercial grassland systems whose structural characteristics (e.g. stocking rates, dairy production levels to the hectare) were similar. Thus, whatever the proportion of maize in the system, the stations whose stocking rate was lower than 2 LU/ha (France and Ty Gwyn, Mabegondo) had inputs to the soil which more or less matched the outputs in crops and grasslands. However, on these sites a considerable proportion of the inputs was from manure (the fraction of available N over the year was considered to be 20-30% of the total N). In fact, the N conversion rate at the field scale (outputs/inputs) was better at these sites (ca.75 %) than the more intensive systems (Hillsborough, Solohead or Behi-Alde).

The Ognoas site stands out from the other sites in the forage crops group because of the considerable presence of grain maize in the rotation which contributed to raised inputs from mineral fertilisers. On the other hand, it exported more N in crops which was favourable to the field balance: the N use efficiency in the maize unit in cash crops was ca. 60%. Because this crop received manures from the dairy unit and so should not, strictly speaking, be excluded from the system studied. This situation reflects the practices in the farms of the region.

4.4. Higher N surpluses per ha in the “semi” housed systems

In Behi Alde (3.7 LU/ha FA), grazed grass represented less than 15% of the total herd feed intake and the productivity of the cows was high (9,900kg milk/cow/year). Inputs in concentrates and forage necessary to maintain the production of 23,307 kg milk/ha AA/year on the farm were therefore very high (500kg N/ha AA). Feed represents 83 % of the apparent farm N balance inputs. Although mineral fertiliser use was low (31 kg N/ha/year), the farm N balance was high at 590 kg N/ha AA (because of imports in feed), as was the agronomic balance because of the high levels of organic manures applied (Figure 3). However, taking into account the high productivity of the system, the farm N balance surplus expressed per ton of milk was 21 kgN/ha, which compares well with the other sites. Similarly, the N conversion rate at Behi Alde was 22 %, which is close that at Mabegondo (23 %) and Ty Gwyn PF (24 %) where productivity was lower.

5. Losses of nitrogen towards water and air

5.1 Nitrogen losses to water

5.1.1. Variable soil N contents

Soil N contents at the start of drainage on the various fields of the systems studied, on six sites in the first year then eight sites in the second year, for the grasslands and maize, were very variable but with a consistent behaviour for a given site (appendices 2 and 3). The forage crop soils contained more than 75% of the mineral N as NO₃-N at the start of drainage whereas the permanent grassland soils

contained more $\text{NH}_3\text{-N}$. Figure 4 shows the average soil mineral N expressed at system scale (Table 8) in relation to the N surplus at the field/agronomic scale.

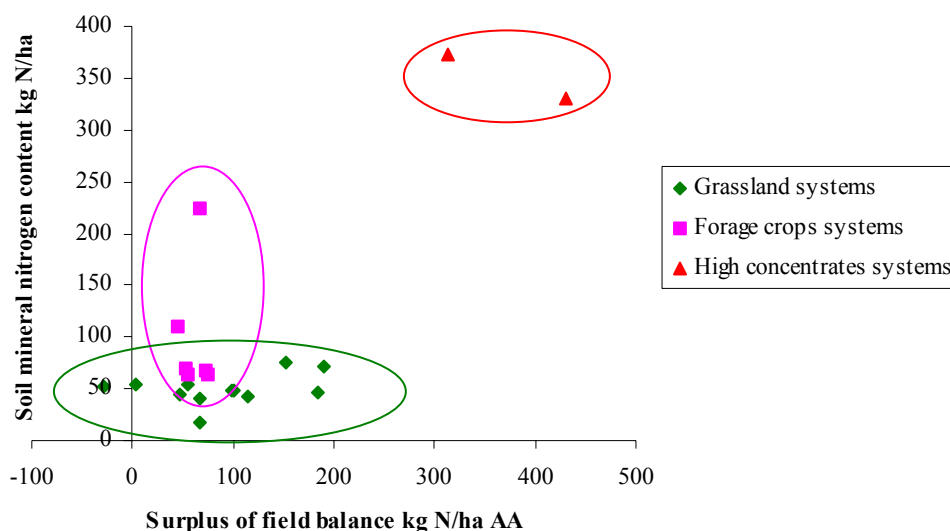


Figure 4: Relation between the agronomic N balance and soil mineral N status at the start of drainage residue (average for 2004 and 2005)

Overall, there was no relationship between the soil mineral N residues and the field/agronomic balance, which showed excesses of fertiliser inputs. Contrasting behaviour can nevertheless be observed between groups of systems. The most intensive grassland systems, with agronomic balance surpluses ranging between 100 and 200 kg N/ha AA, had residues close to 50 kg N/ha. On the other hand, forage farming systems had a soil mineral N content at the start of drainage ranging between 60 and 100 kg N/ha whereas the agronomic surplus was less than 70 kg N/ha. The cultivation of grasslands, as part of the forage crop rotation, could explain the sometimes very high soil mineral N contents of ca. 200 to 300 kg N/ha. Lastly, in the very intensive systems, both the surplus and the soil N contents were high, but there were fewer measurements on which to base conclusions.

5.1.2. Leaching of N in the grassland systems

- *Losses of $\text{NO}_3\text{-N}$*

Within the framework of the project, $\text{NO}_3\text{-N}$ losses were assessed at the farm scale at seven sites, over the two years of study, either from changes in soil mineral N contents or from the nitrate concentration in the water in ceramic cups or drains. These years of study were characterised by drainage which was lower than the normal at the French sites.

The $\text{NO}_3\text{-N}$ losses were similar from one year to another for the different sites, except at Derval where no leaching was observed during the winter of 2004/2005, because of the absence of drainage (table 7). The trends seen in the soil mineral N at the start of drainage were also seen with leaching but no relation was observed between $\text{NO}_3\text{-N}$ leaching and the farm scale surplus (Figure 5). On the other hand, contrasting behaviours were still observed between the groups of systems.

Table 7: Soil mineral N contents at the start of drainage and nitrate losses at system level

	2004/2005						2005/2006					
	Field balance kg N/ha	SNM kg N/ha ⁽¹⁾	% NO ₃ ⁻⁽²⁾	Drainage mm	N leaching kg N/ha	Nitrates concentration mg NO ₃ -/l	Field balance kg N/ha	SNM kg N/ha [*]	% NO ₃ ⁻⁽²⁾	Drainage mm	N leaching kg N/ha	Nitrates concentration mg NO ₃ -/l
Hillsborough High N	230	-	-	394	43	48	191	72	72	394	19	22
Hillsborough Low N	204	-	-	394	38	43	153	76	62	394	13	15
Solohead Ferti N-230	185	47	64	461	18	17	114	43	47	350	17	22
Solohead WC-90	99	48	44	461	12	11	101	49	27	350	21	26
Solohead WC-REPS	48	45	60	461	25	24	67	40	28	350	16	21
Ty Gwyn self-sufficient	-20	-	-	713	-	-	-28	52	61	598	16	12
Ty Gwyn purchased feed	44	-	-	713	-	-	3	54	56	598	17	13
Dumfries High forage	110	-	-	242	-	-	51	-	-	292	-	-
Mabegondo	67	18	57	457	19	18	54	54	77	648	47	29
Trévarez	72	67	84	280	68	108	55	63	68	288	57	87
Derval	45	111	66	0	0	0	66	224	98	89	73	364
Ognoas	75	63	73	97	5	23	52	70	77	85	11	55
Dumfries Low forage	48	-	-	242	-	-	259	-	-	292	-	-
Behi-Alde	313	373	98	800	-	-	430	330	99	800	-	-

⁽¹⁾ Start of drainage residue = content in mineral nitrogen (N-NH₄ + N-NO₃) on 0-90 cm, the average residue at system level.

⁽²⁾ % NO₃⁻ corresponds to the proportion of nitrate nitrogen in the residue

The most intensive grassland systems, with N surpluses from 100 to 200kg/ha had leaching rates ranging between 10 and 30 kg N/ha. At Solohead, Hillsborough and Ty Gwyn, the lower N surplus did not result in much reduction in NO₃-N losses, probably reflecting past management history. The forage crop systems had more variable NO₃-N losses, from 10 to 65 kgN/ha for the two years, whereas the N surpluses were lower. The atypical character of the leaching at Ognoas for both years and at Derval in 2004, reflect the low or non-existent drainage.

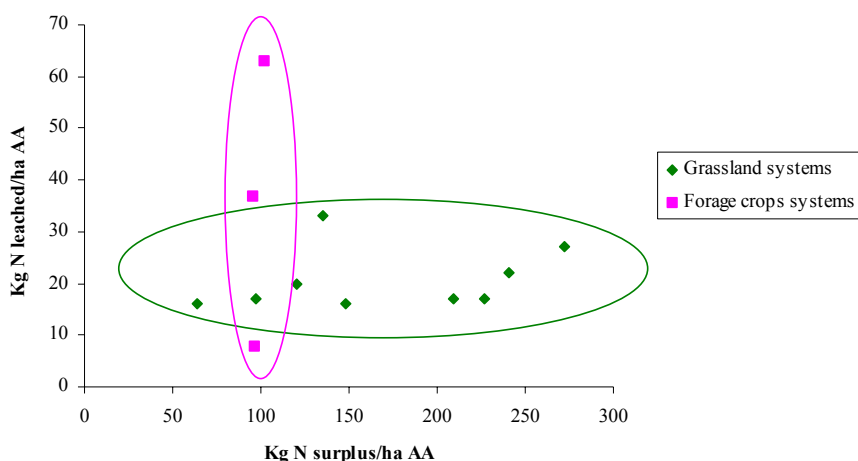


Figure 5: Relation between leached N and farm gate balance surplus (grassland systems and forage crops)

- Nitrate-nitrogen losses observed in previous studies at the Green Dairy sites

It was possible to examine results obtained in previous studies at the experimental sites at Solohead (Ireland), Ty Gwyn (Wales) and Trévarez, Derval and Ognoas (France), in order to consolidate the results obtained in the Green Dairy project (Table 8). These results were observed over longer periods

from 3 to 8 years, and for the French sites, they represented more normal climatic years with drainage close to the average.

In the British and Irish grassland systems, the soil mineral N contents at start of drainage and NO₃-N losses were of the same order as those recorded during the Green Dairy project, except for the intensive system at Solohead which had a significant N surplus, associated with high fertiliser rates (330 kg N/ha). In the forage crop systems of the French Atlantic Area, NO₃-N losses ranged from 30 to 50 kgN/ha with N surpluses ranging between 100 and 150 kg/ha. These complementary results confirm the contrasting behaviour between systems based on permanent grassland or forage crops.

Table 8: NO₃-N losses observed in previous studies of the Green Dairy experimental sites

Experimental site	Reference	Years of study	% grassland/FA	Surplus (kg N/ha AA)	SNM (kg/ha)	Drainage (mm)	N leaching kg (N/ha)	Nitrates concentration (mg NO ₃ -/l)
Solohead REPS	Humphreys et al., 2003	2000/2003	100	151	29	-	-	-
Solohead Extensive	Humphreys et al., 2003	2000/2003	100	146	23	-	-	-
Solohead Moderate	Humphreys et al., 2003	2000/2003	100	231	45	-	-	-
Solohead Intensive	Humphreys et al., 2003	2000/2003	100	293	112	-	-	-
Ty Gwyn organic	Haggar et al., 1996 Cuttle 1997	1992/1995	100	91	36	700	33	21
Trévarez	Bossuet et Le Meur, 2006	1999/2003	70	156	52	406	47	51
Derval	Bossuet et Huneau, 2006	2003/2005	61	92	162	109	54	
Ognoas Grassland +	Legarto, 1999 et 2006	1993/2001	65	104	-	441	30	30
Ognoas Maize +	Legarto, 1999 et 2006	1993/2001	20	120	-	495	45	40

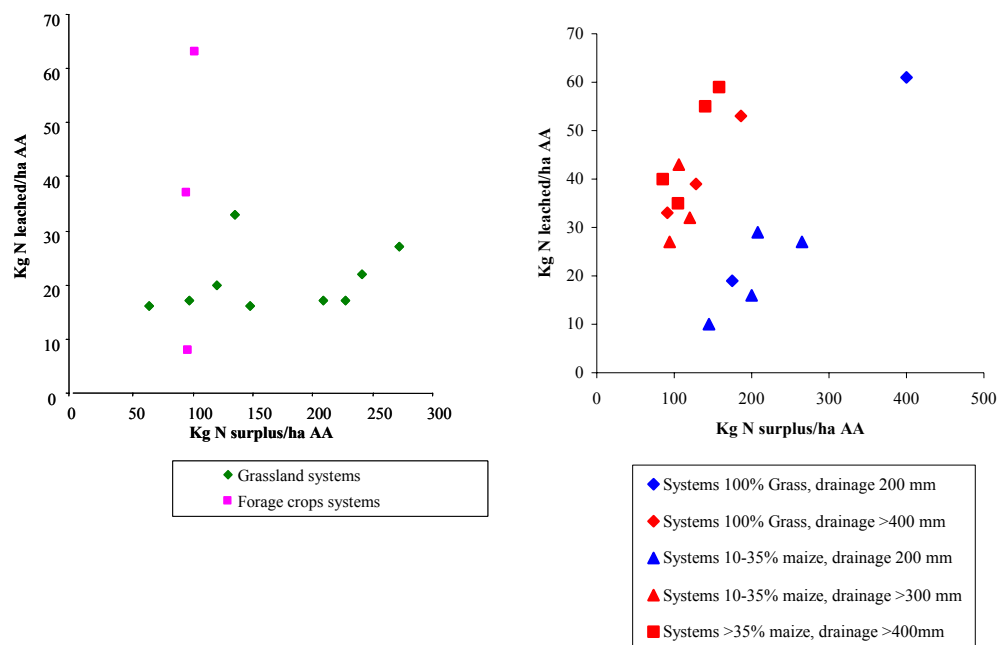
- *Nitrate-nitrogen losses observed in similar studies in Europe and New Zealand*

The results obtained in similar studies carried out on complete systems in Europe and New Zealand were also examined (Table 9). For systems combining temporary pastures and maize forage, the NO₃-N losses were between 20 and 60 kg N/ha with N surpluses ranging between 90 and 150 kg/ha. In the grassland systems of England and New Zealand, significant NO₃-N losses were observed when N balances were higher than 300kg N/ha. These results are also corroborated by those obtained in large scale lysimeter experiments on the impact of N fertiliser on grasslands on NO₃-N leaching (Scholefield et al., 1993; Watson et al, 1998; Laurent et al, 2000).

