High output farming systems in Europe: the French case

Brocard V.[1], Belot P.-E.[2], Foray S.[1], Perrot C.[3] and Rouillé B.[1]
[1]Institut de l'Elevage, BP 85225, 35652 Le Rheu Cdx France, [2]Institut de l'Elevage, CRA de Franche-Comté, Valparc, Espace Valentin Est, 25048 Besançon Cedex, France, [3]Institut de l'Elevage, 149 rue de Bercy, 75595 Paris Cedex 12, France; valerie.brocard@idele.fr

Abstract

This paper focusses on dairy production systems in France. First, the huge diversity in production backgrounds and systems will be presented to put its main variation factors to the fore: the differences between plains and mountains, the low level of specialization of the dairy farms and the differences in terms of density of farms on the territory. The relatively high availability of land as well as the moderate price of agricultural land in France compared to the other European and world dairy farming areas are put to the fore. The feeding systems for each class of production system are described to underline the strong link between land, forage production and performances of dairy herds. The search for high levels of self-sufficiency in dry matter, energy and proteins in French dairy farms also accounts for the relatively low levels of stocking rates and milk production per hectare reached in many areas. Finally, the relations between the high production output strategies and some environmental issues such as nitrate leaching and biodiversity are discussed. The issue of the definition of 'high output farming systems' in such contrasting situations is addressed.

Keywords: dairy farming, France, high output, self-sufficiency, eutrophication

Introduction

The qualification of dairy farming systems as 'high output' systems may have different meanings in different countries. In France, dairy farms are generally not qualified in terms of productivity and it is not common to distinguish 'high output farms'. Productivity can vary widely due to the strong diversity of the territory, in terms of climate, soil quality, altitude, and types of productions. Consequently, productivity in France (national average) is far below most of our neighbouring dairy farming areas. Moreover, the strong environmental regulations restrict the stocking rates and thus 'the milk produced per ha'. But one of the main factors is that land is available at low cost. Therefore, the target of dairy production systems in France is not to maximize the amount of milk per ha, but to meet the feed requirements of the animals as much as possible with home grown fodder and crops. Efficient use of resources is an important aspect in these systems. Inputs of nutrients are tuned to the requirements of the production system. This strategy is important to reduce losses to the environment, e.g. through nitrate leaching and greenhouse gas emissions. Finally, the notion of 'high output per hectare' may, besides production per hectare, refer to a variety of outputs, such as added value (e.g. the mountain regions with PDO cheeses), or ecological services provided, like water quality, biodiversity, landscapes, rural activity. These are the issues addressed in this paper.

Classification of the production systems and areas

In 2013/2014, France produced 23.29 million l of milk from 68,224 farms delivering an average of 341,000 l per farm per year (FranceAgriMer, 2014). Some 70% of this production is from farms on plains, while 30% is from farms located in mountains/unfavourable areas. The average quota per farm reached 366,888 l with mountain regions (221,000 l), far below lowland areas (355,000 l) (Table 1).

The bovine dairy chain is a major actor in France's territory use and occupation, in its agricultural job sector and in the economic activity of many French regions. The French production systems vary a lot

Table 1. Productivity of dairy farms per area, France (source: RGA 2010 analysed by Institut de l'Elevage).

Zone[1]	# farms	Agr. area (AA, ha)	Forage area (FA, %)	Maize silage % FA	Stocking rate (LU ha^{-1})	# cows	Quota per farm (×1000 l)	Quota cow^{-1} (l)	Quota per ha AA (l)	Quota per ha FA (l)
LDA	34,369	89	74	30	1.6	54	351	6,500	3,900	6,600
West	24,482	82	71	35	1.6	52	352	6,800	4,300	7,000
CLA	22,044	119	51	28	1.6	51	361	7,100	3,000	7,400
intensive	10,132	104	48	36	1.9	50	357	7,100	3,400	8,600
MPA	17,444	75	91	5	1	38	221	5,800	2,900	3,700
Jura	2,892	95	92	1	0.9	44	257	5,800	2,700	3,000
Other areas	2,791	101	76	13	1.1	45	303	6,800	3,000	5,300
France	76,648	95	69	23	1.4	49	323	6,600	3,400	5,800

[1] LDA = lowland dairy areas; CLA = dairy crops and livestock areas; MPA = dairy mountains and piedmont areas.

between regions for obvious geographical reasons, as well as historic and sociologic reasons. For dairy production, production models can be very different and be as economically efficient as long as they are well mastered by the farmers. This is an undeniable asset to adapt to the background evolutions in terms of production conditions, rules and markets.

In relation to the agricultural potentials, to the production systems developed, and the density of the farms on the territories, three main dairy production areas can be described (Figure 1, from Agreste, 2013, and Dossier Economie de l'Elevage, 2013):

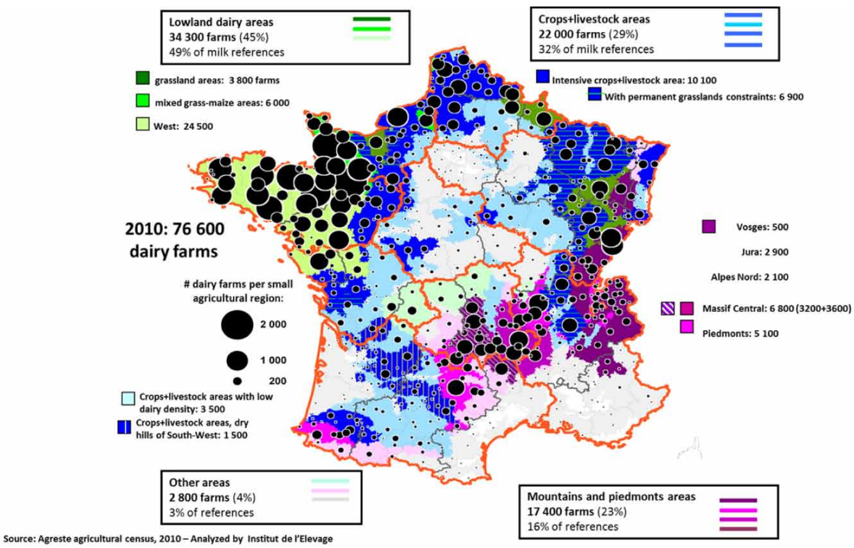

Figure 1. Classification of French dairy systems (source: Agreste, RGA 2010, analysed by Institut de l'Elevage).

