The Afterres2050 scenario 2016 version

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Thanks :
The refined and consolidated version of the scenario presented in this book builds on the work conducted by Solagro in 2014 and 2015 for the regional version of the Afterres2050 scenario.

This work was done thanks to:
- in support of ADEME, the Charles Léopold Mayer Foundation for Human Progress, the Center Val de Loire, Ile-de-France, Picardie and Rhône Alpes regions,
- the active participation of more than 200 regional players in workshops and plenary sessions,
- contributions and constructive criticism from the 18 members of the Scientific Council.

They are all here strongly and warmly thanked.

Some words of forewarning

Reading guide: a systemic approach, nonlinear reading

This document describes the Afterres2050 scenario highlighted from different angles: food, cultivating, breeding animals, using biomass and farmlands, evaluating agronomical, environmental and socio-economic impacts.

Read from left to right and from top to bottom, and take breaks: these are the only reading instructions we shall give you. You may start where you wish to and browse freely from one chapter to another. There is no single way in, and reading is neither linear nor chronological, because the Afterres2050 approach is holistic -and the overall vision will appear progressively. It is also an iterative approach: the initial hypotheses are revised according to the results obtained; they are impossible to separate. We have tried wherever possible to present our choices reflecting our trade-offs and our preferences. The aim was to contribute to the debate upon reasoned and substantiated bases, without claiming to turn it into a program.

The «*The making of Afterres2050*» chapter is composed of two parts:
The first part - «*the approach*» - explains the genesis and the conduct of the project from its beginning at the end of 2010. Who are the authors, why this endeavour, what is the «*regionalisation*» step, why a scientific counsel? It also details the key points of the methodology: modelling tools, scale choices.

The second part - «*Within the accounting intricacies of the bioeconomy*» - broaches accountancy questions. All these subjects - the contents of our plates, supply balance, forestry accounting, carbon accounting -are paved with traps. A must read for those who wish to understand the numbers!

Reference points for comparison

It is tempting to compare Afterres2050 to the current situation (our reference point is 2010). If this comparison does allow to measure possible evolutions, the comparison with other scenarios is what enables to form an opinion. In 2050, all the prospective agricultural scenarios will have to contend with the same constraints: a larger population, the confirmed impacts of climate change, the collapse of fishing resources… Hence the presentation of the Afterres2050 scenario almost systematically with two variations, «*BHF*» and «*PAR*», and a so called «trend» scenario consisting essentially in a continuation of past trends, with the same external constraints as those considered in Afterres2050.

BHF (Biodiversity, Health, Food) generalises organic agriculture and agrochemical-free production systems. PAR (Production & Resilience) favours photosynthetic production in order to increase carbon capture. These scenarios are not extremes, but variations of Afterres2050.

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Feeding humanity

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Food demand, an object of public debate

«If the whole world were to follow the north-American food regime[1]*, it is highly likely that our planet would not be able to provide enough food»*, explains agronomist Michel Griffon[2], who adds: *«eating too much meat causes cardiovascular diseases, and eating too many simple carbohydrates causes type 2 diabetes… It appears advisable to limit whatever causes disease in each food tradition, so to limit meat, simple carbohydrates and to increase complex carbohydrates, vegetables and fruit in our intake»*.
This is not a recent diagnostic, but what is new is that agronomists, nutritionists, starred top chefs and movements emerging from civil society are meeting in their questioning of a diet that is no longer adapted to the nutritional needs of our society.
Thus, the AGRIMONDE prospective carried out by INRA (National Institute of Agricultural Research) and CIRAD (Agricultural research for development) explains that *«yes, we will feed the 9 billion human beings living on Earth in 2050, on condition that we do not perpetuate the current trends»*[3]. In particular, for the first time, agricultural forecasting considers that the food regime is not input data, nor a demand to satisfy, but an object of public politics that can and must be questioned.
The French Science Academy renders a similar opinion[4]: reminding us that we must *«maintain the important production capacities of the European farming profession without fail, while reorienting them towards ecologically acceptable productions»*, above all, it underlines that it is necessary to *«encourage people to reduce their consumption of animal products»*.
For top chef Alain Ducasse, the naturalness concept is to become the gastronomical concept of the coming years: *«today, eating in a healthier and more natural way is expected and it's a necessity that it is high time to translate to haute cuisine. Exceptional products that can express their simplicity and a technique that is elegant enough to step back in order to serve them. That is cuisine as I sincerely love it»*[5].
If food has always been subject to passions, we have been witnessing problems converging for several years. Our food system has become a focal point of utmost importance for all things that affect such aspects as vital as health, environment and culture. This central position is what compels a systemic vision, as these questions appear as so many different aspects of a single subject.
Up until now, in many prospective exercises, demand was considered as input data that the productive system aimed to satisfy. The underlying postulate is that «stewardship will ensue», that is to say that we will manage to find the necessary resources, and repair any damage caused.
We consider on the contrary that it is legitimate to question our needs in the light of the consequences they lead to regarding the biosphere's capacity to provide these resources and to withstand these impacts. Our consumption should thus be sustainable, applying principles of restraint and overall system efficiency, *«from pitchfork to fork»*.