Table 9: NO₃-N losses observed in studies carried out on dairy systems in Europe and New Zealand

Experimental site	Reference	Years of study	Texture of soil	% grassland/FA	Surplus (kg N/ha AA)	Drainage (mm)	N leaching kg N/ha	Nitrates concentration mg NO ₃ -/l
De Marke (NL)	Hilhorst and al. 2001	1993/1998	Sandy	60	158	475	59	55
Bridgets conventional (UK)	Peel et al., 1997	1994/1996	Loamy clay	100	389	202	44	97
Bridgets optimised (UK)	Peel et al., 1997	1994/1996	Loamy clay	68	254	202	25	55
Bridgets low SR (UK)	Peel et al., 1997	1994/1996	Loamy clay	74	189	202	22	48
Bridgets conventional (UK)	Withers and al, 2003	1997/2000	Loamy clay	68	200	184	16	39
Bridgets optimised 1 (UK)	Withers and al, 2003	1997/2000	Loamy clay	71	175	184	19	46
Bridgets optimised 2 (UK)	Withers and al, 2003	1997/2000	Loamy clay	71	145	184	10	25
Crécom 40 % maize (F)	Le Gall et Cabaret, 2001	1996/1998	Sandy loam	62	85	400	40	44
Crécom 20 % maize (F)	Le Gall et Cabaret, 2001	1996/1998	Sandy loam	82	106	388	43	49
Hamilton 0 N (NZ)	Ledgard et al., 2000	1993/1996		100	97	503	40	-
Hamilton 200 N (NZ)	Ledgard et al., 2000	1993/1996		100	228	503	81	-
Hamilton 400 N (NZ)	Ledgard et al., 2000	1993/1996		100	334	503	152	-

Whereas no direct link was observed between the surplus and N leaching within the Green Dairy project (Figure 6a), results from the literature show that $\text{NO}_3\text{-N}$ losses are better more related to the surplus, if care is taken to distinguish the intensity of drainage and soil type (Figure 6b). Thus, the quantity of $\text{NO}_3\text{-N}$ leached represents from 30 to 50 % of the surplus with well drained soils with a high water flow (more than 300 mm) but only 10 % on poorly drained loamy soils with a low water flow (less than 200 mm).



Figures 6a and 6b: Relation between the N surplus and N leached on the Green Dairy sites (6a) and on other experimental sites taken from the literature (6b)

These complementary results also show that the proportion of maize or grasslands has little impact on $\text{NO}_3\text{-N}$ losses in forage crop systems with grassland/maize/cereals successions. These systems have to have similar surplus levels and effective plant cover during the winter (as was the case in the studies carried out at De Marke, Bridgets, Crecom and Ognoas) in order for this to be true.

Lastly, it is important to place these results for livestock systems in the context of those for arable crop systems. The organic matter content of the soils is often much lower (less than 2 %) in arable farms, as are the number of N flows involved. Their N balances are low, with surpluses ranging between 0 and 50 kg N/ha when N fertilisers are adjusted carefully. Nevertheless, $\text{NO}_3\text{-N}$ losses are often between 30 and 50 kg/ha and depend more on the volume of drainage water than on the surplus (Beaudoin et al, 2004a; Beaudoin et al, 2004b).

5.1.3. The risks of nitrate losses in dairy systems

Our results, and those quoted in the literature, clearly show that there are different behaviours according to systems in the risks of loss in water. In forage crop systems, losses by leaching were between 30 and 50 kg/ha even though the balance was close to zero. In forage crop systems with grassland/crop rotations, the $\text{NO}_3\text{-N}$ losses varied from 30 to 60 kg/ha for N surpluses between 100 and 150 kg/ha and depend on the intensity of drainage. In systems based on permanent grasslands, the $\text{NO}_3\text{-N}$ losses were lower, between 10 and 30 kg/ha for the Green Dairy sites with surpluses of 120 to 250 kg N/ha, even with a significant proportion of grassland, as was the case in Southern Ireland. Nevertheless, when the N surpluses were high through high rates of fertiliser, $\text{NO}_3\text{-N}$ losses were considerable.

These differences between groups arise through combinations of management and climatic conditions:

- The grassland systems, based on permanent grasslands, undoubtedly store more N, as indicated by the high organic matter content of the soils. Conversely, rotations of forage crops with frequent turnover of grasslands stimulate N mineralisation. In these systems with changes in the cover crops, the plant demand is not always sufficiently developed to absorb all the available N.

- The climatic conditions of the British Isles are favourable to grass growth. Differences between these sites and others were exacerbated during the two study years of the study with a marked summer moisture deficits at Derval, Trévarez and Ogoas. For example, because of the late regrowth in the autumn, swards could not use all the available soil N. Thus, in Trévarez, between 1st November and 1st March, winter cover absorbed approximately 20 kg N/ha whereas in Solohead over the same period, the grasslands used up to 40 kg N/ha.

The overall N balance at the farm and/or the agronomic scale did not appear to be useful for a classification of dairy systems at the European scale, taking into account the system effects described above. Nevertheless, these indicators are relevant for a particular region and an intra-system analysis, as indicated by other. Lastly, NO₃-N in water are part of a complex cycle and should be considered together with losses to air and the storage in the soil.

5.2. Nitrogen losses by gaseous emissions

5.2.1. Total emissions varying from 4 to 7 kg N for 1,000 litres of milk

Nitrogen losses by gaseous emissions, induced by farming practices, were assessed by using emission coefficients (see section 2). These assessments must be considered with care because the emission factors selected usually have a variability of +/- 50 % and their use can cause uncertainty of +/-17% for NH₃ and +/-33% for N₂O, (Payraudeau et al, 2006). Background emissions from the denitrification of the soils, were not considered at this stage but are discussed later.

Gaseous N losses varied from 40 to 113 kg N/ha and represented from 23 to 64% of the surplus (Table 10). The NH₃ losses were the most significant and varied from 18 to 81kg N/ha. The emissions of N₂O and of nitric oxide (NO) were much lower, respectively between 2 and 11 kg N/ha and 0.5 and 1 kg/ha. These two gases have a high capacity for global warming, in particular N₂O whose global warming capacity is 310 times higher than that of CO₂. Nitrogen gas (N₂) is harmless for the environment and emissions of this gas were estimated to be between 10 and 30 kg N/ha.

Table 10: Estimation of gaseous N emissions at the different experimental sites

	Kg NH ₃ -N /ha AA	Kg NO-N /ha AA	Kg N ₂ O-N /ha AA	Kg N ₂ -N /ha AA	Total air emissions kg N/ha AA	Total air émissions kg N/1,000 L milk	Kg NH ₃ -N/ 1,000 L milk	Kg N ₂ O-N / 1,000 L milk
Hillsborough High N	60	1.5	8	22	92	7.4	4.8	0.7
Hillsborough Low N	60	1.4	9	23	92	7.3	4.8	0.7
Solohead Ferti N-230	47	0.9	11	29	88	7.4	3.9	0.9
Solohead WC-90	44	1.1	10	29	84	7.0	3.7	0.9
Solohead WC-REPS	41	1.1	9	25	77	7.0	3.8	0.8
Ty Gwyn self-sufficient	20	0.3	4	7	31	6.8	4.4	0.8
Ty Gwyn purchased feed	28	0.8	5	10	43	6.4	4.1	0.7
Dumfries High forage	54	1.1	6	12	73	5.9	4.4	0.4
Mabegondo	18	0.4	5	14	37	5.1	2.4	0.7
Trévarez	25	0.4	4	10	40	6.5	4.1	0.7
Derval	27	0.4	2	15	46	6.2	3.7	0.3
Ogoas	21	0.6	2	7	31	7.3	5.0	0.5
Dumfries Low forage	70	1.1	5	9	85	4.0	3.3	0.2
Behi-Alde	81	0.8	9	22	113	4.7	3.4	0.4

These emissions appeared to be independent of dairy production per cow but increased with production per ha. The total emissions per ha depended upon the farm scale N surplus (Figure 7), which was itself related to the production per ha (Figure 2). The total emissions were greatest in systems producing more than 10,000 kg milk/ha (Hillsborough, Solohead, i.e. more than 85 kg N/ha). They were much lower (about 40 kg N/ha) in the extensive systems (Ty Gwyn) and in the French forage crop systems. The highly intensified systems with animals producing more than 20,000 kg milk/ha (Dumfries low forage and Behi-Alde) led to high losses but overall of the same order of magnitude as the intensive grassland systems. These losses were generally inversely proportional to the N leaching losses.

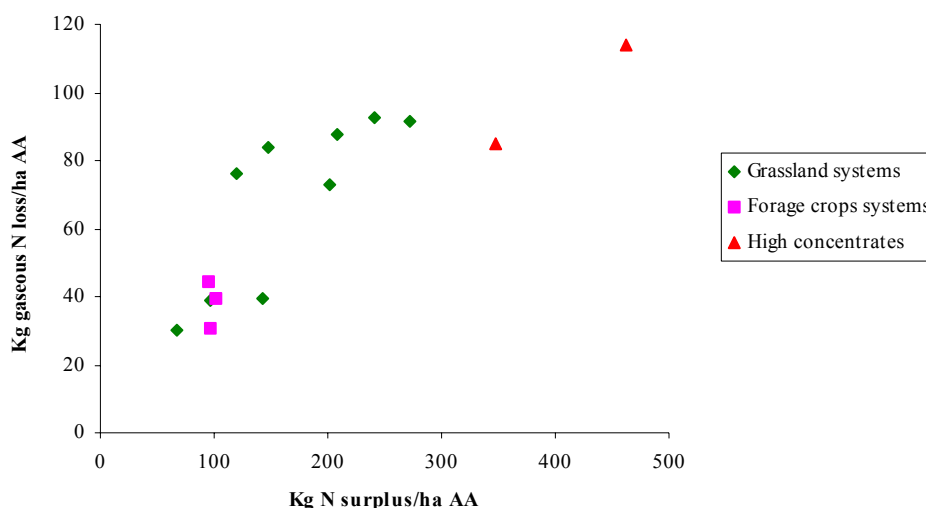


Figure 7: Relation between N surplus (kg N/ha AA) and gaseous emissions (kg N/ha AA: average for 2004 and 2005)

When these losses were expressed per 1,000 l of milk, the differences between sites were smaller. The hierarchy previously established remained in the case of the most self-sufficient systems. The gas emissions were thus between 6 and 7.5 kg N/1,000 litres, except in the very intensive systems where high dairy productivity reduced this indicator of losses to 4-5 kg of N/1,000 l.

5.2.2. Ammonia losses in relation to the stocking rate and N excreted

Ammonia losses represented more than 60% of the total N gas emissions (Table 11) i.e. between 3.3 and 4.8 kg N/1,000 l or between 18 and 81 kg N/ha.

Table 11: Assessment of ammonia emissions

	Kg N excreted/cow before ammoniac emissions	Kg N excreted/cow after ammoniac emissions	Kg NH₃-N /ha	Kg NH₃-N/ 1,000 L milk	% buildings / storage	% spreading	% grazing
Hillsborough High N	124	113	60	4.8	49	31	20
Hillsborough Low N	120	109	60	4.8	49	30	21
Solohead Ferti N-230	129	117	47	3.9	26	18	56
Solohead WC-90	129	117	44	3.7	27	14	59
Solohead WC-REPS	129	117	41	3.8	27	13	60
Ty Gwyn self-sufficient	109	99	20	4.4	50	20	30
Ty Gwyn purchased feed	132	120	28	4.1	60	10	30
Dumfries High forage	139	127	54	4.4	37	47	16
Mabegondo	98	89	18	2.4	13	15	72
Trévarez	110	100	25	4.1	48	24	28
Derval	132	120	27	3.7	57	21	21
Ognoas	115	105	21	5.0	48	33	19
Dumfries Low forage	141	128	70	3.3	49	38	13
Behi-Alde	132	120	81	3.4	58	22	20

In the grassland-based systems, NH₃ losses were between 4 and 5 kg/1,000 l milk, except in Mabegondo, where the protein content of the total ration was less than 14% whereas it was between 16 and 20% at the other sites. The distribution of these losses was very dependent on the time spent in the housing and at grazing. About 60 % of the NH₃ losses occurred in the systems in Southern Ireland, based on grazing. In the forage crops systems, the NH₃ losses per 1,000 l milk were at the same level. The major part of the losses occurred on the building/manure storage and spreading component of the farm, the consequence of 6 months spent inside. Lastly, in the very intensive systems, the NH₃ emissions 1,000 l milk were slightly lower, because of the high productivity.

Finally, the NH₃ emissions noted overall at the farm scale depended in particular on the N excreted, the time spent in the housing, the spreading conditions and the N inputs to the field. A comparison of the NH₃ emissions between Solohead in Ireland and Trévarez in Brittany (as contrasted systems) shows that losses expressed per 1000 l milk can come from different phenomena (Table 12). Given the significant proportion of grass in the ration, and the content of total N, results in N excretion at Solohead being higher. The proportion excreted in the buildings was lower but the rate of loss was higher. The NH₃ emission per cow during housing was thus very similar. At grazing, the rate of loss was equivalent but the emissions per cow were twice as large, because of the additional N excreted at grazing. Finally, NH₃ losses per cow or per 1,000 l milk were very similar: per ha, the emissions were twice large at Solohead because of the stocking rate.

Table 12: Comparison of NH₃ losses per unit at Solohead and Trévarez

		Solohead	Trévarez
Cow	N total excreted (kg/cow)	129	110
	N excreted in buildings (kg/cow)	27	64
	N excreted at grazing (kg/cow)	102	46
Buildings/storage	N excreted (kg/ha AA)	68	65
	% losses	18	18
	N-NH ₃ emission (kg/ha AA)	12	12
Manure spreading	N spread (kg/ha AA)	55	65*
	% losses	7	7
	N-NH ₃ emission (kg/ha AA)	4	5
Mineral fertilization	N spread (kg/ha AA)	220	47
	% losses	2	2
	N-NH ₃ emission (kg/ha AA)	4	1
Grazing	N excreted (kg/ha AA)	281	79
	% losses	9	10
	N-NH ₃ emission (kg/ha AA)	26	8
Total	N-NH ₃ emission (kg/ha AA)	46	25
	N-NH ₃ emission (kg/1,000 L)	3.9	4.1

**imported pig slurry is spread*

The NH₃ losses observed can be compared with those observed in similar studies carried out on dairy systems (Table 13). This analysis requires care because the assessment methods rely either on different techniques, i.e direct measurements or on emission factors similar to those used in the Green Dairy project. The emissions per 1000l milk were similar to the French sites. The NH₃ losses are less when procedures are implemented to reduce emissions (covering the storage pits, injection of slurry or spreading very close to the soil) or when the proportion of grazing is significant and is combined with careful fertiliser use (New Zealand). In another study carried out in the United Kingdom by simulation, based also on emission factors, Webb et al.(2005), quote very similar emission levels of between 3 and 5 kg NH₃-N for 1000 l of milk. They also show that the extension of the grazing period by one month makes it possible to reduce slightly these emissions of ammoniacal nitrogen.

Table 13: Ammonia losses observed in studies carried out in dairy systems in Europe and New Zealand

Experimental site	Reference	Years of study	Techniques to reduce ammoniac emissions	Methods of evaluation	Surplus (kg N/ha AA)	N-NH ₃ (kg /ha)	N-NH ₃ (kg/1,000 L)
De Marke (NL)	Hilhorst and al. 2001	1993/1998	Yes	Measures	158	22	1.9
Bridgets conventional (UK)	Withers and al, 2003	1997/2000	No	Emission factors	200	19	1.5
Bridgets optimised 1 (UK)	Withers and al, 2003	1997/2000	Yes	Emission factors	175	15	1.4
Bridgets optimised 2 (UK)	Withers and al, 2003	1997/2000	Yes	Emission factors	145	13	1.1
Crécom 40 % maïze (F)	Le Gall et Cabaret, 2001	1996/1998	No	Emission factors	85	35	5
Crécom 20 % maïze (F)	Le Gall et Cabaret, 2001	1996/1998	No	Emission factors	106	44	6.4
Ognoas 100 % maïze (F)	Legarto, 1999	1993/1997	No	Emission factors	140	60	6.9
Ognoas 35 % maïze (F)	Legarto, 1999	1993/1997	No	Emission factors	120	47	5.3
Hamilton 0 N (NZ)	Ledgard et al., 1998	1993/1996	No	Measures	97	15	1.1
Hamilton 200 N (NZ)	Ledgard et al., 1998	1993/1996	No	Measures	228	41	2.6
Hamilton 400 N (NZ)	Ledgard et al., 1998	1993/1996	No	Measures	334	65	4.1

5.2.3. Emissions of N₂O in relation to N inputs in the field

The emissions of N₂O developed at this scale concern only those related to farming practices and not those related to background denitrification associated with the soils. Use of the chosen emission factors, indicated that about 2% of the N excreted in the housing and at grazing and of applied mineral N were lost as N₂O and relate to N flows operating at the stages of the management (Table 14). Most of the loss occurred in the field, and was dependent upon the organic or mineral N inputs.