- The lowland dairy areas (LDA) cover western France (including Brittany). This area included 45.6% of the dairy producers in 2012/2013 (Table 2) and represents 51.6% of the milk deliveries.
- The dairy crops and livestock areas (CLA) include intensive high-potential areas like Nord-Picardie. Some 28% of the farms are located in this area, producing 31% of the French milk in 2012/2013.
- The dairy mountains and piedmont areas (MPA) include eastern mountains like the Jura and piedmonts regions. Some 22% of the farms are located in this area, producing around 15% of the French milk in 2012/2013. The average delivery per farm is much lower than the French average.

Over the last five years, the amount of milk produced increased by 3.5% in the LDA, by 2.3 % in the MPA but decreased by 2.4% in the CLA (Perrot *et al.*, 2014). The number of farmers decreased by 15% in the LDA and MPA, and by 20% in the CLA (FranceAgriMer, 2014).

The lowland dairy areas (LDA)

These areas the main dairy farming areas, except in mountains, are characterized by a high density of dairy farms (43 per 100 km^2, Table 2). The West lowland area includes Brittany and Pays de la Loire regions with intensive dairy farms and a large resort to maize silage. The soil and climatic conditions are favourable for forage production and account for the large development of dairy production over the last 50 years. Because of the high density of farms, their size remained moderate for a long time (currently 52 cows, 82 ha), leading to a high level of specialisation (42%) compared to other regions, and the frequent association with pigs or poultry production after the implementation of the quota system. The dairy systems are relatively intensive for France, with a stocking rate around 1.6 livestock units (LU) per ha of forage area (FA). The production per cow reaches 7,000 l per ha FA (4,300 l per ha agricultural areas, AA). The high forage and animal intensification levels in these areas, as well as the presence of pig and poultry units, have created high nitrogen surpluses with frequent high nitrate levels in rivers. The strong environmental regulations applied to these areas after 1991 led to a decrease in these levels but also contributes to the reduction of the animal pressure per hectare.

The dairy crops and livestock areas (CLA)

Because of the high quality of soils on sedimentary materials, most of the farms in this class have developed commercial crops and only 22% of the dairy farms are considered as specialized (Table 2). The farm density is lower than in the previous area (10 for 100 km^2). The intensive CLA cover the western and northern borders of the Parisian basin together with Alsace and part of the South West. Again, dairy production is relatively intensive with a large resort to maize silage (1.9 LU per ha, 36% of maize silage on FA). In many areas, cows can be fed partially with by-products of the crops' industrial chain (sugar

Table 2. Contribution of farm categories to French dairy production, 2012 (Source: FranceAgriMer, 2014; SAFER, 2014).[1]

Zone[2]	% farms	% deliveries	% specialized	% dairy PDOs	#dairy farms per 100 km^2	Average land € ha^{-1} (min-max)
LDAs	46.5	51.6	37	3	43	Brittany
West	33.2	37.3	42	1	44	5,240 (2,120-7,540)
CLA areas	28	31	23	4	10	Nord Pas-de-Calais
Intensive	13.4	14.7	22	2	17	12,340 (1,160-30,450)
MPAs	22	15	67	38	25	Franche-Comté
Jura	4	3.2	84	87	30	4,640 (2,510-8,690)
Other areas	3.5	2.4	41	6	2	
France	100	100	40	12	14	5,750

[1] The colour of lines refers to Figure 1.

[2] LDA = lowland dairy areas; CLA = dairy crops and livestock areas; MPA = dairy mountains and piedmont areas.

beet pulp, brewery and distillers' grain). The dairy production per cow reaches an average of 8,000 l per year and 8,600 l per ha FA (3,400 l per ha AA). Because the forage area represents only 48% of the agricultural area, the notion of 'milk produced per ha agricultural area' has little significance, particularly when compared to farms of the other areas (plains and mountains).

The mountains and piedmont areas (MPA)

These areas are characterized according to their dairy processing chain, strongly linked to local production schemes. The farm density is quite high (25 dairy farms per 100 km^2) but the average quota is far below the level reached in the two previous zones: 221,000 l versus 351-361,000l (Table 1). The climatic conditions with cold winters and wet summers account for grassland-based production systems. The average stocking rate reaches only 1 LU per ha. The Eastern mountains including Jura and Northern Alps include specialized dairy farms (84% of the dairy farms in Jura, Table 2) producing for PDO cheese chains (87% of the farms) with a high milk price. The average farm has 44 cows on 95 ha and is highly specialized in forage production (92% of the AA). For each PDO, a contract defines the breed and types of feed allowed with generally no silage permitted and a limited level of concentrates. The cow breed is usually not Holstein, with an average production level between 5 and 6,000 l per year. The milk production reaches only 3,000 l per hectare FA (2,700 l per ha AA).

In conclusion, French dairy farming is characterized by substantial differences between its three main production areas. The average stocking rate is 1.4 LU per ha, milk produced amounts to 5,800 l per ha of forage area (ranging from 3,000 in the Jura mountains up to 8,600 in intensive crops and livestock areas). The level of milk produced reaches an average of only 3,400 l (2,700-4,300) per ha of agricultural area but has little significance in low specialized areas.