Influencing eating habits

Changing our diet is a necessity. As a matter of fact, eating habits constantly evolve. But is it possible to influence these evolutions?
The relative value of household food expenditure is decreasing (not its absolute value however), decreasing from 28% gross available revenue in the early 60's down to 17% by the end of 2009. Today it is stable, or even on a slight increase[6].
Bread and potato consumption are decreasing, fresh fruit and vegetable consumption is increasing. Meat consumption is decreasing, with the proportion of pork and poultry increasing and that of beef decreasing. We consume less milk but more yogurts, we drink less wine but of far better quality, mineral water demand has exploded.
Food inequalities persist, demand is increasingly for transformed products and out of the home food services (25% compared to 14% in 1960 according to INSEE). *«We will probably witness a multiplication of profiles, more than a food reconfiguration according to new norms and values… A single person will change from one type of consumer to another according to multiple factors»*[7]. Food has to do with health, culture, tradition, education, religion but also pleasure. Hence the importance of using these different levers, in a different way according to the public concerned, and paying more particular attention to older and younger people, who are powerful «transmitters» of intergenerational change. Information and nutritional and environmental education are both fundamental eating habit deciding factors. They are effective if generic messages are combined with various tools allowing to aim at precise goals and groups. Food policies must first and foremost act on the offer: the nutritional quality of food via regulatory or incentive measures; food availability (fresh fruit); packaging and nutrition claim labelling; etc.[8]
Teaching dietetics is at the heart of all public action. It should be noted that it is today heavily influenced by the agribusiness actors, and that nutrient intakes recommendations are not always based solid scientific facts.
Cacophony prevails as far as food recommendation is concerned, contributing to disorientate the consumer citizen

[1] We could just as well say *«European»*.
[2] Michel Griffon: *«We would need 2 planets to fill stomachs, reservoirs and to preserve biodiversity»*. Le Monde, 05/04/2007
[3] *«The world's challenge: Feeding 9 billion people»*. Marion Guillou (Chief Executive Officer of the INRA) and Gérard Matheron (President of the CIRAD), 2011.
[4] French Science Academy Report, *«Démographie, climat et alimentation mondiale»*, 2011 ("Demography, climate and global food").
[5] Alain Ducasse, Plazza Athénée, *«La naturalité»* ("Naturalness")
[6] Brigitte Larochette and Joan Sanchez-Gonzalez, *«Fifty years of food consumption»*, INSEE Première n°1568, October 2015
[7] Céline Laisney, L'évolution de l'alimentation en France (Food evolution in France), Work document published by the Centre d'études et de prospective of the French Ministry of Agriculture, n°5, January 2012.
[8] INRA published a collective scientific expertise in 2010, « Dietary Behaviours. What factors come into play? What action, for what result?», June 2010.

and to paralyse politics. Admittedly, *«the overall French health condition appears to be good»*[9], the French have enough to eat and can easily find good quality products. Public authorities have put numerous devices in place: France's national health and nutrition program (Programme national nutrition santé: PNNS) was launched in 2001, the 2004 French public health law is subject to annual assessment reports, a Food quality observatory (Observatoire de la qualité de l'alimentation: OQALI) created in 2008 by INRA and ANSES evaluates the nutritional quality of the food offer, the French National Programme for Food (Programme national pour l'alimentation) established by the French 2010 farming and fishing modernisation law sets the framework for the development of the public food policy.