These losses were between 7 and 11 kg N₂O-N/ha in the most intensive systems with stocking rate higher than 1.8 LU/ha AA and using considerable fertilisation and decreased with more moderate stocking rates. Expressed per 1000 l milk, the losses appeared to be higher in the intensive grasslands systems, because of the large quantities of N involved with both animal and field components.

Table 14: Detail of emissions of N₂O-N

	Kg N ₂ O-N /ha	Kg N ₂ O-N / 1,000 L milk	% buildings/ storage	% spreading	% grazing	% induced losses
Hillsborough High N	8	0.7	11	62	27	0
Hillsborough Low N	9	0.7	11	62	28	0
Solohead Ferti N-230	11	0.9	4	48	44	4
Solohead WC-90	10	0.9	4	43	48	5
Solohead WC-REPS	9	0.8	4	42	49	4
Ty Gwyn self-sufficient	4	0.8	8	52	29	11
Ty Gwyn purchased feed	5	0.7	12	45	34	10
Dumfries High forage	6	0.4	15	52	23	10
Mabegondo	5,4	0.7	1	39	45	15
Trévarez	4	0.7	9	24	31	36
Derval	2	0.3	20	32	48	0
Ognoas	2	0.5	13	43	35	9
Dumfries Low forage	5	0.2	32	56	0	12
Behi-Alde	9	0.4	17	27	57	0

These values appear consistent with those obtained in similar studies, carried out by simulation from emission factors and equations from the bibliography. Olesen et al., (2006) thus quote emissions of nitrogen protoxide close to 9 kg/ha, i.e. about 0.9 kg of N-N₂O for 1,000 litres of milk, for dairy systems of the Atlantic Area, based on grassland and maize. Schils et al. (2005) observe emissions respectively of 9.4 and 6.6 kg of N-N₂O/ha for Dutch systems based on fertilised rye grass or rye grass associated with white clover, i.e. 0.7 and 0.6 kg for 1,000 litres of milk.

5.3. Distribution of the N surplus

After the assessment of the losses in water and to air, it is useful to analyse the distribution of the N surplus. Again, this analysis must be carried out with care because some of the resulted from experimental measurements and others from calculation. In addition, the temporal scale should also be taken into account because not all effects are demonstrated in the current year because of the time taken for different components of the N cycle to take place.

The results from this project do, however make it possible to observe trends and differences in the N surplus, and losses by leaching and into the atmosphere (Table 15). Defects in the balance result from measurement/estimate errors, background soil denitrification and immobilisation or mineralisation of N into or from the soil organic pool.

Table 15: Distribution of the N surplus at the 9 experimental farms

	Surplus kg N/ha	N leaching kg N/ha (% surplus)	Ammonia emissions kg /ha (% surplus)	Others gaseous losses kg N/ha (% surplus)	Default of balance kg N/ha
Hillsborough High N	272	27 (10)	60 (22)	32 (12)	153
Hillsborough Low N	241	22 (9)	60 (25)	32 (13)	127
Solohead Ferti N-230	209	17 (8)	47 (22)	41 (20)	104
Solohead WC-90	148	16 (11)	44 (30)	40 (27)	48
Solohead WC-REPS	120	20 (17)	41 (34)	35 (29)	24
Ty Gwyn self-sufficient*	67	16 (24)	20 (30)	10 (15)	21
Ty Gwyn purchased feed*	97	17 (17)	26 (27)	13 (13)	41
Mabegondo	135	33 (24)	18 (13)	19 (15)	65
Trévarez	102	63 (62)	25 (39)	14 (14)	0
Derval	95	37 (39)	27 (28)	19 (20)	12
Ognoas	96	8 (8)**	21 (22)	10 (10)	57

*: data for 2005 only

** about 40 kg of nitrogen leached in normal drainage conditions at Ognoas i.e. 33 % of the nitrogen surplus

The analysis of these results, consolidated by those quoted elsewhere (Table 16) make it possible to distinguish two distinct situations:

1. **Grassland systems based on permanent grassland and loam-clay soils**, the proportion of leaching is low, between 10 and 25 % of the surplus, as long as this remains less than 250kg N/ha. These results are confirmed by those shown by Pflimlin at al, (this volume) in the regional scale analysis. Nitrate concentration in surface water is thus low in Southern Ireland, in spite of significant N surpluses. Conversely, gaseous are high and represent between 40 and 70% of the total surplus and are related to the quantities of N cycling at the different stages. Denitrification could be significant in these systems (Humphreys, this volume). At Hillsborough, Watson et al., (1998) observed N₂O losses close to 25kg N/ha for fertiliser rates of 200kg N/ha. The considerable denitrification rate raises the question of the division between N₂O and N₂.

2. **Systems based on forage crops in rotation**, with more ploughing (about half of the area each year), where nitrate losses are greater and represent between 30 and 60 % of the surplus, depending upon the intensity of winter drainage: this conclusion is also confirmed by the regional analysis described by Pflimlin. Gaseous losses are lower and represent between 30 and 60 % of the surplus and vary according to the N content of the feed and methods of managing the manures. Missing components of the balance are clearly lower in this situation. However, denitrification losses from the soil could be between 15 and 25 kg/ha, as shown by measurements carried out by Durand et al., (2005) in the cattle production farms in the west of France. This would then result in net N mineralisation or only low rates of immobilisation, in agreement with the soil carbon contents observed. The assumptions made seem to be consistent with the flows observed in the farming systems: i.e. low to no N surpluses, NO₃ by leaching ranging between 20 and 50kg N/ha, low N losses as gases and high mineralisation rates

Table 16: Distribution of N surplus in other similar studies

Experimental site	Reference	Years of study	% grasslands /FA	Surplus (kg N/ha AA)	Drainage (mm)	N leaching kg /ha (% surplus)	N-NH ₃ kg /ha (% surplus)	N denitrification kg /ha
Hamilton 0 N (NZ)	Ledgard et al., 2000	1993/1996	100	97	503	40 (41)	15 (15)	5
Hamilton 200 N (NZ)	Ledgard et al., 2000	1993/1996	100	228	503	81 (35)	41 (18)	17
Hamilton 400 N (NZ)	Ledgard et al., 2000	1993/1996	100	334	503	152 (45)	65 (19)	25
Bridgets conventional (UK)	Withers and al, 2003	1997/2000	68	200	184	16 (8)	19 (9)	-
Bridgets optimised 1 (UK)	Withers and al, 2003	1997/2000	71	175	184	19 (11)	15 (9)	-
Bridgets optimised 2 (UK)	Withers and al, 2003	1997/2000	71	145	184	10 (7)	13 (9)	-
De Marke (NL)	Hilhorst and al. 2001	1993/1998	60	158	475	59 (37)	22 (14)	29
Trévarez (F)	Bossuet et Le Meur, 2006	1999/2003	70	156	406	47 (32)	31 (20)	-
Crécom 40 % maïze (F)	Le Gall et Cabaret, 2001	1996/1998	62	85	400	40 (47)	35 (41)	-
Crécom 20 % maïze (F)	Le Gall et Cabaret, 2001	1996/1998	82	106	388	43 (41)	44 (41)	-
Ognoas Grass + (F)	Legarto, 1999	1993/1997	65	120	441	32 (27)	47 (39)	-
Ognoas Maïze + (F)	Legarto, 1999	1993/1997	0	140	495	55 (40)	60 (39)	-

Conclusions and prospects

- In dairy production systems, nitrogen losses in water depend on the local environment (type of soil, climatic conditions), on the level of intensification and thus on the N surpluses, the type of forage system and farming practices. The results of this project show that systems based on permanent grasslands, even with much grazing, present fewer risks for water quality than forage crop systems which include a high level of ploughing. For this category of systems, the proportion of maize and temporary grassland would have fewer impacts on leaching, if they are managed at the same stocking rate and are optimized with respect to environmental considerations. In risky environments (well draining soils, average to high drainage water flow), systems, based on permanent grassland, should therefore be encouraged. Failing that, N management must be optimized in the forage crop systems in accordance with crop demands and seasonal constraints and taking note of supplies from all sources.

- Nitrogen losses to air depend primarily on the N content of the diet, on the proportion of N in excreta collected in the housing and the methods of spreading manures. In the experimental farms, these losses were more significant in the grassland systems when they are expressed per unit area unit, along with

greater intensification, and when denitrification losses are incorporated. There is therefore a preferential division of the surplus, with more losses towards water or air depending on the forage system involved which is determined by adaptations to local environments (climate/soils/practices). When expressed on the basis of 1000l milk, there does not seem to be any clear link with the forage system because the losses are similar both at grazing (relatively low loss rates) and in the housing (relatively high loss rates at building/storage/spreading stages).

- This study also made it possible to test several **global indicators** at the scale of the herd and the whole dairy system. Taken separately, it appears that N excretion per cow is not a good indicator of the risk of water pollution or even of air at the regional scale, because many processes intervene between the animal and the areas involved. In the experimental units examined, neither **the agronomic/field balance, the surplus nor the organic applied per ha** did not appear relevant indicators of N losses in water. Nevertheless, these indicators remain relevant at the smaller scale and for comparisons of similar systems, in similar situations.

- The study centred on dairy systems which were not necessarily optimised for N management. In order to reduce losses **N management** will have to be optimised to a much greater extent than before in order to meet environmental requirements. Thus, the control of the protein content of the diets, the control of NH₃ emissions from buildings and manure storage, restricted access to grazing in summer when there is no grass growth as well as in winter, better management of manures, planned fertiliser applications, extending the life of swards and establishment of catch crops all offer opportunities to improve N use efficiency, to reduce surpluses and therefore losses to water and air. The experiments carried out at De Marke, in the Netherlands (reduction of the surplus by 83% compared to a conventional system for an almost similar milk production/ha), at Solohead in Ireland (reduction in surplus of 40% operating within with the Irish environmental scheme (Reps) system for a production per ha reduced by only 8%), at Crécom in Brittany (reduction of the surplus of 40 to 50 % compared to current practices) are very encouraging. The experience of the pilot farmers who gradually incorporate the most environmentally-friendly techniques has a very important role to play in making progress in other farms.

- This work made it possible to make progress on our understanding of **the distribution and fate of the N surplus at the dairy system scale**. Because of temporal variation it is necessary to continue measurements of longer duration, integrating inter-annual climatic risks, in order to have a better data base on which to base advice for farmers. In addition, this study also shows the need for better understanding of denitrification and the immobilisation/mineralisation processes in interaction with the grassland and crop systems involved. Future progress will also involve inputs from modelling combined with observations in both experimental and commercial farms.

- Lastly, this study focused on N flows and losses at the scale of dairy systems. It would be useful to continue to work at this scale level in order to incorporate other concerns such as the risks of phosphorus transfer to waters, greenhouse gas emissions and energy consumption.

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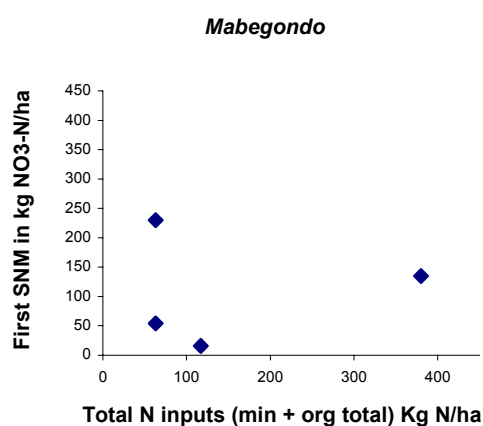
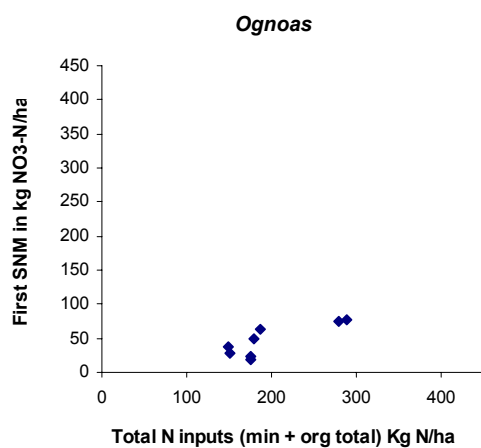
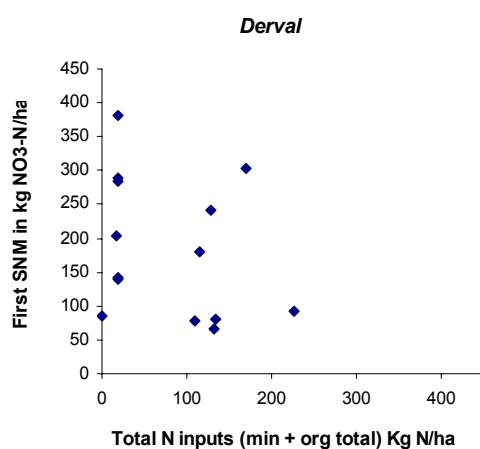
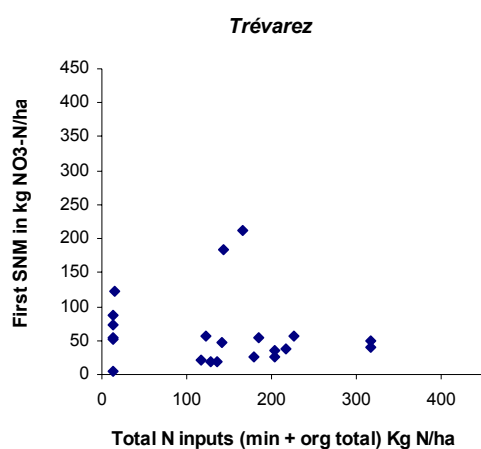
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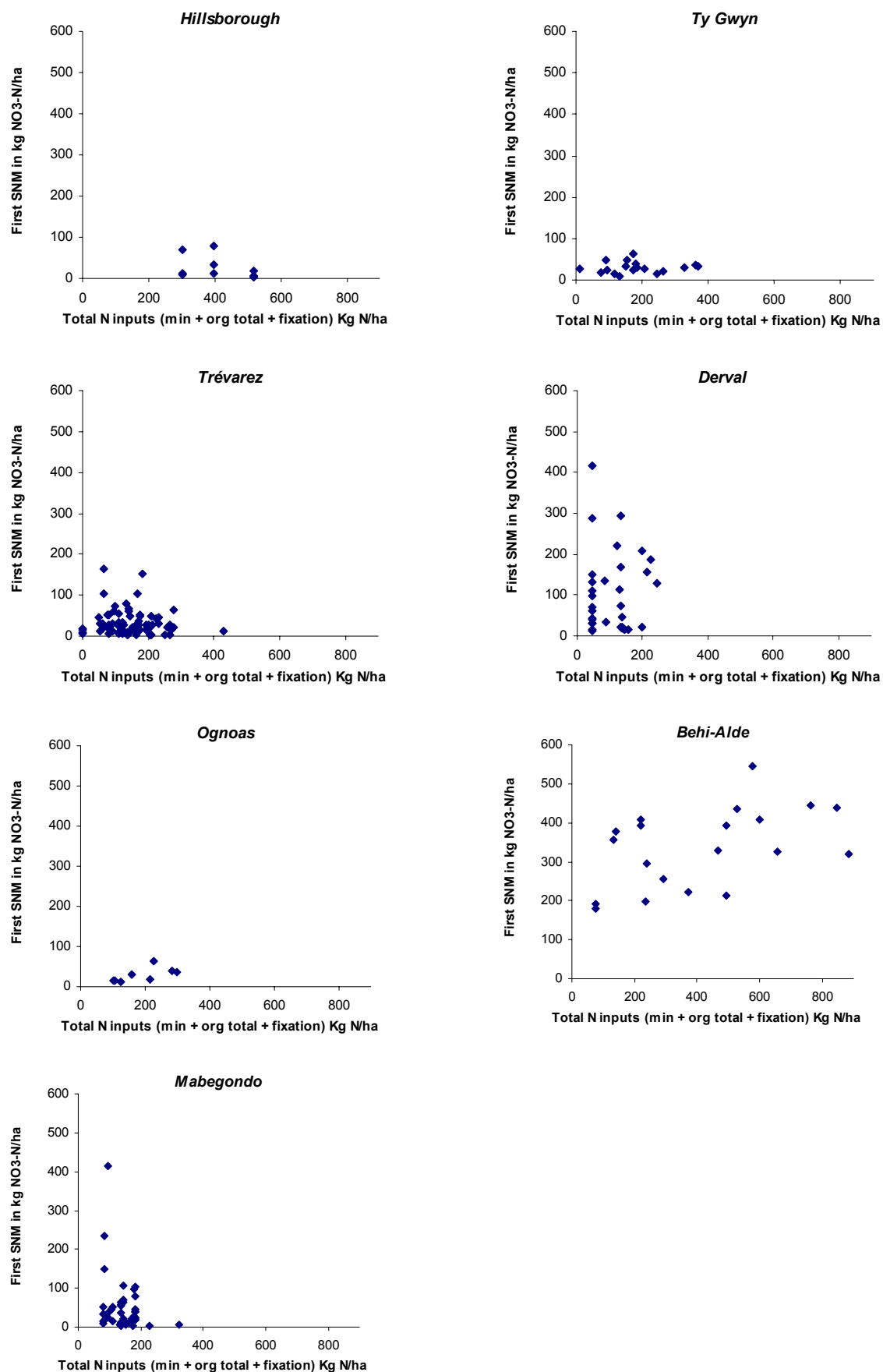
Appendix 1 : Gas emission factors taken from the literature to assess NH₃ and N₂O losses