Milk production per hectare and stocking rates

This productivity per hectare appears to be relatively low compared to the European neighbouring countries studied during the European Dairyman project (De Vries *et al.*, 2013; www.interregdairyman.eu). The productivity of the 128 pilot farms that participated in the European DAIRYMAN project, ranged from 6,519 in Luxemburg up to 19,735 l per ha of forage area in the Netherlands (Table 3; Bechu, 2013). In 6 of the areas studied, the milk per hectare of FA is close to or above 10,000 l. The level

Table 3. Intensification level per hectare of specialized dairy farms in some European dairy farming areas, data for the 128 pilot farms of Dairyman project (sources: Bechu, 2013 and De Vries *et al.*, 2013). For Dairyman data: years 2009-2010-2011.

Region Dairyman[1]	**Belgium, Flanders**	**Belgium, Wallonia**	**France, Brittany**	**France, Nord Pas de Calais**	**Germany, Baden-Würtemberg**	**UK, Northern Ireland**	**Republic of Ireland**	**Luxemburg**	**the Netherlands**
No. of farms	11	10	8	7	7	10	21	4	16
Stocking rate LU ha^{-1}	2.6	1.9	1.4	2.0	1.7	2.1	2.3	1.3	3.0
Milk per cow (kg)	8,425	7,438	7,119	8,220	8,734	7,413	5,088	7,413	8,670
Milk ha^{-1} FA (kg)	15,803	9,948	7,224	10,736	10,061	11,958	8,480	6,519	19,735
Milk ha^{-1} AA (kg)	13,979	5,870	5,884	5,291	7,078	10,743	7,501	3,821	19,733
g concentrate kg^{-1} milk	170	247	121	216	245	302	155	216	232
N min ha^{-1} AA (kg)	120	95	41	121	79	145	183	86	105
N balance ha^{-1} (kg)	186	141	98	145	140	243	179	112	194

[1] AA = agricultural areas; FA = forage area; LU = livestock unit.

of milk per hectare of total AA also exceeds 10,000 l ha^{-1} in Flanders (Belgium), Northern Ireland and the Netherlands. These data are consistent with the calculations of the stocking rates in these farms. In western France it is rather low, considering that the forage production potential is high in this region. This is caused by the severe environmental regulations and the strong incentives to limit impacts of agriculture on water and air quality. This is illustrated by mineral N inputs per hectare that amount to only 41 kg per hectare AA, which is much lower than in Ireland for instance

Finally, compared to the rest of the world's dairy farming areas, using data of the IFCN typical farms (IFCN, 2014), the different French areas and examples chosen belong to the bottom list in terms of milk per hectare, with figures almost always below 5,000 l. This is far below the Netherlands or Lombardy (Italy) in Europe, Australia or New Zealand (between 10 and 20,000) or indoor feeding systems with no land, as in Japan or Israel. The French Franche-Comté mountains are particularly low in terms of milk per hectare and stocking rate because of the limited production potential, and the mixed crops and dairy systems combine a high production per hectare of forage area with a stocking rate but a high share of non-forage area, leading to this low figure of milk produced per hectare of total agricultural area.

Effects of land price

The relatively low production intensity can partly be explained by the relatively low land prices. The average cost for one hectare of agricultural land free of tenancy in 2013 reached 5,750 € with variations between regions, with only 2,530 € per ha in Franche Comté mountains but 12,340 € in Nord Picardie with high quality soils and then pressure for crop production. Compared to all other dairy regions from the FNSAFER database and the costs reported by the IFCN experts for typical farms, French regions are far below Denmark, Italy, Western Germany, Ireland and New Zealand around 20,000 € per ha, or China, India, Switzerland or the Netherlands over 45,000 € per ha. Thus, France appears to be the only area in the world to produce large amounts of milk with a land cost below 10-15,000 € in almost all its producing regions.

Another explanation is the strong link between land and quota in France: it has been kept during the whole quota period with no possibility for farmers to increase their milk deliveries without buying or renting the land 'bearing' the milk quota. No leasing or quota market system without land was ever implemented. The target was to maintain a more even distribution of dairy farms over the country, even in unfavourable areas. This forced farmers to increase land size in order to produce more milk, which slowed down their development. It explains the implementation of other production on dairy farms and the low level of specialization still observed, except in mountain areas.

Thus, the main target of the production systems in France is rather oriented towards an increased self-sufficiency in animal feed to limit the production cost and keep the link between territory and milk products, rather than to maximise the production per hectare.

French dairy systems aim for self-sufficiency, not productivity per hectare

French dairy production systems are strongly linked to the ground

First of all, the French dairy production is linked to the ground and is mostly based on forage self-sufficiency of the farms, to be able to face the requirements of the herd; maximizing the quality of the home grown forages will enable a good transformation of their energy value into milk by the cows. The French bovine dairy production sector shows its strong link with land and forage production through its resort to maize silage (46% of the diet in DM), and to grass: grazed, zero-grazed, silage, haylage or hay (29% of the diet in DM of dairy cows, Figure 2). The total DM intake is estimated at 6.9 Mg DM per cow per year (Brunschwig *et al.*, 2014). Altogether, forages represent 78% of the diet of French dairy cows.

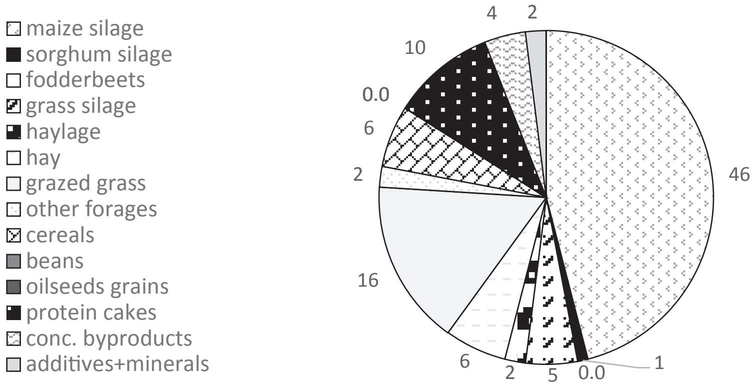

Figure 2. Diet composition of the French dairy cows (source: Brunschwig *et al.*, 2014).