However, the PNNS recommendations generate criticism that can be vehement: in particular, they were not founded on environmental considerations and thus neglect diet impacts. Independent and critical thought on nutrition abounds[10]. We must remain vigilant and alert to public health and environmental questions, which could have devastating medium term and long-term effects, while not giving way to an anxiety-provoking vision.

From slow-food movements to Disco-Soups, through CSAs, dynamics emerging from civil society aim to invent and to put into practice ways of consuming and eating far removed from guilt, pathologized eating, or returning to an idealised past.

Eating less to eat better

Today's diet, rich in fats and in energy dense food, centred around foods of animal origin, has replaced our traditional diet. This modification has played a key role in the increase of the prevalence of nutritional related chronic illnesses that are considered avoidable: mainly obesity, diabetes, cardio-vascular disease, cancer and osteoporosis (according to a WHO and FAO joint report published in 2002[11]).

Other factors related to our farming production methods add to the misdeeds of an over rich diet. Several studies[12] establish a link between certain synthetic molecules (pesticides, but also plastics, metals) and the prevalence of obesity and diabetes. These chemicals might interfere with our natural hormones and disrupt our endocrine system.

The rate of obesity in France, although among the lowest of the OECD countries, continues to progress regularly and concerns 14.5% of the French population in 2012, compared to 8.5% in 1997. One of the most worrying phenomena is child obesity that may have increased by 300% in ten years[13]. The phenomenon seems to have stabilised, concerning 3.5% of French 5 to 6-year-old children in 2013[14]. It seems that 20 to 27% of cancers in Europe[15] could be attributed to nutritional factors, with alcohol, excess weight and obesity, insufficient fruit and vegetable consumption, too much red and cured meats ranking the highest. Pesticides and the role of endocrine disruptors present in our food should be added to that list.

We French are reminded by the injunctions of the INPES[16] that our food is «Too fat, too sweet, too salty" (part of the French mandatory legal slogan on food advertisements: *«Trop gras, trop sucré, trop salé»*). According to INCA[17] surveys, we consume 45% excess protein for example, that is to say 90 grams per day and per person instead of the 52 gram recommendation, and 25% excess sugar. Let us add «too rich, too refined, too processed»: raw sugar, wholemeal bread and pasta offer far better nutritional value than their white counterparts.

This overconsumption is the first thing to tackle: eating less is not depriving oneself, but eliminating excess.

Afterres2050 proposes to reduce our total protein overconsumption by 50%; to reduce the proportion of sugar in our energy intake from 14% to 11% (the recommended value is 10%), that is to say to eliminate the equivalent of 4 lumps of sugar a day of the 20 we currently ingest either directly or indirectly (sweetened beverages, cakes, etc.).

Less waste

An important part of the consumable agricultural production ends up in the bin. At a global level, an estimated third of the food production is lost or wasted every year, representing 1.3 billion tons of food[18]. In Europe, loss and waste reach a total of 39% of consumption.

By cross-referencing several sources[19], these losses can be estimated per product type, and per stage, from field to kitchen. Loss and waste is estimated at 260 kg per person and per year, and equally distributed over 3 main categories: the agricultural production step, the final consumption step, and finally all the intermediate steps between field and kitchen (storage, transport, transformation, distribution).