Segment	Coefficient of emission	References
NH ₃ -N in buildings	0.12 kg NH ₃ -N per kg N excreted in buildings	EMEP-CORINAIR, 2001
NO-N in buildings	0.003 kg NO-N per kg NH ₄ -N excreted in buildings	Skiba and al. 1997 corrected by Pauraudeau and al., 2005
NH ₃ -N in storage	0.06 kg NH ₃ -N per kg N excreted in buildings - (NH ₃ -N+ NO-N) lost in buildings	EMEP-CORINAIR, 2001
N ₂ O-N during storage	0.57 kg N ₂ O-N per 100 kg N excreted in buildings	Amon and al.2001 corrected by Hacala and al., 2006
N ₂ -N in buildings and storage	N ₂ -N lost = [N excreted in buildings + N litter - N spread]* Error on P - (NH ₃ -N + NO-N + N ₂ O-N) lost buildings and storage	EMEP-CORINAIR, 2001
NH ₃ -N at grazing	0.12 kg NH ₃ -N per kg N urine excreted at grazing	IPCC. 1997 IPCC. 1997
	0.03 kg NH ₃ -N per kg N dung excreted at grazing	
NO-N at grazing	0.003 kg NO-N per kg NH ₄ -N excreted at grazing	Skiba and al. 1997 corrected by Pauraudeau and al., 2005
N ₂ O-N at grazing	$(1.5\% * \text{kg N urine} + 0.4\% * \text{kg N dung}) * a$ kg N ₂ O-N lost <i>a=1 if stocking rate between 1 and 1.5 LSU/ha FA</i> <i>a= 1.5 if stocking rate between 1.5 and 2</i> <i>a=2 if stocking rate > 2</i>	Oenema and al. 1997
N ₂ -N at grazing	3 kg N ₂ -N lost per kg N ₂ O-N lost at grazing	Webb, 2001
NH ₃ -N during spreading of cattle FYM	0.57 kg NH ₃ -N per kg NH ₄ -N spread (winter)	EMEP-CORINAIR, 2001
	0.76 kg NH ₃ -N per kg NH ₄ -N spread (spring)	
NH ₃ -N during spreading of cattle slurry	(10.7 + 1.165 T ₂ - 1.238 P ₁ - 0.39 P ₅) kg NH ₃ -N per kg NH ₄ -N spread	T. Morvan, 2002, unpublished
	With T ₂ : the average temperature in C over the 5 days after the spreading of slurry	
	P ₅ : the cumulated rainfall in mm from the day of the spreading to 5 days after. P ₁ : the cumulated rainfall in mm between the day of the spreading and the day after	
NH ₃ -N during spreading of pig FYM	0.76 kg NH ₃ -N per kg NH ₄ -N spread (winter)	EMEP-CORINAIR, 2001
NH ₃ -N during spreading of pig slurry	0.15 kg NH ₃ -N per kg NH ₄ -N spread (winter)	Morvan et Leterme 2001
NH ₃ -N during spreading of mineral fertilizers	2% N spread (ammonium nitrate, calcium ammonium, nitrate, complex NPK) 5% N spread (ammonium phosphate) 15% N spread (urea) 10% N spread (ammonium sulphate) 8% N spread (urea ammonium nitrate solution)	EMEP-CORINAIR, 2001
NO-N during spreading of FYM and slurry	0.003 kg NO-N per kg NH ₄ -N spread	Skiba and al. 1997
NO-N during spreading of mineral fertilizers	0.003 kg NO-N per kg NH ₄ -N spread	Skiba and al. 1997
N ₂ O-N on crops fields	0.6+0.002*Fert+1.27*Csoil-0.024*Sand	Freibauer et al. 2002
	where Fert= N mineral + N organic direct effect in kg N	
	C soil = C org in %	
	and Sand = rate of sand in %	
N ₂ O-N on grasslands fields	2.4 + 0.015*Fert	Freibauer et al. 2002
	where Fert = N mineral + N organic direct effect + N fixed	
N ₂ -N during spreading	3 kg N ₂ -N per kg N ₂ O-N loss during spreading (mineral and organic)	Webb 2001
N ₂ -N due to fixation	0.0125 kg N ₂ -N per kg N fixed	Payraudeau and al. 2005
N ₂ O-N due to leaching	25 g N ₂ O-N per kg N leached	Velthof and al. 1998
N ₂ O-N due to volatilisation	5 g N ₂ O-N per kg NH ₃ -N volatilised	Velthof and al. 1998

Appendix 2: Variability of soil mineral N contents at start of drainage in relation to inputs by fertiliser inputs to maize (average for 2004 and 2005)



Appendix 3: Variability of soil mineral N contents at start of drainage in relation to inputs by fertiliser inputs to grassland (average for 2004 and 2005)



Contribution of the dairy herd to nitrogen and phosphorus surplus at regional scale and risks for water quality

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Summary

The aim of this third part of the Green Dairy project was to make the link between the assessment of progress in reducing nitrogen (N) losses at the farm scale and the potential impact of these improvements at the regional scale (including all agricultural activities). The other aim was to estimate the share of the N surplus likely to be transferred to surface waters, these being a major source of drinking water and often demonstrate eutrophication problems. The study was divided into three stages: computation of a global regional surplus, assessment of the contribution of the dairy herd in 2000 to the regional surplus and estimation of the situation in 2014 (with some very simplified hypotheses being made), assessment of the proportion of the surplus likely to be transferred to surface water.

The area studied was composed of the 9 regions involved in the Green Dairy project having a pilot farms network and extended from Scotland to Portugal, thus included a wide diversity of environments, and very diverse animal husbandry and cropping systems.

Examining these diverse environments in relation to the water quality brought us to the following conclusions:

- the contribution of the dairy herd to the N and P surpluses largely depends on other agricultural activities in the region.
- the increase in the milk production per cow had much less effect on the regional N surplus than an adjustment of mineral fertiliser rates.
- there was no simple relationship between the regional N surplus and the nitrate content of waters; for instance grass-based systems had very small nitrate losses in spite of high N surplus.
- mixing intensive dairy systems with risky management practices in risky environments must be avoided.

Introduction

Dairy farms belonging to the regions involved on the Green Dairy project account for 25% of the EU 15 milk production and of the fodder crops area. These regions of the Atlantic Area are all part of an intensive cattle production area in which animal husbandry is sometimes associated, or even competing, with arable crops or intensive housed pig or poultry production. In addition, this largely coastal area has also a high population density and tourism accounts for an ever growing part of the local economy and where fishery and shellfish industries are experiencing problems. This situation provides a conflict with dairy farmers because nitrogen (N) and phosphorus (P) surpluses arising from intensive dairy farms are being held responsible for algae pollution that prohibits shellfish consumption, and is damaging for tourism.

Recent European rules and especially the Nitrates (1991/676 EEC) and Water Framework Directives (2000/60 CE) aim to promote good quality of fresh and marine waters by the end of 2015. Moreover, the recently reformed Agricultural Policy requires these and other regulations to be followed in order for farmers to be able to be eligible for financial support. As a result, there is a gap between these strict and uniform environmental rules on the one hand, and the diversity of the physical environment and of the farming systems throughout the Atlantic Area (from Ireland to Portugal) on the other. This diversity of contexts is such that it justifies regional adaptation of the rules, in order to ensure a better ecological and economical efficiency.

The aim of the third part of the Green Dairy project was to estimate the link between the progress made at the dairy farms scale and the potential impact of these improvements on regional N and P surpluses (taking into account all agricultural activities). This was used to assess the importance of the dairy herd in the regional economy (Chatelier & Pflimlin 2006; this volume), and also in the regional land use and regional amount of N arising from manures. The second step was then to estimate the proportion of the N surplus likely to be transferred to surface water over the short term. Surface water is important from at least two points of view; it is a major regional provider of drinkable water, and is very sensitive to eutrophication.

1. Main characteristics in the Green Dairy regions and importance of milk production

1.1. The environment: although within the same biogeographical area there is much variability in climate, soils and agricultural systems including grass and fodder crops

The 11 Green Dairy regions, including 9 with pilots farms and 2 with only experimental farms (Northern Ireland and Wales) are all part of the same biogeographical area as defined by the European Environment Agency (EEA 2001) with the following common criteria: climate, altitude and type of vegetation (see Map 1). This forms the “Atlantic Area”. Only North-East Portugal and South of the Spanish Basque Country are part of the “Mediterranean Area”, but most of the Green Dairy pilot farms are within the Atlantic area. All the Green Dairy regions are part of the same marine area and their watersheds and corresponding rivers and streams flow into the Atlantic Ocean.

The area concerned has significant rainfall and a temperate climate (Maps 3 and 4): the major difference between the 11 regions occurs during the summer when it is mild with substantial rain in the Northern regions, warm and dry in the Southern regions and intermediate in the French regions. In the northern regions, the soils are mainly loamy with a high organic matter content and more or less poorly drained and support mainly (and exclusively in some parts) permanent pastures. In the southern regions, the soils are mostly well drained, have a lower organic matter content and support fodder crop systems based on irrigated maize. As a result, pastures are dominant in the North and are mainly grazed. Irrigation is largely dominant in the South, and the French regions combine both systems. Thus, pastures account for more than 80% of the agricultural area (AA) in western England and Ireland, 65% in Galicia and Basque Country, less than 45% in Brittany and Pays de Loire and less than 30% in Aquitaine and Portugal. Conversely, fodder maize is a relatively minor crop in Ireland and the UK (except in England where there has been a substantial increase in fodder maize production on the eastern side of the Green Dairy region). In contrast, fodder maize accounts for 20% of AA in the cattle production regions of Western France and Galicia. This figure is much higher in the coastal area of North Portugal (Maps 5-6-7-8).

1.2. Importance of the dairy herd

The intensity of dairy production varies from 0.1 to more than 1 dairy cow/ha AA, on average, at regional level. Higher densities are found in South Ireland, Eastern Brittany and near the North-Western Portuguese coast. Dairying accounts for 10% of all the regional farms in England, Portugal and Scotland but this rises to 20% in Western England, 30% in Pays de Loire, 35% in Galicia and 45% in Brittany. Overall cattle production intensity varies from 1 to 1.5 LU/ha AA in most of the regions. Much higher figures can be found especially in the Cork region (Ireland) and Western Galicia. It should be noted that AA accounts only for 30% of the total area in Galicia and Portugal whereas forest accounts for 60% and this dilutes any impacts of intensive animal production in these regions. In contrast, AA accounts for more than 60% of total area in Western France and for 80% in Southern Ireland (Map 12).

In our study, in order to estimate the contribution of the dairy herd in the regional nitrogen (N) surplus, we have to take into account all animal production activities. Maps 13 and 14 show the amount of N

coming from animal manure per ha AA and its origin (dairy cows, other ruminants (including heifers), as well as pigs and poultry. Three regions (Western Brittany, Galicia and North Portugal) have a much greater amount of total manure N than the others (i.e. more than 130 kg N/ ha AA). As previously noted, this large amount is diluted by the extent of forest in Galicia and Portugal, but not in Brittany. The aim of this study was to assess the share of the dairy herd in the N and P surpluses at regional scale to better quantify the risks for water quality. These risks can be grouped into three types:

1. Sensitivity of the environment to leaching, rate of drainage and denitrification and dependent upon soil and climatic factors (especially winter rainfall). These environmental conditions are relatively stable and cannot be modified by farmers to any extent.
2. Cropping and animal production intensity (indicated by the amount of N from animal manure per ha AA and the amount of milk produced per ha AA). The farmer can reduce both of these, but this often has negative consequences on economic results.
3. Agricultural practices: the proportion of pastures and crops in the AA, the amount of bare soil, the amount of N manure spread and the period when it is spread.

The combination of these three groups creates water quality problems but also provides the basis for tools to be developed to provide solutions, especially with regard to nitrate and phosphates.

2. Materials and methods

This study mainly deals with agricultural N surplus in the different Green Dairy regions and with losses to surface water. Estimates were made at the regional scale and an overall estimate was first made, and then another specifically linked to the regional dairy herd. The P aspect was limited to a simplified method dealing with the assessment of the medium-term risks of P losses to water for the dairy farming sector only.

The three steps of the study on N surplus are illustrated in Figure 1:

- First, a global surplus concerning all agricultural activities was made
- Second, the contribution of the dairy herd (cows + replacement heifers) in the global surplus was calculated (using the same data base to allow an appropriate comparison). Production per cow, and herd and the farm management practices were then modified, and impact of these changes on the global surplus was calculated.
- Third, we built a statistical relationship between the N surplus and nitrate content of surface waters.