Almost all French farms practise grazing during one period of the year (92%; Autograssmilk, 2012) in variable proportions; thus, this practice is decreasing with the ongoing enlargement of farms and the development of robotic milking. According to the area and the grass growth duration, the farm structure and the aims of the farmer, dairy cows go out of the sheds between 2 and 10 months per year. For the largest farms, grazing is often restricted to heifers and dry cows. Only 9% of the cows are considered 'not grazing' and 22% 'little grazing' (below 0.15 ha per cow). The contribution of grazed grass to the cows' diet ranges thus from 500 kg up to 3.0 Mg DM per year but it remains the main nitrogen source for the animals.

Farmers regularly adapt the ration of the cows with concentrate feeds. They represent on average 22% of the diet, but only 3 of these 22% are home grown. The specificity of French use of rapeseed cake can be underlined: though generally not grown on farms, this is produced in France and contributes to the national self-sufficiency in animal feed and proteins. It is the main nitrogen source for industrial animal compounds, although France still imports soybean for its dairy cows, while exporting rapeseed.

Regions and rations

The characteristics of the different production systems account for the forage systems implemented by the farmers and thus the cows' diets during the year. It also explains differences in terms of self-sufficiency in total dry matter, energy and proteins.

In the LDA, such as the West lowland (e.g. Brittany), the forage system is based on maize silage for winter (38% of the forage area, see Table 4) and grass. Temporary grasslands are in rotations with maize silage and crops. These grasslands usually stay in place for 5-8 years and mainly comprise grasses or mixtures of grasses and white clover (50% of the sowings). Farms grow an average of 22 hectares of crops, mostly cereals: part of them are kept for the dairy animals after flattening or mashing on farm or by a contractor. Thanks to the high-energy value of forage, over 0.90 UFL per kg DM[1] all year long, the resort to concentrates is limited to an average of 187 g per kg milk produced, and even less in Brittany (121 g per kg milk in the pilot farms of Dairyman project, see Table 3). This is the lowest regional level in France and can be considered as very efficient compared to other situations of over 200 g, except Ireland (152) and Flanders (170).

[1] UFL = Unité Fourragère Lait; Net energy for lactation in MJ = UFL × 6.7 for grass (all types) and UFL × 6.8 for maize silage.

Table 4. Farm characteristics for French typical farms in the dairy farm networks (source: Réseaux d'Elevage, 2012).[1,2]

	LDA	West, maize	CLA	Maize <80 VL	MPA	PDO Franche Comté
No. of farms in France	17,580	7,550	16,720	4,680	1,2430	2,150
No. of farms in networks	138	36	90	18	96	12
Total AA (ha)	96	96	197	150	80	129
Incl. commercial crops (ha)	23	22	117	95	8	8
Milk delivered (×1000 l)	511.7	553.1	598.2	567.3	326.7	355.6
No. of cows	68	71	72	67	49	57
Milk prod cow^{-1} yr^{-1} (kg)	7,650	7,957	8,380	8,604	6,742	6,582
Concentrates kg milk^{-1} (g)	207	187	237	224	249	213
Forage area (% AA)	76	76	41	37	90	94
Maize/forage area (%)	31	38	33	44	10	0
Stocking rate (LU per ha)	1.5	1.7	1.7	1.8	1.00	0.8
Milk per ha FA (kg)	7,742	7,916	8,671	11,096	5,297	3,247
Milk per ha AA (kg)	5,330	5,761	3,037	3,782	4,084	2,757
Input N min fertiliser (kg per ha AA)	81	78	121	133	44	40
N balance per ha AA (kg)	95	88	81	92	60	44
Valor. grass yield Mg DM ha^{-1}		6.01		6.15		4.25

[1] AA = agricultural areas; FA = forage area; LU = livestock unit; DM = dry matter.

[2] The colour of lines refers to Figure 1.

In the dairy CLA, the production systems like in Nord Picardie are often based on temporary grasslands, together with a high share of maize silage (44% of the FA; Table 6). The farms also produce 95 ha of crops on average, accounting for a high mechanization level and the management of large areas of maize in the rotation system. The home-grown cereals contribute to the dairy cows' diets. Thus the productivity is higher than in the other regions (11,000 l per ha FA) but with a greater resort to concentrates and by-products, as many are widely available (224 g per l milk).

Because of the large resort to maize silage, the weak point of these two first systems is the lack of protein concentrates that cannot be produced locally for climatic reasons; they are the highest cost component of the feeding cost, and therefore of the milk production cost.

In the MPA, the forage systems of these areas are based mainly on permanent grasslands with a multi-species botanical composition. These fields are grazed from April till October and most of them are cut for hay making to build stocks of hay for winter feeding, in particular in the cheese PDOs where silage is forbidden. The resort to concentrate is higher than in other dairy areas (213 g per l milk, Table 4), but limited by PDOs restrictions (1,800 kg DM). These systems based on hay and with little solutions to grow crops (8 ha out of 129 for Franche Comté systems) may lack both energy and proteins to properly balance the dairy cows' diets, but mainly lack total dry matter self-sufficiency during the bad' forage years.

Animal feeding and feeding self-sufficiency

Feeding efficiency is defined as the balance between the herd requirements and all the resources than can be harvested or grown on farm (Elluin *et al.*, 2014; Rouillé *et al.*, 2014). This factor can be analysed through three indicators: the mass self-sufficiency (in kg DM), the energy self-sufficiency in UFL (energy unit of the French INRA feeding system) and the protein self-sufficiency in kg of crude proteins.