A more recent study[20] details these losses from field to plate. Even if the global result (a 150 kg loss per person) differs from previous research because of different perimeters and methods,[21] it confirms the distribution over the main steps and the loss levels in the main categories. The highest loss level is for fruit and vegetables and tubers, as in this case, losses represent

[9] *«L'état de santé de la population en France - Suivi des objectifs annexés à la loi de santé publique»* (French population health condition – A follow-up of the goals annexed to the French public health law), 2011 and 2015 reports.

[10] See for example the *« Nutrition, economical interests and political power: what critical education?»* symposium organised by the Association de diététique et nutrition critiques (Critical Dietetic and Nutrition Association) in May 2011. We collaborated with several of the speakers: Paul Scheffer, president of the ADNC; Christian Rémésy, emeritus research director at INRA; Claude Aubert, INAPG agronomical engineer.

[11] «Diet, nutrition and the prevention of chronic diseases», WHO (World Health Organisation), FAO (Food and Agriculture Organization of the United Nations), 2002

[12] Review of the science linking chemical exposures to the human risk of obesity and diabetes, CHEM trust obesity, and diabetes review, January 2012; Montgomery MP et al.: Incident diabetes and pesticides exposure among licensed pesticides applicators, Agriculture Health study 1993-2003 Am. J. of Epidemiology 2008; 167: 1235-46

[13] According to Laurent Chevallier, a nutritionist doctor, at the Montpellier CHU (Montpellier University Hospital).

[14] Report on the French population state of health in 2015.

[15] Quoted by the French National Cancer Institute, «Les cancers en France» («Cancers in France»), 2014. There is no French survey of this type.

[16] INPES, INCA: see *«Counting our food» in chapter «Within the accounting intricacies of the bioeconomy»*

[17] INCA : (French) Individual and national study on food consumption (INCA1 in 1998-1999 and INCA2 in 2006-2007)

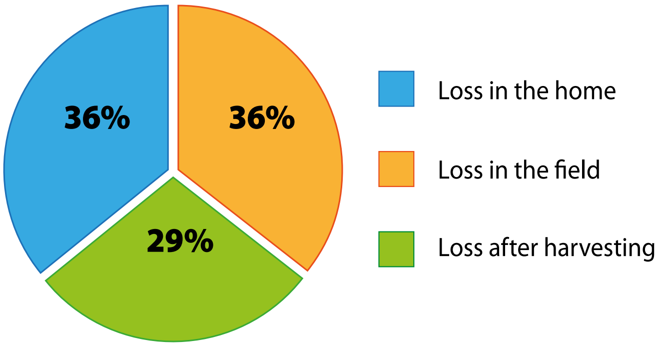
[18] FAO, 2012. Global food losses and food waste - extent, causes and prevention. Rome.

[19] FAO study on losses and waste, and *« La grande [sur-] bouffe »* (*«[Over-] blow-out»*), Bruno Lhoste, October 2012, Rue de l'Echiquier Editions

[20] Pertes et gaspillages alimentaires : l'état de lieu de leur gestion par étape de la chaine alimentaire. (Food loss and waste: an overview of their management at each step of the food chain.) Income consulting and AK2C for ADEME, May 2016

[21] For example, the study counts certain products *«as are»* and not as an equivalent of the primary production. See *«Within the accounting intricacies of the bioeconomy»*. The differences are mainly on fruit and vegetables.

half of the quantities put to market. However, losses are also massive for all products in general: between a quarter and a third of the quantities put to market.