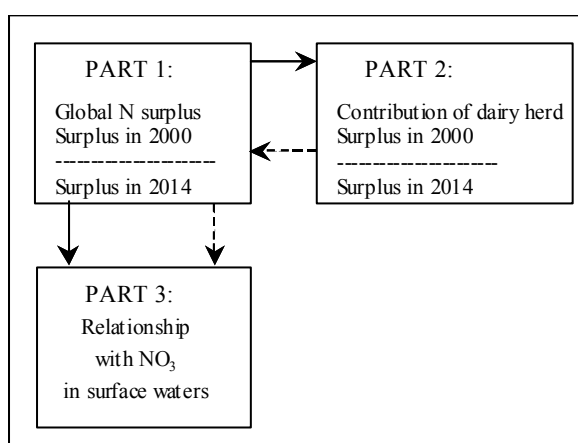


Figure 1: Conceptual description of the three stages of the analysis of regional N surplus and its relationship with NO₃ in surface waters.

2.1. Computation of the global N surplus:

2.1.1. Principle

This surplus takes account of the entire agricultural contribution and includes:

- as inputs: mineral fertilisers and animal excreta
- as outputs: all the crop production (cereals, oil seeds, forage/ fodder crop, including grazed grass)

This type of surplus is the most commonly used by the OECD and the EEA as an environmental indicator for N surplus. In France, the same method was used by CORPEN to build a diagnostic tool for farms. The surplus used in our study was simplified for some items that seemed inaccurately estimated or not influential given the precision of the estimates. Some improvements were also included in software designed for this type of regional computation (NOPOLU constructed for the IFEN, 2003). Other improvements were made to allow us to test the impact of changes in agricultural practices (see later).

2.1.2. Databases and improvements to N surplus computation method

- *Assessment of the inputs*

For mineral fertilisers, information came from the results of the “Pratiques culturales” inquiry for France (SCEES 2001), and from information obtained from the project partners for the other regions.

For N manure estimates (i.e. the assessment of animal excretal N) some adjustments were made:

- Excreta by dairy cows were calculated from details of milk production, total N in the diet and the average grazing time based on an INRA equation (Vérité & Delaby 1998). Pasture use has two effects on the computation: first it is a N- rich fodder and second as a factor tending to limit ammonia volatilisation. We assumed 10% N loss by volatilisation at grazing and 30% during housing and during manure storage and spreading.
- For all the other animals, we used standard French values for all regions: this allowed us to make comparison on a common basis of the effects of the changes of dairy farming practices.

All the calculations included atmospheric N deposition in inputs, based on EMEP estimates (2003) and accounted for ca. 5 to 10 kg/ha in most of the regions, except Brittany where it was up to 20 kg/ha.

- *Assessment of the outputs*

The estimate of N export in arable and fodder crops is a product of yields and their N contents. This is easily and accurately achieved for the major crops that are sold (cereals, oil seeds...) because many analyses are made and product quality is relatively stable. In contrast, for fodder crops, the estimate of yields is approximate and the assessment of N content is even more inaccurate, and dependent on the harvesting conditions. For grassland yields, 2 different methods were used, one referring to regional yields in DM/ha (national statistics) the other to roughage intake by herbivores assuming an intake of 5 t DM/ LU. If the 2 estimated values were different, we took into account the smallest. For the N content of fodder maize, we used 12.5kg N/ton dry matter for all regions; for grass, however, we adjusted values according to fertiliser rate.

- *Difficulties / limitations*

There was a different geographic scale for different countries. The calculations were made at the NUTS V scale (municipality) in Ireland and Basque Country, NUTS IV (county) in France, England, Galicia, Portugal and NUTS III (group of counties) in Scotland because of the difference in the availability of data from the Green Dairy partners. In the case of Scotland, this may be a problem

because it was difficult to provide relevant results at the watershed scale because the database was at a wider scale.

Export coefficients for grassland play a large role in determining the effects on the surplus. Given the importance of the grassland area (90% of AA in Ireland), even a slight variation of the grass N content can trigger a big change in the value of the surplus. We used information provided by our partners to give the basis for the calculation, but as a result, we cannot exclude a lack of homogeneity and this must be kept in mind when discussing the final results.

2.2. Impact of the dairy herd in the regional surplus

2.2.1 Computation of the dairy cow excreta

The aim was to assess the contribution of the dairy farms in the global surplus that was previously obtained. In addition to quantifying this, the development of such a method may be useful to enable us to estimate the margin that there is to improve the practice and reduce the surplus. The basis of the calculation was dairy cows + replacement heifers, which allowed us to make an easy link with the regional statistics. In addition, to obtain a more accurate estimate of the surplus from dairying, we took into account the 2 or 3 main types of dairy farms in each region to have a better idea about fodder crops, cow feed rations and fertiliser practice. Based on the data provided by the partners it was possible to calculate N excretion coefficient for each cow and replacement heifers, and then to calculate an overall surplus. The principle of the calculation is described below (blue circles indicate data provided by partners).

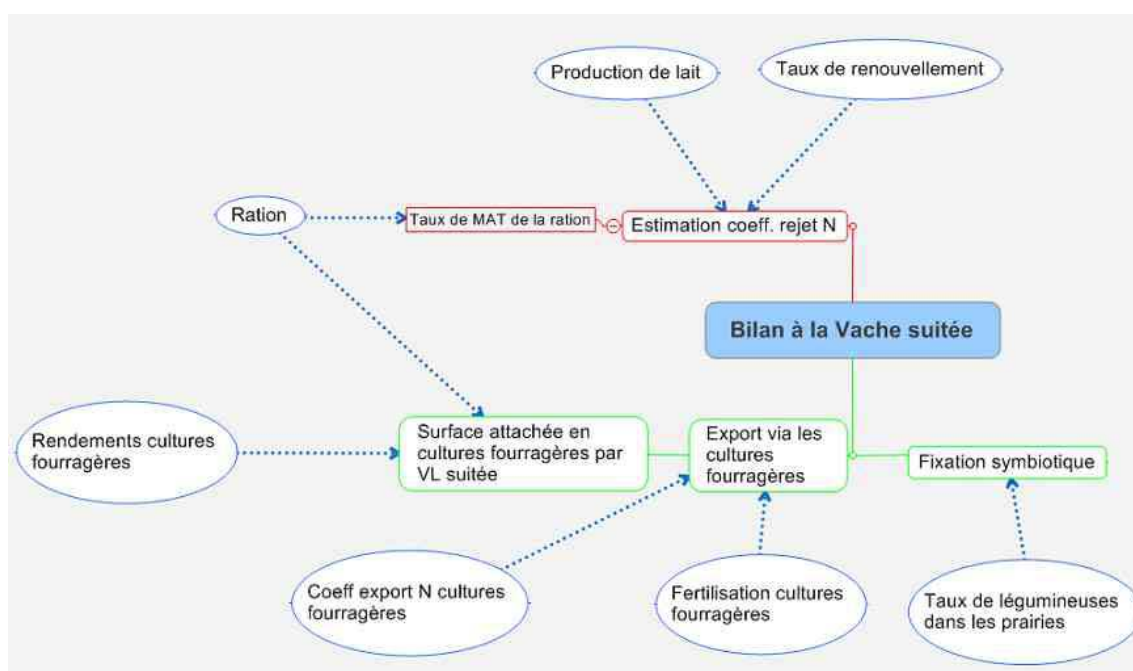


Figure 2: Principle of calculation of the N surplus per cow and replacement heifer

As we can see, the calculation of excreted N is strongly based on the total N content of the feed ration. This value is calculated thanks to a simple equation:

$$\text{Nitrogen in ration} = \sum_i \text{Nitrogen in food}_i * \text{Ton of food}_i / \text{Overall tons of food}$$

The N content in each component of the feed corresponds either to CORPEN values (1998) or to values adjusted region by region, especially those for grass. We then, used an equation to provide the excretion coefficient depending on the N content of the feeding ration, based on an INRA study (Vérité & Delaby 1998), adjusted to milk production.

2.2.2. Assessment of the contribution of the dairy herd to the regional N surplus in 2000 and 2014

Having calculated the surplus per cow and replacement heifer, we calculated an average dairy surplus value depending on the frequency of each type farm type in the region and then a surplus value for the whole of the regional herd using values from the agricultural census. This allowed us, with the global regional surplus, to calculate the contribution of the dairy herd to the global surplus which provided the basis for “scenario 2000”. An assessment was then made of what could be the situation in 2014. Two hypotheses of change were chosen: either an increase of 1,000 or 2,000 kg of milk per cow in this period. To achieve these, we adjusted the dairy herd (but maintaining the regional quota at the same level). The feed ration was also adjusted, with different rules according to the region and based on observations from the pilot farms in 2004/2005. As an example, an increase of 1,000 kg milk required an increase of 500 kg dry matter of fodder consumption in which the share of the concentrate varies: 100 g/l in Ireland, 130 g/l in Brittany, 200g/l in Aquitaine and Pays de Loire, 300 g/l in England and Scotland and 500 g/l for the 3 southern regions.

Moreover, because each cow produced more, less fodder surface was required to produce the same amount of milk. The released areas were allocated as follows:

- other grassland use in Ireland.
- temporary grassland changed to wheat and oilseed rape in France and England for temporary meadows and also extra fodder maize. Such substitution could contribute to bio fuel production.
- 25% of the area allocated to wheat or grain maize in Basque Country, Portugal and Galicia and 75% either urbanised or planted with Eucalyptus. This was justified by the intensity of the dairy systems in these regions and the ever increasing price of land in these Southern coastal regions.

Other types of animal and of crop production were assumed to be constant as was fertiliser practices in order to see more clearly the specific impact of the dairy herd. (An additional study allowed us to make more accurate 2014 scenarios for the 3 French regions, integrating changes in the herd, of land use and also the most likely changes in fertiliser practices.)

2.3. Relationship between N surplus and nitrate content in surface water

For this component, a statistical approach was used. The goal was to estimate the link between different variables of influence and the nitrate content of the surface water using a linear regression model. The variables were selected using expert advice and on this basis it was considered that the nitrate content of surface water depended primarily on the quantity of N in the soil during the leaching period, the quantity of drainage water and the land use.

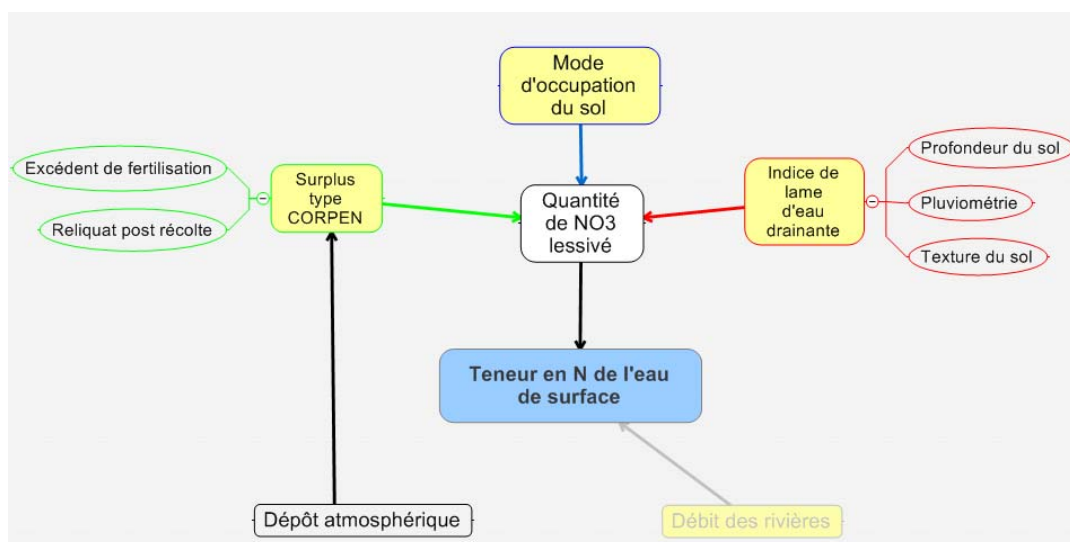


Figure 3: Variables selected for building the model

As a result, three groups of variables were chosen:

- **The “climate” group**: which included a drainage water index (in mm) calculated using the MARS data from the JRC (see glossary). These data take account precipitation (P), evapotranspiration (ETP) on bare soil, and under a crop canopy and the index equates to P-ETP during the leaching period from October to June.
- **The “land use” group**: which contained the proportion of total surface in forestry, in agricultural use and urbanised and built areas. The agricultural area was divided into cereals and other tillage crops, pastures and fodder crops. These values were extracted from CORINE Land Cover information (see glossary) and from the agricultural census data from the partners.
- **The “surplus” group**: which contained the surplus, mineral N fertiliser and the manure N content all expressed as kg N/ha AA

2.4. Phosphorus surplus and risks for the water

Since we did not have sufficient data on P fertiliser use in the different regions, we used a simpler approach and considered that P losses in the field mainly depend on:

- **Erosion**: this factor was estimated with the PESERA model developed by JRC.
- **The P surplus**: we took as reference values data from the Green Dairy pilot farms as being representative of future dairy farms

3. MAIN RESULTS

3.1. The global surplus at regional scale

The surplus was calculated with the agricultural census and agronomic data from each region, but to obtain results more relevant to the regional context, specific adjustments were made. We thus recalculated the excretal coefficient for an average dairy cow using regional data bases provided by the partners. The excretal coefficient varied a good deal between the regions and was higher in dairy systems based on a long grazing period (Table 1).

Table 1: Recalculated N excreta for dairy cows (volatilisation deducted)

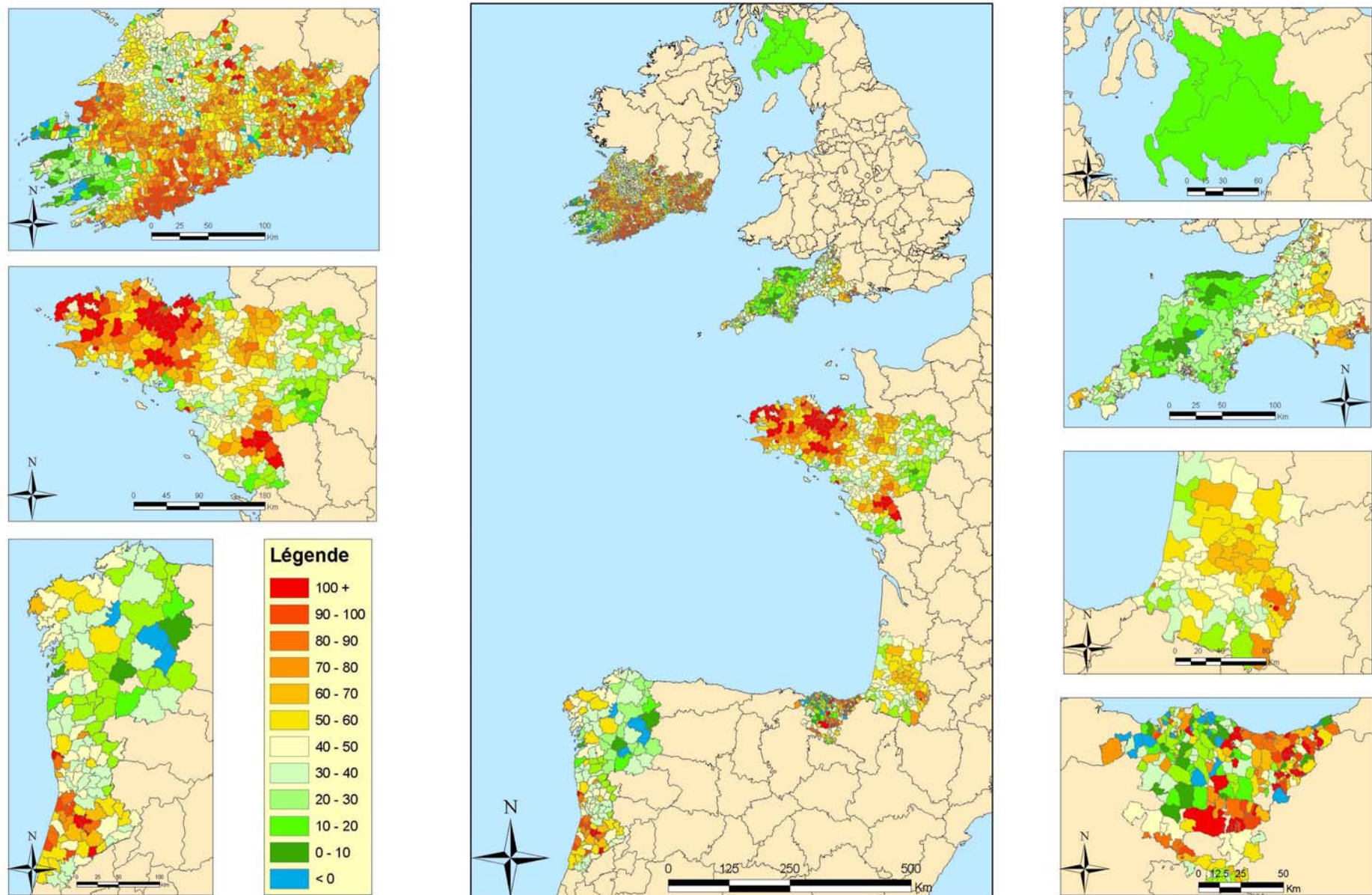
	England	Aquitaine	Brittany	Scotland	Galicia	Ireland	Basque country	Pays de Loire	Portugal
Recalculated N coefficient (kg N/cow/year)	115	76	86	105	108	115	128	81	90

The other main adjustment dealt with the fodder crops and the pastures; the values for mineral fertiliser rates, yields and (where they were available) the export coefficients. In most cases, these adjustments were necessary because the dairy farms were more intensive than other cattle production systems: these adjustments were made after discussion with the partners from each region.