For the total diet (Table 5), the mass self-sufficiency is globally high and varies between 79 and 81.6% according the production system/area. The forage self-sufficiency is very high and is around 97% in all systems. The concentrates mass self-sufficiency remains weak to moderate, between 12% in plains and 26% in mountains. Because of the large share of forages in the diets (concentrates limited to 18.1 to 21.0% of the mass DM), and of the high-energy value of the forages, the energy self-sufficiency values are close to the mass self-sufficiency values. Finally, the different production systems are mainly discriminated by their self-sufficiency in proteins and protein concentrates. The protein global self-sufficiency is much lower than the mass or energy self-sufficiency (between 53 and 74% of the diet). The forage protein self-sufficiency is high and close for all systems (97%). But the concentrate protein self-sufficiency remains low and much lower with lowland maize-based systems (around 5%) compared to mountain grass-based systems (15.9%). The higher productivity and nitrogen requirements of the animals reared in plains also accounts for the lack of self-sufficiency in these systems.

Self-sufficiency is a competitiveness asset for the French dairy chain

On average, French dairy farms produce 83% of the feed used by their herds (Rouillé, 2014). This high level, together with the diversity of production systems, is considered by the whole dairy chain as an important asset in terms of competitiveness, although it might be threatened after the end of the quota system. Actually, the volatility and relatively high prices of purchased feeds on the markets have a lower impact on French dairy farms than in other countries. The recent study made by IFCN and the IDF federation for FAO (FAO, IDF and IFCN, 2014) show that many large dairy sarming areas suffer from a lack of self-sufficiency with high feed prices. Many countries are below 80% of global self-sufficiency with some American or Spanish typical farms around 20% for the total diet and only 40% for the forages. The Danish or Dutch systems reach around only 70% of total self-sufficiency with no home-grown concentrates at all. The other group of countries or regions shown are above 80% of global self-sufficiency. The three French areas chosen to illustrate this paper belong to this group, as well as some German and Italian typical farms. The Irish grass-based systems reach almost 100% of forage self-sufficiency, but lack 20% of their dry matter because they must buy their concentrates. The New Zealand systems are more sensitive to drought than the Irish ones and this has an impact on their purchases of feed.

As a conclusion, the high level of self-sufficiency in good quality forages (grass and maize silage), the possibility in plains to also grow the energy concentrate (cereals) and the relatively high availability of land gives a competitiveness asset for French dairy farms as long as they keep a production system based on forages. Together with the low land price compared to that of other producing countries, it underlines the importance of criteria such as 'milk produced from forages per hectare' or 'autonomous milk production'

Table 5. Self-sufficiency levels for dairy herd, per class of French dairy system, based on data of pilot farm networks (Source: Réseaux d'Elevage, year 2008; Cniel-Idele, 2012).

System[1,2]	Dry matter self-sufficiency (%)				Energy self-sufficiency (%)			Protein self-sufficiency (%)		
	total diet	forage	concentrates	concentrates in diet	total diet	forage	concentrates	total diet	forage	concentrates
LDA, maize	81.6	97.2	12.0	18.3	79.8	97.1	13.8	57.7	97.9	4.8
CLA, maize	79.0	96.8	11.9	21.0	77.4	97.6	13.6	53.2	96.7	5.1
MPA, grasslands	84.4	97.3	26.3	18.1	82.0	97.7	29.3	74.1	97.8	15.9

[1] The colour of lines refers to Figure 1.

[2] LDA = lowland dairy areas; CLA = dairy crops and livestock areas; MPA = dairy mountains and piedmont areas.

rather than milk produced per hectare. To keep this asset, and maintain a relatively low feeding cost, French systems must find the best balance possible between grass and maize silage in areas where both crops can be grown. The differences between systems in terms of protein concentrates (the highest cost of the diet for a lactating cow) come from the share of maize silage in the system (Paccard, 2003; Rouillé, 2014). The differences between systems come mainly from criteria describing the farm structure such as: the stocking rate, the production per cow and the concentrate per cow. In Paccard's study, based on 383 farms of the Réseaux d'Elevage[2]/dairy farm networks, a statistically significant negative relation was found between mass self-sufficiency and the global intensification level. Self-sufficiency in proteins was also statistically reduced by the same three variables and the part of maize silage in the system. The autonomy in concentrates only discriminated organic production systems from the others.

In the same study, Paccard also found statistical relations between mineral balances of the farms (inputs-outputs for N, P and K) and self-sufficiency in feeds. The self-sufficiencies for total diet and concentrates in crude protein, energy and dry matter appeared to be negatively correlated to the nitrogen mineral balance. This is consistent with a lower nitrogen concentrate purchase leading to a lower N-input level. But this study also confirmed the high relation between the mineral balance, the mineral nitrogen inputs per hectare and the nitrogen concentrate purchases. Criteria such as stocking rate and milk per hectare of FA appear to have a negative impact on mineral balance and self-sufficiency in protein concentrates. Under French conditions, intensification of animal production through nitrogen concentrates, and intensification of crops through mineral fertilizer are strongly related. It is not the case in New Zealand for instance, with intensification per hectare but low animal productivity, or in countries with feed purchases. Moreover, mountain situations such as Franche Comté, with a low intensification per hectare but a relatively high resort to concentrates, must be studied separately.

Therefore, the milk produced from home-grown forages appears to be correlated to 'other outputs' of the system such as mineral balance and its possible negative impacts on the environment. The intensification level of the production systems must thus be chosen taking these aspects into account in order to limit the risks of possible negative impacts on water or air quality. They will also be driven by the environmental regulations implemented.