- Loss per product category and per stage. *(Cf. detailed table page 98)*

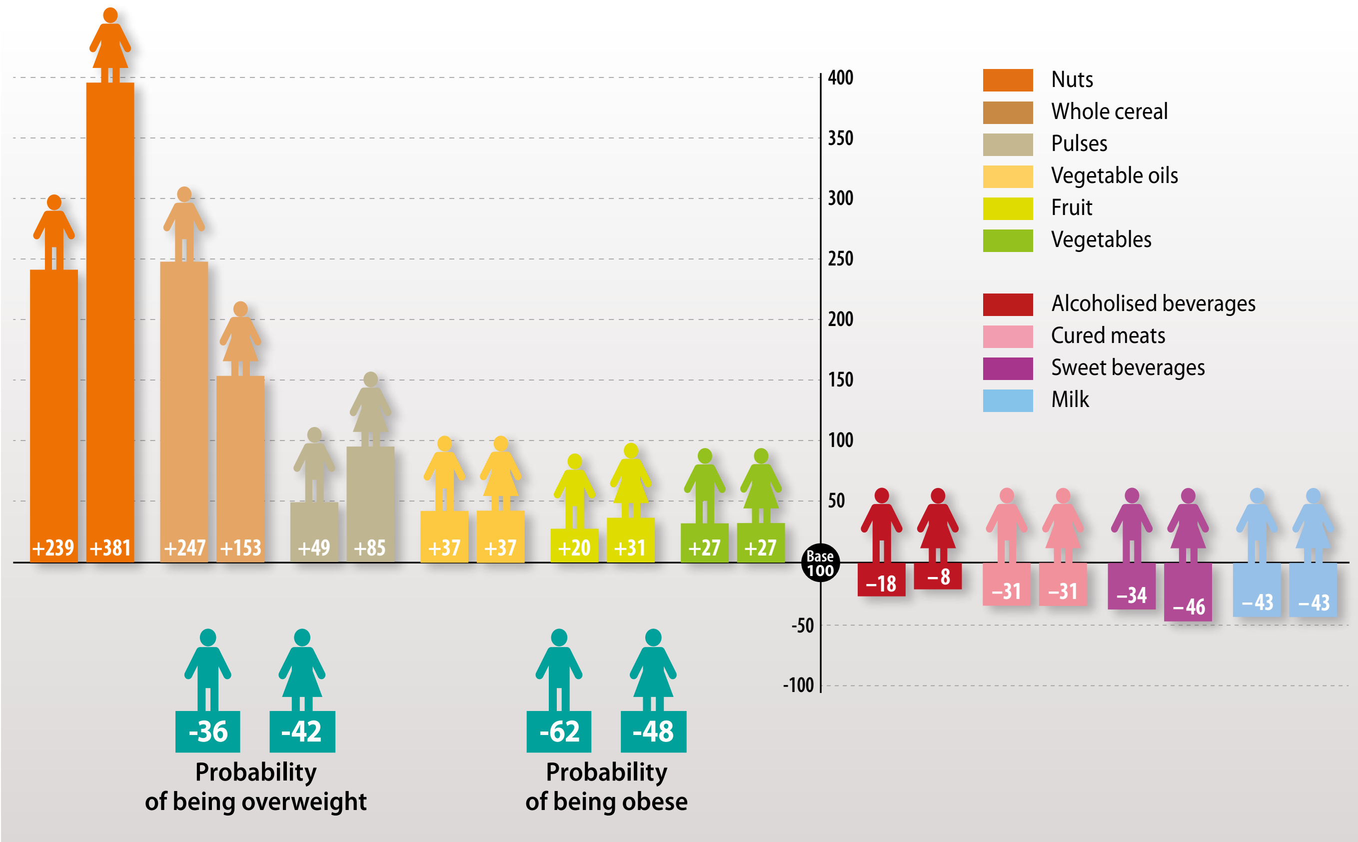
According to Bruno Lhoste, fighting food waste entails the 6 Rs:

- Recognising the problem, which is the first inevitable step as few actors were conscious of its extent until very recently;
- Reconnecting with the agricultural production cycle, for example via vegetable plot programs in schools or in cities, to understand where our food comes from;
- Relearning how to cook and the «art of preparing left-overs»;
- Reducing over-consumption;
- Redistributing, in particular via food banks, that today only mobilise 0.3% of lost quantities;
- Recycling what couldn't be avoided in the previous 5 Rs, for animal feed when possible, for compost or anaerobic digestion otherwise.

The potential of loss and waste reduction would be of 64 kg per person and per year, that is to say 58% of the quantities lost during distribution and consumption [22].