There was an obvious similarity between Irish and English regions. In Ireland, the dairy area had much higher surplus values than the other regions whereas the values of N surplus were slightly lower, even in the most intensive dairy area, probably because of a lower stocking rate. The values obtained for Scotland cannot be usefully compared because the computation scale was too wide. In France, the highest values of surplus were in Brittany, and were linked with a high density of other animal production systems (pig and poultry as well as dairy). In Pays de Loire, the situation was more contrasted and the values of surplus were higher in the dairy areas, but low elsewhere, especially in the beef cattle areas). In South Aquitaine, the high surplus values were mainly due to grain maize cropping (high mineral fertiliser rates) and to the dairy area at the base of the Pyrenees. In the Southern areas, there was always a clear difference between the very intensive were much lower. Another common factor was that high surpluses were often explained by a high rate of N manure per ha AA, the amount of mineral N per ha AA being relatively low most of the time.

**Figure 4: Nitrogen surplus in the Green Dairy regions (in kg of N per ha of AA)
(data taken from FFS 2000 and regional data bases)**

In South Ireland and SW England Nitrogen surplus have been overestimated due to the N excretion / cow used in the calculation by NOPOLU (125 kg N/cow whereas the average is closed to 115 kg/cow). So, there is an overestimation of 15 to 20 kg N/ha for the most specialized dairy countries which are over 80 kg N/ha AA. and around 10 kg/ha AA for the others



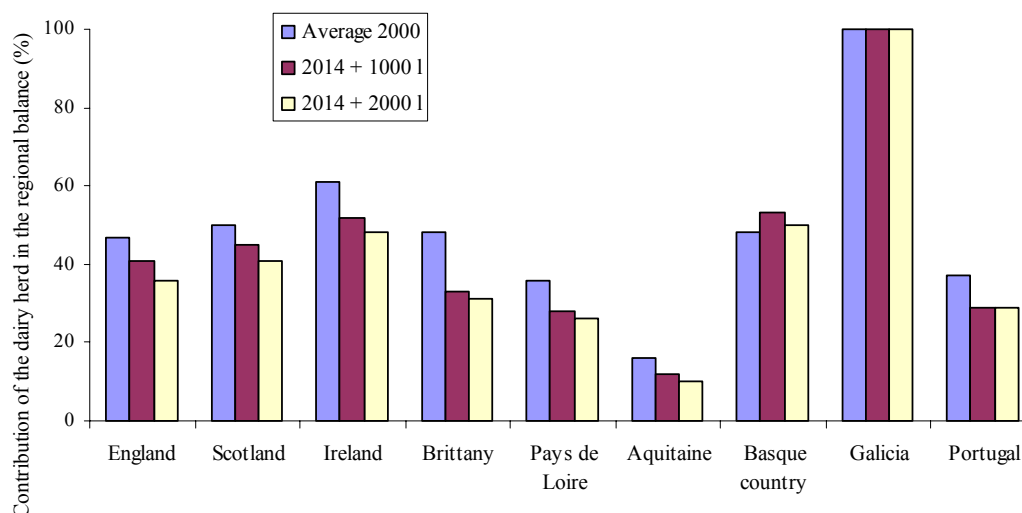
3.2. The contribution of the dairy herd to the regional N surplus

The results for the reference situation in 2000 are presented in Table 2 which shows that the dairy herd contribution varied a good deal between the different regions. For example, in Aquitaine the dairy herd accounted for a very small part of the regional surplus which was relatively high, whereas in Galicia dairying accounted for 100% of a smaller overall surplus.

Table 2: Average regional surplus and contribution of the dairy herd in 2000

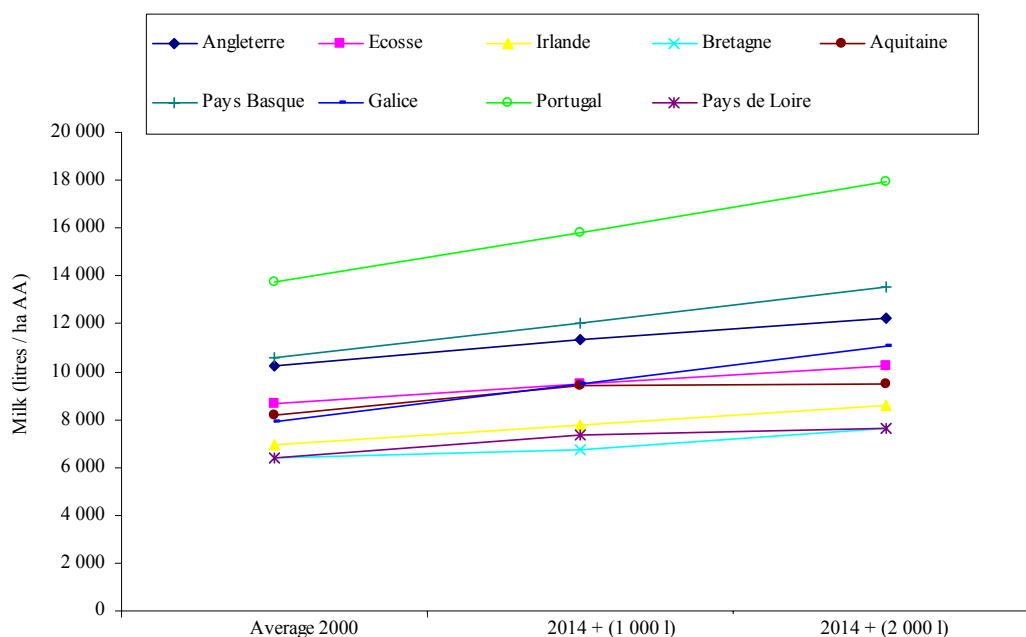
	Surplus per ha of AA (kg N/ha)	Contribution from the dairy herd
England	28	47%
Scotland	43	38%
Ireland	60	39%
Galicia	33	100%
Basque country	54	51%
Portugal	53	37%
Brittany	86*	48%
Pays de Loire	59	36%
South Aquitaine	67	16%

To estimate the effect of an intensification of dairy breeding, we recalculated the surplus where the production characteristics were changed as described earlier. Figure 4 shows changes in the impact of the dairy herd in the different scenarios and for almost all the regions, the contribution from the dairy herd to the surplus tends to decrease a little when milk production per cow increases. In other words, dairy systems would be more efficient and would produce more milk whilst their share in the global N surplus would be relatively less important, assuming that other agricultural activities in the region did not change



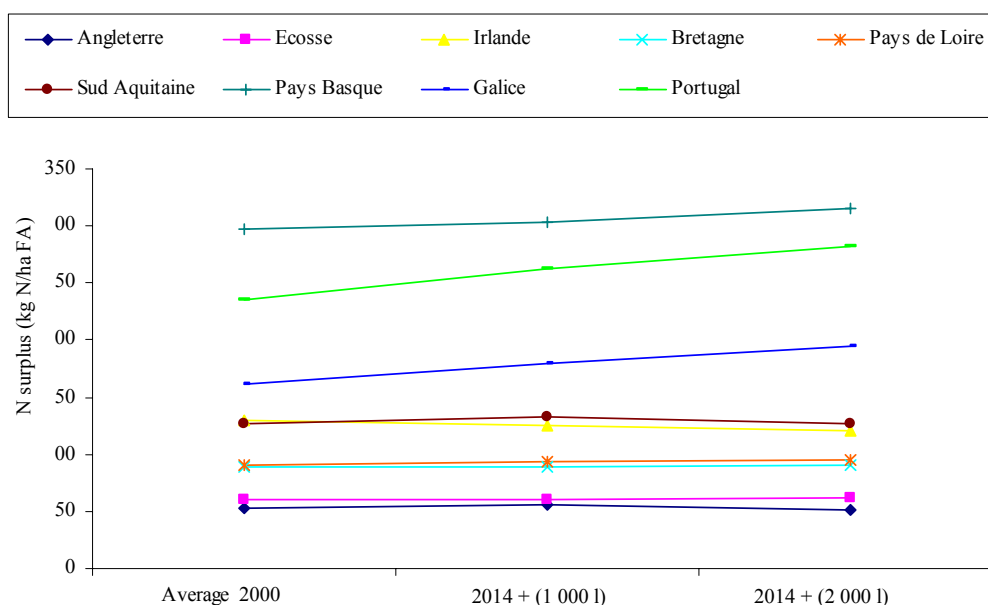
Graph 1: Contribution of the dairy herd to the regional N balance in 2000 and 2014

To examine further detail the effects of changes in the dairy farms, we analysed effects on the surplus when expressed per ha of forage area on the dairy farms. This value can then be compared with the amount of milk produced per ha fodder crops.



Graph 2: Milk production per ha of forage area in 2000 and 2014

Firstly, the amount of milk/ha increased slightly and was more marked in the dairy systems of the South because we assumed that all of the additional milk would be produced with extra input of concentrate.



Graph 3: N surplus per ha of forage area in 2000 and 2014

A close look at the 2000 situation shows that English and Scottish grass-based systems had the smallest surplus per ha of dairy farm. The Irish systems had a higher value, because of a smaller average milk production per cow and a higher cow density. French dairy farms in Brittany and Pays de Loire were similar and the Aquitaine had a higher surplus. Last, the three dairy systems in the South of Europe are again shown to be more intensive as to be expected because they have the highest animal stocking rate and these regions are also the only ones where the surplus/ha dairy farm increases with increasing milk production. This is quite logical since we assumed that the additional milk would be produced by using additional concentrate. In Galicia we assumed that the traditional dairy systems would decrease, being replaced by intensive systems. However, even in these regions the data show that input to the global surplus from the dairy herd will decrease, or at least remain steady.

A complementary study was also made on the French regions (Mirabal 2006). The basic principle was the same, i.e. computation of the surplus for the average 2000 situation, and then changes based on two different hypotheses:

- an increase in milk production per cow of 1,000 l between 2000 and 2014
- the same increase in milk production, but in addition a reduction of the mineral fertiliser on all the crops.

The results on Figure 5 show clearly that the effects of changing mineral fertiliser were greater than those of changing cow husbandry practices to reduce the N surplus.

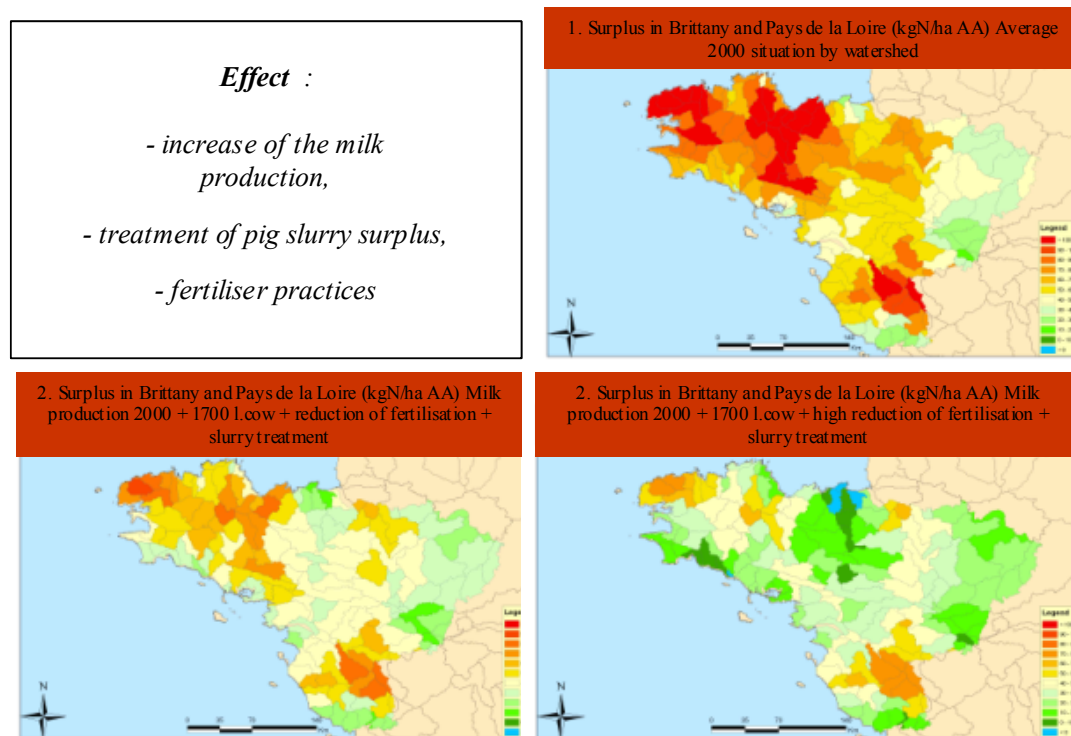
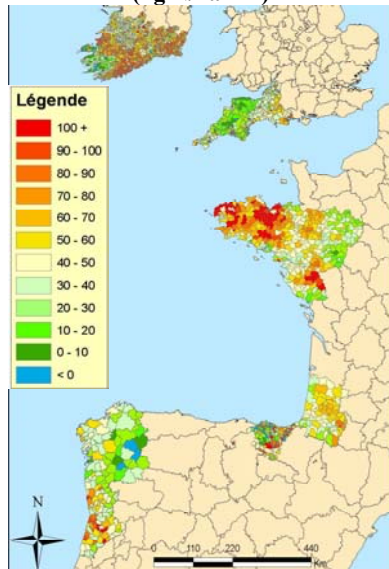


Figure 5: N Surplus evolution in Western France according to different scenarios

3.3. Relationship between the N surplus and the surface water quality

The comparison of both cards of the Green Dairy regions shows a certain similarity between the nitrogen surplus and the contents in nitrates of surface waters measured for year 2000 (figure 6) In Galicia the surplus as well as the contents in nitrates is low and conversely in Brittany both values are high. On the other hand these contents in nitrates are not coherent with the nitrogen surplus calculated in the pilot farms only, even in regions where dairy farming is important: the lowest content in nitrates are measured in Galicia and in Portugal where the surplus of the pilot farms are very high and on the contrary the highest contents are observed in Brittany where the pilot have the lowest surplus! These findings lead us to look for a more complex statistical model and analysis developed there after.