Avoiding negative outputs (environmental effects) by limiting inputs

Environmental impact

The 76,000 French dairy farms are using some 20% of the territory and thus have a major role to play towards the environment (Dollé, 2013). In the coming years they will have to face challenges such as producing good quality dairy products in larger quantities but also keeping high levels of environmental, social and economic performances. In terms of environment, the challenges are particularly related to the limitation of risks of pollution of air and water, and to the preservation of biodiversity.

For agricultural activities, the eutrophication potential is mostly due to nitrate leaching and phosphorus run off, which are related to the inputs in organic manure/slurry and mineral fertilizers. To limit these risks, the French state assigned targets to the agricultural sector by designing areas at risk of eutrophication; they are almost all classified as 'vulnerable zones' (44% of the French territory) in the European Nitrates Directive (1991). Most of the intensive lowland production areas are limited to 170 kg organic N per ha, and 210 kg total N per ha since 2010 (Grenelle de l'Environnement laws). Many dairy production areas like Brittany face an even more restricted resort to N fertilization in 'green algae catchment basins' with a total amount of N allowed between 140 and 160 kg total N per ha. France unlike other European dairy

[2] French bovine dairy farms reference network made of 630 farms followed on a regular yearly basis

countries (Ireland, the Netherlands) has no derogation to apply a higher fertilizer level on grasslands, as the water quality in many areas remains considered as too poor by the European Commission; this statement leads to regular convictions of the French state by European courts, and makes it impossible to apply for a 'nitrogen' derogation. With the French average cow producing 'officially' 85 kg of N per year before 2013, and being followed by 0.3 LU (calves and heifers) for its replacement, the nitrates regulation automatically limited the stocking rates below 170/(85×1.3)= 1.54 LU per ha of total area. The new regulation with an excretion around 100 kg N according to the share of grass in the diets will lead to even lower levels of possible stocking rates.

Agricultural practices have an impact on biodiversity (Clergue *et al.*, 2005). The agricultural specialization of some regions has a negative impact, while the diversity of productions, the presence of mixed and imbricated vegetal covers, the existence of agro-ecological structures such as hedges and grasslands can have a positive impact. The permanent grasslands present a high potential of biodiversity influenced by practices: a good management of grazing and/or mowing, a stocking rate adapted or a good level of fertilization, contribute to preserve the wildlife and the flora (Amiaud *et al.*, 2014). Dairy farming, as a user of grasslands and crops, has lots of assets because it directly monitors areas with agro-ecological services (Ryschawy, 2013). This target is translated into European regulations and French frame laws to support sustainable farming systems defined by extensive practices (low stocking rates for instance). Again this will limit the possibility of intensification in MPA to keep the subsidies related to environmental rules and therefore the level of milk production per hectare. But at the same time, other productions or services will be provided through good grassland management: landscapes, high quality water and air, biodiversity, limitation of snow avalanche risks, maintenance of footpaths and ski slopes and tracks (Huygues, 2014). Moreover, the production services may appear limited in amount per hectare but this relative extensive production per hectare is creating more jobs on the territory than in more intensive areas (Perrot, 2008 and 2010). In Franche-Comté for instance, thanks to the high added value of the PDO cheese, it is considered that one farm job creates 7 other jobs in the dairy chain (Rieutort, 2014). The production per hectare should then include the total added value created and not only the milk per hectare produced to better estimate the total production and services offered by dairy farms in such situations.

A strong link between practices and environmental performances

The analysis of environmental impacts shows differences between production systems related to the part of grass in the system, the stocking rate and the breeding practices (Dollé, 2013):

- The share of grazed grass in the diets: it limits the inputs of protein concentrates and reduces the GHG emissions thanks to the longer time spent by animal outside.
- The management of the herd: the replacement rate, the sick cows, the age at first calving influence the number of 'unproductive' livestock units and thus the stocking rates.
- The level of inputs (concentrates, mineral fertilizers, fuel). The lack of self-sufficiency creates a strong dependency for energy resources and a high and risky N balance.

The search for improved environmental practices to limit risks on water quality (first mitigation targeted in the 1990s) together with the regulation frame account for the relatively low level of mineral input per hectare on French typical farms (Table 4) and pilot farms of the Dairyman project (Table 3). The mountain systems with their limited potential of permanent grasslands and relatively low level of quota per hectare only use around 40 kg of mineral N per hectare. In relation, they show a limited N balance (44 kg per ha for Franche Comté systems) but also a low stocking rate of 0.8 LU per ha and a yield of 4.25 Mg DM of grass per ha. The CLA systems (maize <80 cows) use an average of 133 kg of mineral N per ha with a limited balance (92 kg) and limited risks of leaching, but also reach only a relatively low level of grass use (6.15 Mg DM per ha). Finally, the systems of the West lowlands use, on average, only 78 kg of mineral fertilizer; the balance is also limited but again grass yield (6 Mg DM per ha) is low compared to the potential that could be reached with higher levels of fertilization, but also with higher risks for the environment. Compared to the other dairy basins studied in the Dairyman project, the Breton pilot farms show the lowest mineral N inputs and N balance per hectare (Foray, 2013). These practices account for the relatively low level of stocking rate and milk per hectare (figures already discussed). They are related to the strong regulations implemented.

The aim to reach a low N balance to limit the risks to the environment leads to a moderate level of milk produced, by hectare and stocking rate. The environmental study led within the Dairyman project puts two contrasted situations to the fore (Table 3; Béchu, 2013). The 'intensive' production systems (Flanders, the Netherlands, Northern Ireland, Ireland) show a high N balance per ha; except in Ireland, these regions are characterized by a high level of milk production per hectare. In contrast, the less-intensive systems, including the French regions, show a lower level of N balance with a lower milk production per hectare. The French mountain regions added to this sample (Figure 3) combine a much lower level of balance (40 kg per ha) and of milk per hectare (3,200 kg). The link between the two criteria appears on that Figure as well, as the link between mineral fertilizer inputs and N balance for Dairyman pilot farms. This is why French authorities try to reduce the impacts linked to N management by limiting the inputs or the stocking rates: these indicators are considered as relevant tools to improve water quality at the end of the chain, and as a consequence it also limits the possible development of 'high milk output systems'.