Dietary changes

If public policies globally agree that reducing overconsumption and waste is necessary, the same cannot be said about the contents of our plates, that is to say about the proportion of different food types. The main controversy is over meat and dairy consumption, that is not a simple cooking quarrel, and refers to different imaginaries. Can we identify the impacts of a diet containing less meat on our health? There is much research on this topic. In France, the Bionutrinet program [23] proves it the most clearly.



- A comparison of organic and non-organic consumer diets, according to the Nutrinet - Santé study (%).

[22] VSee *«La grande [sur-] bouffe»* (*«[Over-] blow-out»*), Bruno Lhoste, October 2012, Rue de l'Echiquier Editions. Besides, this goal conforms to the 19th of January 2012 European Parliamentary resolution aiming to reduce food wastage by half within a 2025 timeframe.

[23] BioNutriNet associates several research teams: the NutriNet-Santé team (EREN, U1153 INSERM/INRA/CNAM/ Université Paris 13), the Nutrition, Obesity and Thrombothis Risk unit (NORT INSERM/INRA, Université de la Méditerranée, Marseille); the *«Food and social science»* team (ALISS INRA, Ivry-sur-Seine); the TOXALIM Food Toxicology laboratory (INRA, Toulouse); the Biochemistry department of the Grenoble CHU (University Hospital); ITAB (Organic Agriculture Technical Institute); SOLAGRO and Bio Consom'acteurs.

The study precisely measures the consumption of food produced by organic agriculture and characterises the organic product consumers and the conventionnel food consumers over a vast *«cohort»* (group of subjects followed over several years). The study shows that the organic cohort consumes far more nuts, pulses, whole cereals, fruit and vegetables, and far less cured meats, dairy products and sweet beverages. The energy intakes are identical in both groups. The health indicators such as the probability of being overweight or obese are much improved [24].

What interests us here is not so much the organic/non-organic comparison, but rather the consumption structure. The survey proves that it is possible to be in good or better health when consuming more cereals and legumes, and 40% less milk.

Finding a new balance between animal and plant protein

Animal protein now represents 61% of our protein intake, that is to say around 1 million tons of animal protein for 640.000 tons of plant protein.

Yet animal protein production has far more impact than plant protein production, as it takes between 2 and 10 kg of plant food to produce 1 kg of meat. France thus devotes 80% of its agricultural areas to animal feed: 35% of grasslands, 17% of forage crops, 15% of areas planted with cereals and oilseed crops intended for animal feed, the majority of exported cereals (as they are forage cereals for animal feed); without considering the co-products such as bran or beetroot pulp.

Reducing the proportion of animal protein is possible from a nutritional point of view. According to ANSES (The French Agency for Food Safety, Environment and Labor) we can cover our essential amino acids needs by solely consuming either animal or plant proteins, as long as we associate cereals with legumes.

There is therefore no minimal recommended animal protein intake, but several opinions tend to agree that a third of animal protein in our ration allows to satisfy our essential amino acid needs. That was actually the prevailing situation in France at the beginning of the 20th century.

Afterres2050 thus proposes to reverse the respective proportions of animal and plant protein in our diet, that is to say to cover our protein needs with about 60% of plant and 40% of animal origin.

Cereals represent one of the main sources of protein today, at a level with meat, milk comes in at second position, followed quite far behind by the other sources: fish, eggs, fruit and vegetables. The average Afterres2050 plate has an increased proportion of cereals, a lower proportion of meat and milk, and a fish consumption plunge [25]. Legumes and nuts gain a significantly larger place: five times more than in 2010.

Proteins are composed of 20 amino acids, 9 of which qualify as essential amino acids (EAA) because:
- our organism cannot synthetize them,
- they are all necessary for the correct assimilation of proteins. A deficiency of only one of the EAAs limits the overall assimilation of proteins.

Meat, dairy products, eggs and fish are «high quality» protein sources because they contain the 9 EAAs.

Cereal proteins are considered lower quality, because when consumed on their own, they lack lysine, a limiting amino acid. Hence the benefit of associating cereals + legumes.