**Nitrogen surplus in Green Dairy regions in 2000
(kg N/ha AA)**



**Nitrate contents in surface waters in 2000
in Green Dairy regions (mg NO₃/litre)**

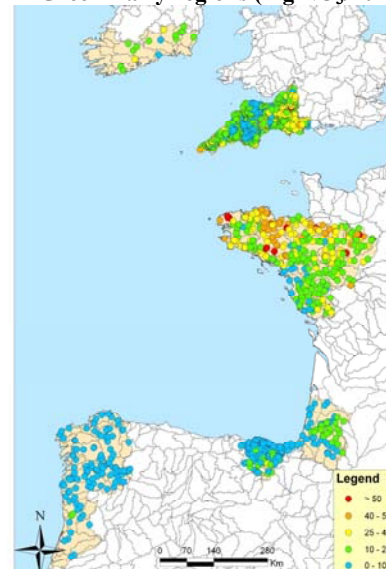


Figure 6: Nitrogen surplus and nitrate contents in 2000

3.3.1. Modelling and choice of the variables

Once we had the values of N surplus and the effects of the dairy herd in this surplus, we modelled the quality of surface water. Schematically, we considered that the N surplus could be partitioned in three different “ways”:

- emission to the air (N₂, NH₃, N₂O)
- accumulation in the soil (immobilisation)
- leaching into the water (nitrate)

Leaching can be either into ground or surface water. In the large majority of the Green Dairy regions, drinking water comes from surface water and therefore we modelled the quality (nitrate content) of the surface water, and more specifically, we assessed the link with the agricultural N surplus that we had previously calculated. Every variable concerned was calculated at the watershed scale. The N surplus values for the watershed we calculated with NOPOLU software and a system based on the CORINE Land Cover layer (see Glossary).

The nitrate content of the surface water was derived from data from our partners which were, in the main, the same as those provided to the European Commission for the last Nitrates Directive campaign. An average value was calculated for each watershed. Some mathematical transformations were made for some variables: these were made based on mathematical and statistical criteria and had no agronomic justification at all. A logarithmic transformation was made on the variable to define the nitrate content. In order to test the spatial distribution of the model, we created a qualitative variable called “region” which corresponded to the region where the watershed was located. The aim was for this variable to have a small effect because it represented the effects linked to all unidentified variables.

3.3.2. Selecting and gathering the variables

Variation of the nitrate content was analysed with a linear regression model:

$$Y = X\beta + \varepsilon$$

where Y is the average nitrate content in surface water in a watershed.

We grouped the variables that could explain the nitrate variability into three groups: “climate”, “soil use” and “surplus” and those finally chosen were those that had a significant effect on the nitrate content with a significance threshold of 5 %. Finally, the variables chosen were:

- volume of drainage water
- proportion of total area in forest
- proportion of total area in agricultural land
- proportion of agricultural land cultivated in crops
- the N surplus for the watershed
- the amount of mineral N/ha AA
- the interaction between the surplus and the drainage water.

This model (Table 4) explained ca. 75% of the nitrate content. The effect of the variable “region” was not significant. We calculated the partial R^2 of each group variable in order to estimate their influence on the nitrate content. The variables were introduced into the model following a given order going from those that were the least likely to change to the those that were the most easily influenced by human activity. This method attempts to quantify the specific effect of the agricultural variables in a given environment.

Table 4: Characteristics of the statistical model

Group	Variable	R^2 variable	R^2 group
Climate	Drained water	15.1%	15.1%
Surface	Forest	30.7%	58.7%
	AA	14.8%	
	Crops	13.2%	
Surplus	Surplus	1%	6.7%
	Mineral N	0.8%	
	Interaction surplus*dw	4.9%	

As noted, the model explains ca. 75% of the total variability ($R^2 = 73\%$ estimated via cross validation). The effect of the “region” variable can be neglected ($R^2 = 3.8\%$) and no spatial correlation appears in the residuals. Lastly, in order to assess the accuracy of the model and its ability to predict values of nitrate content, the values predicted by the model were compared to the real values (Figure 6). The model underestimated the nitrate content in Brittany and overestimated slightly in England.

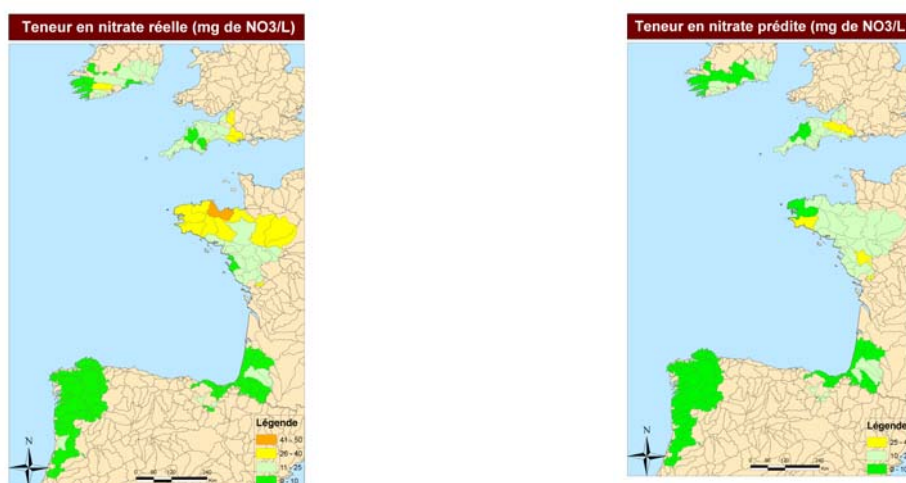


Figure 6: Comparison between the real nitrate contents and the predicted values by the model

3.4. Risk of phosphorus transfer

As noted earlier, the P index was divided into 2 parts:

- a “**source**” factor based on the phosphate surplus measured in the Green Dairy pilot farms.
- a “**transfer**” factor based on the erosion index value given by the JRC model PESERA.

Table 4. Risk of phosphorus transfer to surface water

Green Dairy Regions	Surplus* Kg P205/ha AA	Regional erosion index (2)	Niveau de risque (1x2)
Ireland SW	30	0,2	Low
Scotland SW	40	0,1	Low
England SW	43	0,5	Low
Brittany	41	2,4	Average
Pays de Loire	23	0,8	Low
South Aquitaine	34	7,12	Average
Basque Country	119	2,4	High
Galicia	166	0,3	Low
Portugal NW	122	3,4	High

**Surplus obtained from the Green Dairy pilot farms the first two years before improvement.*

Two groups of regions separate quite clearly:

- Northern Europe, where the surpluses were low as was the erosion index, leading to a low risk index
- Southern Europe, where high consumption of concentrates (in Basque Country and Portugal) combined with a high erosion index gives a high risk factor.

The main limit to this simplified approach is illustrated by the case of Brittany, where the level of risk varied from low to average. However, soils in Brittany have a very high P content (because of pig and poultry manure application and the erosion index is thus important. Since our index did not take into account the stocks of P in soils (because only current agricultural practices were included in the present index), it provides a false picture of the situation for regions such as Brittany. A more complex method could give more reliable information (Sharpley 2002), but this requires data to be collected that are seldom available at the regional scale. However, even the simple approach is useful to stimulate debate, especially in those regions where the P surplus is high because of a high consumption of concentrate.

Conclusion and discussion

The confrontation between the great diversity of environments and animal production systems on the one hand and the nitrate content of waters or the risk of P transfer on the other lead us to the following conclusions:

- The contribution of the dairy herd to N and P surplus and to the water quality depends more on the overall animal density per km², including the forest, than on the level of intensity of isolated herds. It also strongly depends on the other agricultural activities of the region. As a result, in Galicia the dairy herd accounts for more than 2/3 of animal LU and is responsible for the total amount of the regional N surplus without any real pollution problem in spite of agronomic practices that are not optimised. Conversely, in Brittany because of the density of animal production and the importance of the annual crops in a sensitive environment with few buffer areas, additional improvements will have to be made in all agricultural activities in addition to those already made in order to improve the water quality, especially in order to meet the water quality requirements of the Water Framework Directive.

- Many of the opportunities to reduce the surpluses are found in a better management of slurry and manure, thus allowing a reduction of mineral fertilisers without penalising yields and/or reducing stocking rate per ha. This study shows that an increase in milk production per cow has smaller effects on the surplus than a reduction of the mineral fertiliser inputs to crops and pastures. This study assumes that regional dairy quotas will remain constant: this situation could change in the next few years.

- There is no simple and direct relationship between the regional surplus and the risk of pollution, especially for nitrate. The models developed, even the more sophisticated must remain an analytical rather than predictive. Our model is a simple one and does not take into account a number of phenomena such as mineralisation or denitrification. The transfer patterns for N are complex and

depend on the fodder systems, for example, and the inclusion of annual crops, catch crops, temporary or permanent pastures. Grass based systems, in spite of the high amounts of N applied, a long grazing period and higher surpluses usually imply lower risks of transfer to water. The study on experimental farms (Bossuet & Chambaut 2006; this volume) also showed that N excretion per cow increased with the amount of grazed grass and, as a result, trigger an increase in the surplus which need not imply an increase in the nitrate content of water. As a result, the 170 kg manure N/ha criterion used in the Nitrates Directive should be modulated depending on the fodder system, with a different threshold for grass-based systems, and taking into account N export in the fodder crops that will vary with the yields (from 7 T to more than 25 T of DM/ha in the Green Dairy study area).

- According to our results the CORPEN/OECD type of balance is not a very useful indicator of nitrate risk at the interregional scale. However, these balances are good tools at the farm scale and even at the regional scale (i.e. in more homogeneous environment). In this context, a decrease in the N surplus implies less risk for the water and a gain in the economic efficiency of the farm.

- Last, although not absolutely demonstrated, the following statement can be made. The combination of an intensive production system (with high LU/ha), with high risk practices (high fertiliser rates, use of annual crops) within risky environments (sensitivity to leaching and erosion) that initiates water quality problems. As a result, it is not sensible to require the same constraints in all the countries of EU25, and even less for this level of constraint to be used in very risky situations. It is, without any doubt, the logical conclusion that must be considered when discussing the action programmes for the Water Framework Directive.

To conclude, we demonstrated contrasted situations in the different regions. The contribution of the dairy herd to regional N surplus varied between 20% in Aquitaine to 100% in Galicia, depending on the animal intensity and on the global regional surplus value. The study also showed that a change in the animal management practices had less effect on the surplus than a change in mineral fertiliser use. We also showed that the environment and the regional context play a major role in explaining the link or the gap between the N surplus and the surface water quality. Our model is very simple and does not take into account numerous factors such as immobilisation in soil or denitrification which play a major role in the transfer of nitrate to water.

Glossary

AEA/EEAN : Agence Européenne de l'environnement

CORPEN : Comité d'Orientation pour la réduction des pollution des eaux par les nitrates (Fr)

IFEN : Institut Français de l'Environnement (Fr)

SCEES : Service Central des Enquêtes et Etudes Statistiques du Ministère de l'Agriculture (Fr)

JRC : Joint Research Center, Ispra- Centre de recherche de la Commission Européenne

OCDE/OECD : Organisation for Economie Cooperation and Development

PAC/CAP : Politique Agricole Commune

EMEP/CORINAIR : Emission Inventory Guide Book 2003

NOPOLU : Logiciel de calcul des bilans des minéraux à différentes échelles spatiales mis au point pour le compte de l'IFEN

PESERA : Pan European Soil Erosion Risk Assessment

MARS : Base de données Météo harmonisée pour l'Europe

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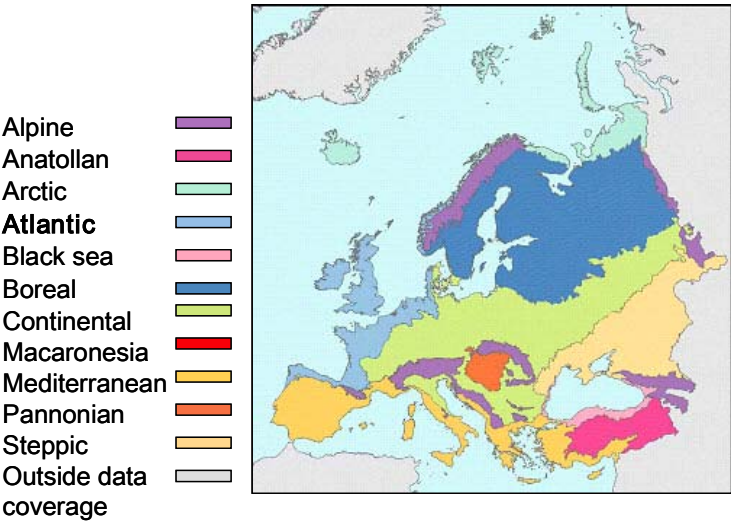
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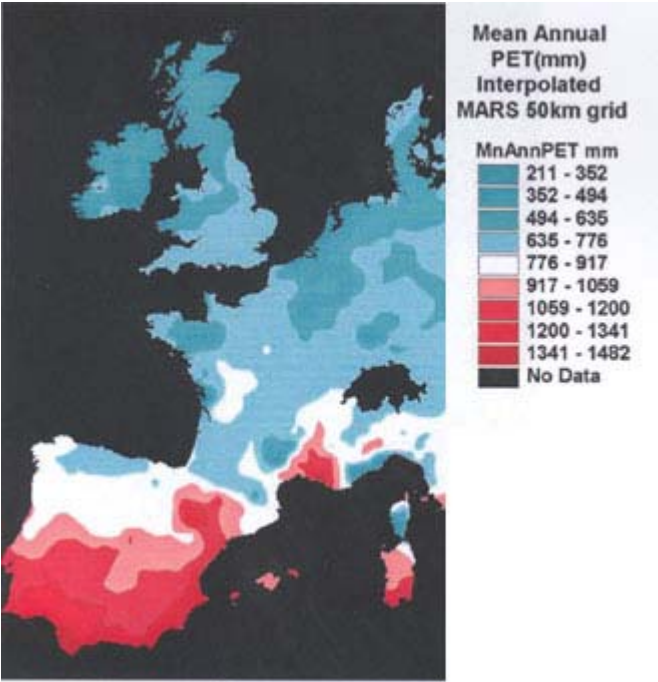
Map 1: The same biogeographical region: the Atlantic area (EEA 2001)



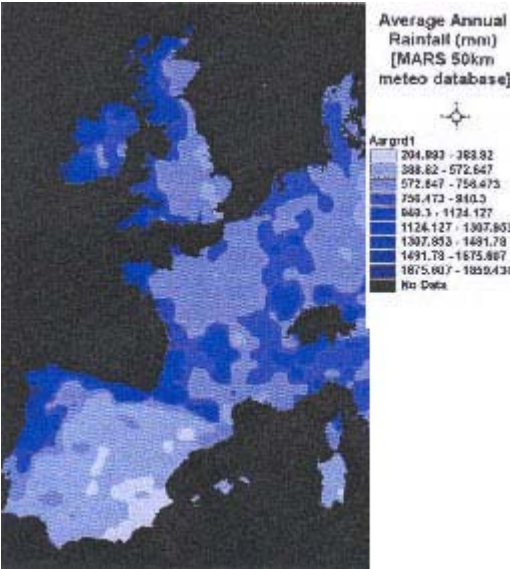
Map 2: The same drainage basin to the Atlantic Ocean (EEA 2001)