Conclusion: future challenges and perspectives

French production systems keep a strong link between land and dairy production with a relatively low level of inputs and outputs per hectare, because land is widely available, the quota system has kept a strong link between quota and land, and because of the environmental regulations in the most intensive regions to limit negative 'outputs' of dairy production. This also explains the moderate level of valorisation of forages per hectare in many areas, which could be improved and lead to higher milk deliveries in the northern half of the country, if dairy processors asked for this. Several negative aspects should be underlined:

- Despite or because of a relatively low population density and in particular in some rural areas of the territory, the land is not properly monitored with the equivalent of one county disappearing every ten years (890,000 ha AA) for human activities (roads, houses, commercial areas); though the agricultural chain has expressed many warnings about the decreasing area available to produce human feed in the country, this trend has not been slowed down in the last period of time (Perrot, 2013). Moreover, the quota system with a strong link between quota and land has reached its target to keep milk production all over the country: 92% of the local communities have at least a dairy farm in the 2010 census. But it also pushed farmers to take land far from their cowshed to have access to

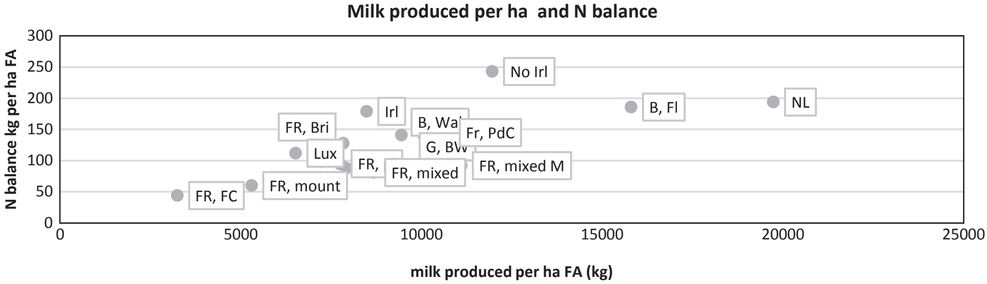

Figure 3. Milk per hectare forage area (FA) in relation to N balance for specialized dairy farms in some European dairy basins (Bechu., 2013, for Dairyman project; Réseaux d'Elevage, 2011/2012).

the quota linked to this land. This has created larger farms but with lots of fields far from sheds and not grazeable by the cows, leading to production systems with higher production costs. No real local of national policy to better monitor land through exchanges for instance has been developed until now and this fragmented land threatens the current and future economic efficiency of production systems which tend to be self-sufficient in feed (and in proteins in particular, grass being the largest source of protein feed available).

- The relatively high availability of land leads to an under-use of the production potential of grass. In many areas it does not exceed 5 Mg DM used per LU per ha, in particular in regions with permanent grasslands widely available. This is due to management practices such as low fertilization levels of N, P and K, and extensive management practices because there is no need to harvest more. The global dairy production of France could be much higher with an improved management of these areas.
- The environmental regulations with no derogation for N application on grasslands currently limits the yields in areas with high forage potentials and high density of dynamic farmers. As a consequence, the average stocking rate has dropped down to 1.6 LU per ha FA in western dairy farms (RGA census, 2010). Together with the quota/land system until 2015, this accounts for the absence of any steep increase in dairy production in areas with good forage potential both for grass and maize and with a good farmers dynamic, breeding oriented, wishing to milk more cows, which is not the case in other areas with less environmental restrictions (Perrot, 2014).

The French dairy production sector is facing an evolution that many European countries have faced earlier, with the increasing size of the farms and the development of indoor production systems with less grazing and more resort to concentrates to reach higher production levels per cow. This can lead to a loss of competitiveness with a decrease of feed self-sufficiency levels and higher feeding costs on dairy farms. Keeping this strong link between dairy production and forage and territory should be a major target both for economic and environmental purposes. It also contributes to the specificity and the image of dairy products for consumers. Finally, the outputs of dairy production per hectare, per cow and per territory should not only include milk and milk products but also all the other services (Huygues *et al.*, 2014) that are provided for society by the land monitored by dairy farmers: provisioning services such as milk production and low-cost animal feed; regulating services such as biodiversity, mitigation of GHG emissions, of avalanche controls; cultural services like beauty of landscape and tourism, and supporting services such as competitiveness or feed protein supply. The most dynamic sector for dairy production in terms of replacement rate of farmers is located in the Jura mountains with 1 settlement for 2 retirements, a rate much higher than the French average (1 for 3.8 Agreste, 2013). In this region, the production output per hectare, per animal or per farm may appear relatively low compared to other regions; though dairy production there has a strong role in keeping landscapes and biodiversity, and a high added value on the territory thanks to the high quality products processed under PDO specifications.

As a conclusion, France has a high natural potential to increase the outputs of dairy production after the end of quotas, although the limiting factor in the coming years will probably be the lack of farmers rather than the lack of land. The sustainability of these systems remains strongly related to the high link between land, forage production and milk production (self-sufficiency) and the maintenance of high added value products on piedmonts and mountain territories thanks to dairy production. 'High output farming systems' will remain diversified in terms of production systems and combinations of 'outputs' delivered. One of the challenges will be the maintenance of production systems combining maize silage and grass, with 'as much grazing as possible' in lowlands, thanks to a good field design, a good management of grass and clover pastures with very limited mineral N inputs. These systems should produce good quality milk with the 'right' fatty acids, and be efficient both on economic and environmental points of view.