Legumes - lentils, broad beans, beans, peas… - indeed provide high levels of lysine. Associating cereals (2/3) and legumes (1/3) in the same meal allows to receive all the essential amino acids and, as a consequence, to satisfy our protein needs.

Reducing the calcium provided by dairy products

France's national health and nutrition program (Programme national nutrition santé: PNNS) recommends eating 3 dairy products a day, or up to 4 for elderly people, in order to satisfy calcium needs, estimated in France at 900 mg Ca/day/person. According to ANSES, the average calcium consumption is of 930 mg Ca/day/person, in conformity with the PNNS recommendations, of which milk provides about half.

There is a lot of controversy over calcium intakes. In several countries, such as in Great-Britain, the health ministry (National Health Service) recommends a consumption of 700 mg Ca/day/person. Based on long term studies, the Harvard School of Public Health, recommends eating a single dairy product a day [26]. The WHO estimates that an average consumption of 400 to 500 mg Ca/day/person is sufficient within a well-balanced diet. In Japan, the average dose is of 300 mg Ca/day/person, without any specific broken bone frequency.

Several studies show that a diet that is less animal protein rich requires a lesser calcium intake level because of the induced *«losses»*.

Tobacco, alcohol over-consumption and a lack of physical activity also seem to be unfavourable elements for a good valorisation of the quantities ingested and for osteoporosis prevention, and inversely, sufficient vitamin D and K intake is necessary. Moreover, dairy products are not the only calcium

[24] The preliminary results were published in the PlosOne review: Emmanuelle Kesse-Guyot et al., Profiles of Organic Food Consumers in a Large Sample of French Adults: Results from the Nutrinet-Santé Cohort Study, PlosOne 10.1371/journal.pone.0076998, 18th October 2013

[25] The drop in fish consumption is solely due to a possible collapse of the resource availability.

[26] Cf. http://www.hsph.harvard.edu/nutritionsource/calcium-full-story

source: almonds, spinach, broccoli, walnuts, oranges, hazelnuts and dates, are all excellent sources of calcium[27]. And let's not forget water, as some mineral waters contain as much calcium as milk. Afterres2050 proposes to reduce milk and dairy consumption by 40%, which corresponds to the observations of the BioNutrinet program. That is to say 1 to 2 dairy products a day rather than the 3 recommended by the PNNS, the rest being supplied by a varied diet.

The calcium paradox: the richer our diet in animal protein, the more calcium we need.
According to certain experts (FAO, WHO), the incidence of hip fractures, one of the major consequences of osteoporosis, is higher in occidental countries where the calcium intake is high, than in developing countries, when intake is low. The explication of this paradox lies mainly in the overconsumption of acidifying animal protein, which limits calcium fixation, and generates the use of the calcium contained in bone mass.
For the FAO, given their diet, occidental populations should consume 840 mg of calcium per day. However, reducing animal protein intake by 40 g can bring this calcium need down to only 600 mg.

The Afterres2050 plate

In Afterres2050, the physiological needs per person would remain stable, or would decrease slightly if the Body Mass Index returned to its year 2000 level. Overconsumption could be much reduced: the quantities ingested per person would be reduced by 10%. In 2050 our plate would contain more cereals, fruit, vegetables and nuts (walnuts, almonds). It would contain half the milk and meat. Meat would not disappear, it simply wouldn't be part of all menus, every day of the week, or if so in smaller portions.

g/d/adult	2010	2050			
		Trend	Afterres	BHF	PAR
Cereals	281	315	340	340	309
Potatoes	58	64	49	49	54
Sugar	21	23	19	19	19
Animal Fats	11	8	8	8	8
Offal	3	1	1	1	1
Pulses	10	15	41	41	15
Oils	15	19	17	17	17
Vegetables	139	146	170	170	160
Fruit	160	168	196	196	184
Alcoholic beverages	155	155	113	113	124
Stimulants (coffee, tea, cocoa)	259	233	233	233	233
Spices	19	17	17	17	17
Meat	185	185	94	89	139
Dairy products	235	223	122	117	176
Eggs	15	15	11	10	13
Fish & seashells	31	8	8	8	8
TOTAL	1 598	1 595	1 439	1 428	1 477

• Evolution of the Afterres2050 plate from now to 2050 - quantities ingested[28].