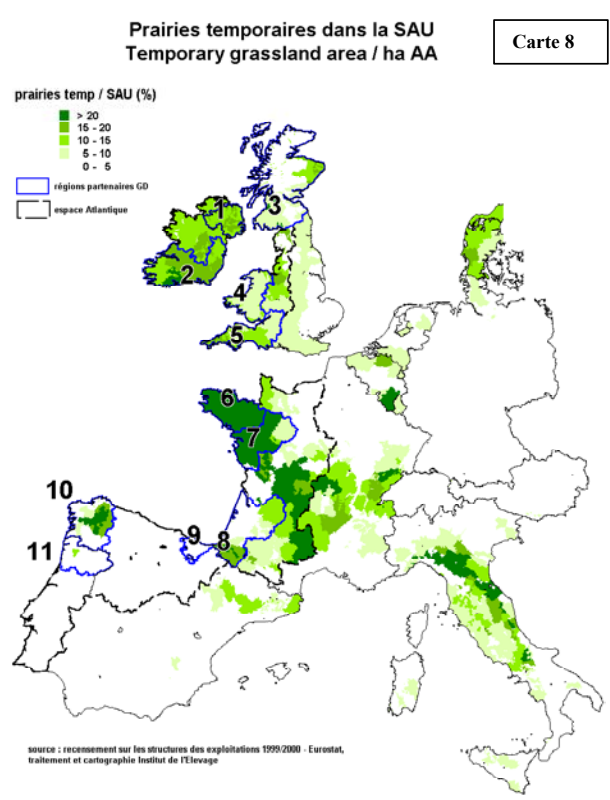
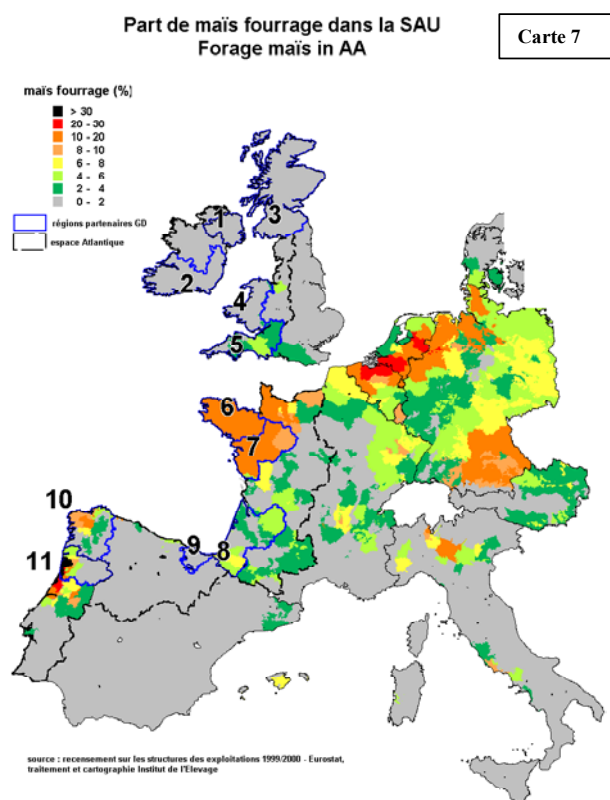
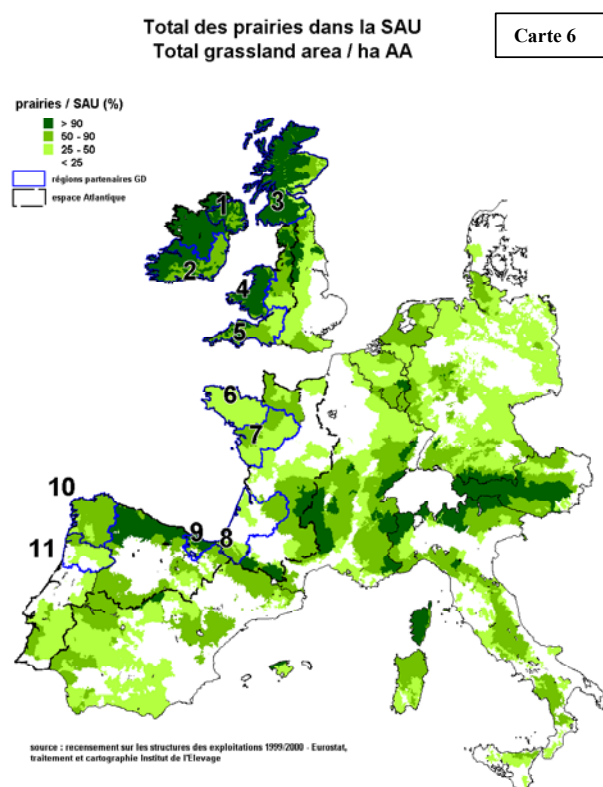
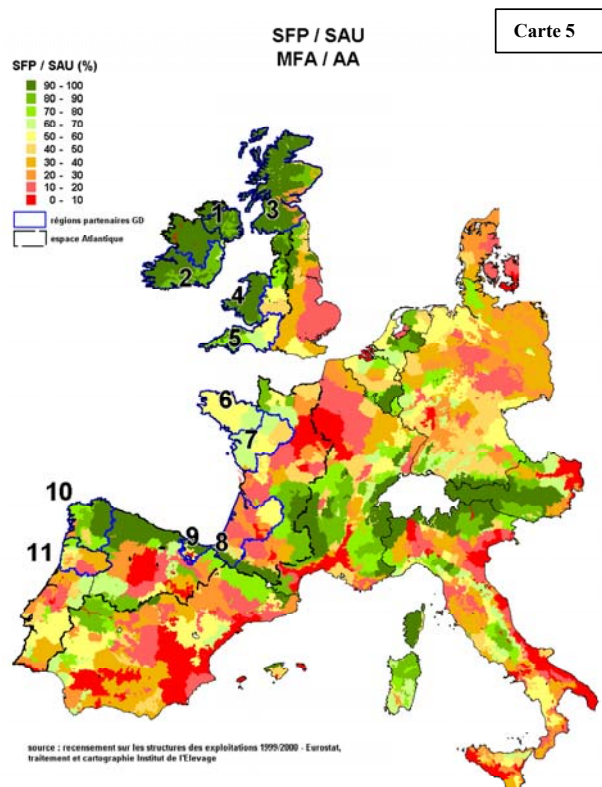


Map 3: A moderate potential evapotranspiration (*MARS 50km meteo database for 25 years*)



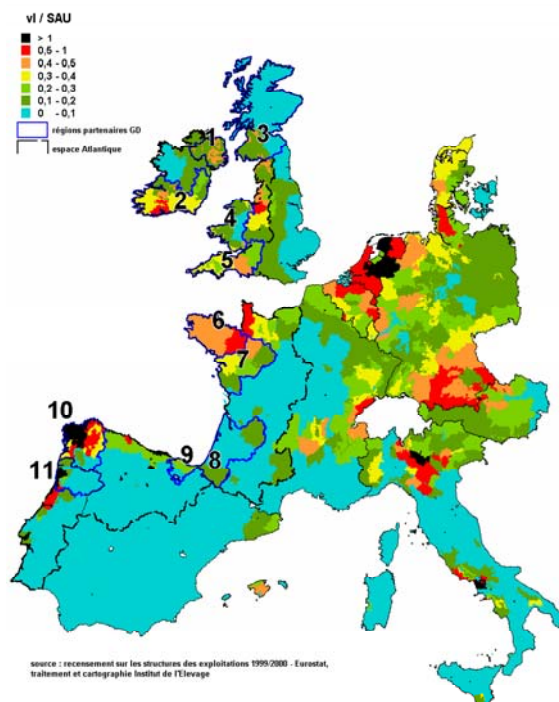
Map 4: High annual rainfalls (*MARS 50 km database for 25 year*)





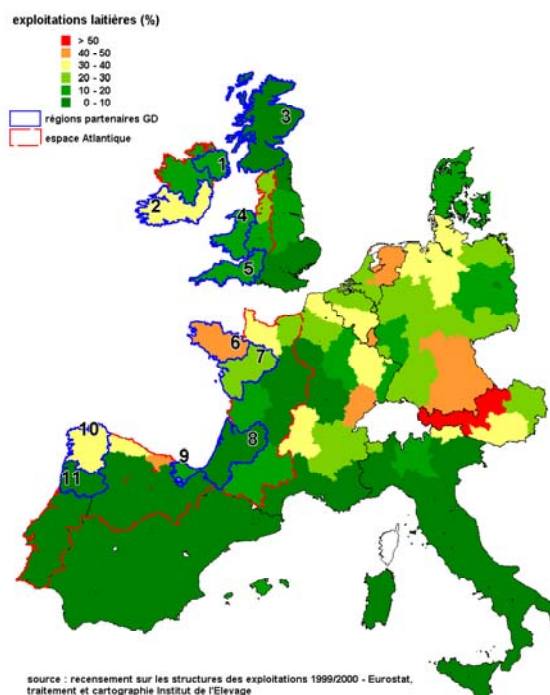
Vaches laitières par hectares de SAU
Dairy cows per ha AA

Carte 9



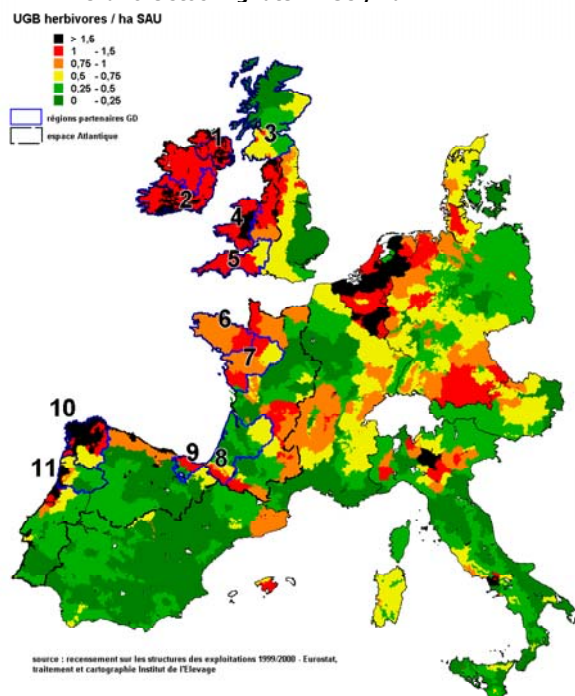
Part des exploitations laitières dans les exploitations totales
Dairy farms farms % in total farms

Carte 10



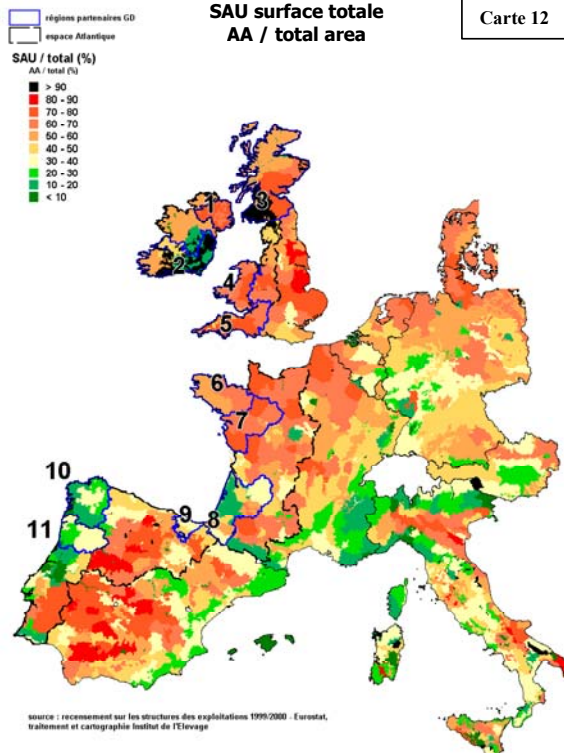
Chargement en UGB herbivores par ha SAU
Herbivore stocking rate in LSU / ha AA

Carte 11



SAU surface totale AA / total area

Carte 12



Charge en azote animal par ha de SAU en 2000 Animal Manure Nitrogen per ha AA in 2000

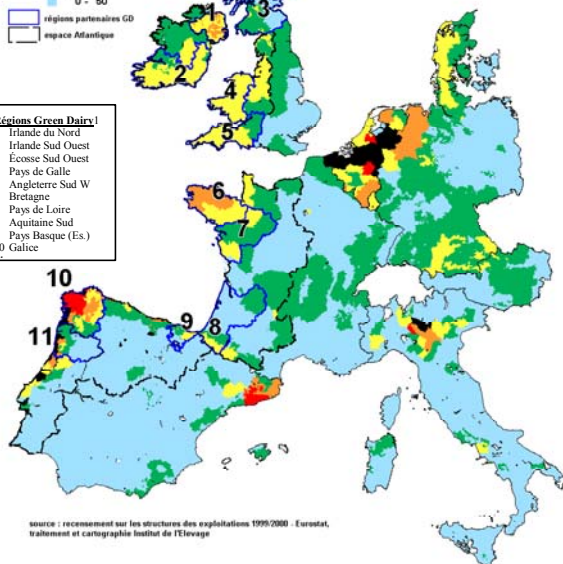
(valeurs standards françaises)
(french animal references)

azote d'origine animale
(kg / ha de SAU)



Carte 13

- Régions Green Dairy!**
- 1 Irlande du Nord
 - 2 Irlande Sud Ouest
 - 3 Ecosse Sud Ouest
 - 4 Pays de Galle
 - 5 Angleterre Sud W
 - 6 Bretagne
 - 7 Pays de Loire
 - 8 Aquitaine Sud
 - 9 Pays Basque (Es.)
 - 10 Galice
 - 11



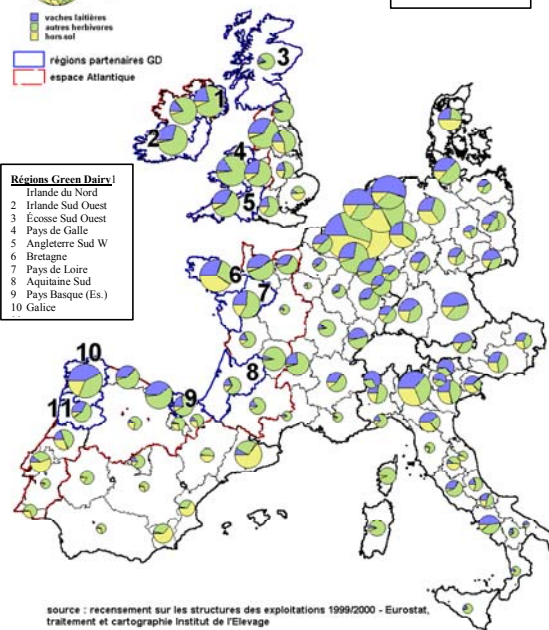
Charge et répartition de l'azote animal / ha SAU Pressure and distribution of animal manure / ha AA

UGB-N / ha SAU



Carte 14

- Régions Green Dairy!**
- 1 Irlande du Nord
 - 2 Irlande Sud Ouest
 - 3 Ecosse Sud Ouest
 - 4 Pays de Galle
 - 5 Angleterre Sud W
 - 6 Bretagne
 - 7 Pays de Loire
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