References

Agreste (2013) *Primeur. Les exploitations laitières bovines en France métropolitaine*. Des territoires laitiers contrastés. N#308, 8 p.

Amiaud B., Chanséaume A. and Manneville V. (2014) *Un espace de biodiversité au service des productions herbivores, la prairie permanente*. Document Institut de l'Elevage, Université de Lorraine, CNIEL, 24p. Available at: http://tinyurl.com/k372kyp.

Autograssmilk (2012) *Innovative and sustainable systems combining automatic milking and precision grazing*. Available at: http://www.autograssmilk.eu.

Béchu T. (2013) *Etude des performances économiques et environnementales des exploitations bovins lait dans le nord-ouest de l'Europe*. Master thesis report. Université de Lorraine, Institut de l'Elevage, Dairyman. 43 p. Available at: http://tinyurl.com/l8r6bne.

Brunschwig P. and Perrot C. (2014) *L'alimentation des vaches laitières et l'autonomie des principaux systèmes spécialisés laitiers français*. Communication for the seminar « Autonomie Alimentaire: Quels enjeux pour la filière laitière après quota ?», CNIEL, Paris, France, 03/07/2014.

Clergue B., Amiaud B., Pervanchon F., Lasserre-Joulin F. and Plantureux S. (2005) Biodiversity: function and assessment in agricultural areas. A review. *Agronomy for Sustainable Development* 25(1), 1-15.

CNIEL-Idele 2012. *Observatoire de l'alimentation des vaches laitières*. Available at: http://tinyurl.com/l86axmb.

De Vries M., Debruyne L. and Aarts F. (2013) *Sustainability of dairy farming and the implementation of EU environmental directives in the northwest of Europe*. Dairyman final report. Available at: www.interregdairyman.eu.

Dollé J.B., Moreau S. and Foray S. (2013) *Combiner production et environnement, un défi pour la filière laitière*. Collection l'Essentiel, Institut de l'Élevage, 16 p.

Dossier Economie de l'Elevage (2013) *L'élevage d'herbivores au Recensement Agricole 2010. N#440-441.* Document Institut de l'Elevage, 100 p. Available at: www.idele.fr

Elluin G., Brunschwig P. and Le Doaré C. (2014) *L'autonomie alimentaire dans les principaux pays laitiers.* Institut de l'Elevage – Cniel.

FAO, IDF and IFCN (2014) *World mapping of animal feeding systems in the dairy sector*. FAO, Rome, Italy, 177 p. Available at: http://tinyurl.com/kgofuv6.

Foray S., Beguin E., Ferrand M., Perrot C., Dolle J.B., Bechu T., Hennart S., Boonen J., Tirard S., Morin C. and Castellan E. (2013) La durabilité des exploitations laitières du Nord-Ouest de l'Europe. *Rencontres autour des Recherches sur les Ruminants* 20, 217-220.

FranceAgriMer (2014) *Évolution des structures de production laitière en France*. 44p. Available at: www.franceagrimer.fr.

Huygues C., Peyraud J.L., Brocard V. and Van den Pol-van Dasselaar A. (2014) Appreciation of the functions of grassland by French stakeholders. *Grassland Science in Europe* 19, 807-809.

IFCN (2013, 2014). *IFCN Dairy report*. 207 p. Available at: www.ifcndairy.org.

Paccard P., Capitain M. and Farrugia A. (2003) Autonomie alimentaire des élevages bovins laitiers. *Rencontres autour des Recherches sur les Ruminants* 10, 89-92.

Perrot C., Reuillon J.-L., Capitain M. and Cassez M. (2008). Forces et faiblesses des exploitations laitières françaises de montagne dans la perspective d'un desserrement de la contrainte des quotas laitiers. *Rencontres autour des Recherches sur les Ruminants* 15, 243-246.

Perrot C. (2010) Projection du nombre d'exploitations bovines laitières ou allaitantes françaises. Une approche par modélisation démographique intégrant des effets territoriaux. *Rencontres autour des Recherches sur les Ruminants* 17, 211-214.

Perrot C., Bataille J.F., Bossis N., Caillaud D., Gallot S., Morhain B., Morin E., Roguet C. and Sarzeaud P. (2013) Diversité de l'élevage français et dynamiques territoriales. Les enseignements des recensements agricoles. *Rencontres autour des Recherches sur les Ruminants* 20, 341-344.

Perrot C., Caillaud D., Chatellier V., Ennifar M. and You G. (2014) La diversité des exploitations et des territoires laitiers français face à la fin des quotas. *Rencontres autour des Recherches sur les Ruminants* 21, 203-210.

Réseaux d'Elevage, 2012. *Synthèse annuelle des données des Réseaux d'Elevage. Bovins lait 2011*. Doc. Institut de l'Elevage-Chambres d'Agriculture, 52 p., available at: www.idele.fr.

Rieutort L, Ryschawy J., Doreau A. and Guinot C. (2014) *Atlas de l'élevage herbivore en France. Filières innovantes, territoires vivants*. Editions Autrement, 96 p.

Rouillé B., Devun J. and Brunschwig P. (2014) L'autonomie alimentaire des élevages bovins français. *Oilseeds and fats, Crops and Lipids* 21(4), D404.

Ryschawy J., Disenhaus C., Bertrand S., Allaire G., Aubert C., Aznar O., Guinot C., Josien E., Lasseur J., Perrot C., Plantureux S., Tchakerian E. and Tichit, M. (2013). Evaluer les services rendus par l'élevage dans les territoires: une première quantification sur le cas français. *Rencontres autour des Recherches sur les Ruminants* 20, 303-306.

SAFER (2014) *L'essentiel des marchés fonciers ruraux en 2013. Le prix des terres/La synthèse – mai 2014*. Document FNSAFER, 12 p., available aat: http://www.le-prix-des-terres.fr.