Food availability (that is to say the agricultural wares bought, in «*production equivalent*»[29]) would be reduced by 2% since the population would increase by 12%, reaching 72 million inhabitants[30], whereas it would increase by 13% in the Trend scenario.

[27] See the CIQUAL tables: https://pro.anses.fr/TableCIQUAL/index.htm
[28] In the «*INCA*» sense: see the «*Within the accounting intricacies of the bioeconomy*» annexes.
[29] Counting in the FAO supply balance sense: see the «*Within the accounting intricacies of the bioeconomy*» annexes.
[30] INSEE scenario, central projection Scenario, published end 2010 - «*Population estimates and population projections 2007-2060*»

Food consumption, kt/year	2010	2050			
		Trend	Afterres	BHF variant	PAR variant
TOTAL	61 000	70 000	58 000	57 000	61 000
Cereals	7 900	10 000	10 000	10 000	9 400
Potatoes	3 500	4 400	3 200	3 200	3 500
Sugar	2 400	3 000	2 400	2 400	2 400
Pulses and nuts	380	660	1 900	1 900	660
Oils and oilseeds	1 500	2 100	1 900	1 900	2 000
Vegetables	6 500	7 800	8 600	8 600	8 100
Fruit	7 100	8 600	9 400	9 400	8 900
Stimulants, spices	640	660	630	630	630
Alcoholic beverages	5 200	6 000	4 200	4 200	4 600
Meat, offal, animal fats	7 100	7 600	4 300	4 100	5 800
Milk	16 000	17 000	9 400	9 100	14 000
Eggs	840	980	680	620	810
Seafood	2 200	770	630	630	630

- Food availability [31] per product category and per scenario

The PAR variant is closer, from a diet standpoint, to the trend scenario, in terms of the proportions of animal protein and milk consumed. The energy needs are similar in all three variants: we need our daily petrol bowl, that is to say a third of a litre.

Indicators		2010	2050			
			Trend	Afterres	BHF	PAR
Proportion of plant protein		35%	41%	59%	60%	46%
Protein consumption	g/adult.day	120	115	94	92	100
Protein needs	g/adult.day	57,9	64,7	59,1	59,1	59,1
Protein over-consumption		107%	77%	59%	56%	69%
Energy intake	MJ/day	16.0	16.7	14.9	14.8	15.0
Energy needs	MJ/day	12,1	13,4	12,2	12,2	12,2
Energy over-consumption		32%	24%	22%	21%	22%
Dairy products	g/adult.day	235	223	122	117	176

- Main diet indicators

What about seafood?

Each person in France currently eats slightly less than 35 kg of seafood products: shrimps, salmon, cod, tuna fish… and seashells, 2/3 of which are imported. The world fish supply is estimated by the FAO at 17 kg/pers/year.

The amounts extracted from the sea (that have been stable for 10 years) are above the balance level that is necessary to the renewal of a growing number of species. According to IFREMER, barely 22% of the stock is in a good *«state»* in the Gascogne Gulf and 18 % in the West Channel. Neither marine pisciculture nor professional river fishing –also disaster stricken- seem able to step in today. At what speed and how are our resources going to be able to renew over the next decades? Will we have to go without the benefits of fish and turn to other food types to find them?

The preservation of our fishing resources being a major issue for future generations, Afterres2050 has chosen -by default- to considerably reduce our consumption of sea products.

Aquaculture could offer an alternative that Afterres2050 has not yet explored. In particular, the question of the types of fish farms to favour will need to be considered, knowing that currently a majority of farmed fishes are carnivorous and that their food consists mainly of seafood.

Key hypotheses

- Cut overconsumption by a third
- Cut losses and waste by 50%
- Maintain Body Mass Index
- Reverse the animal protein / plant protein ratio

[31] In production equivalent.

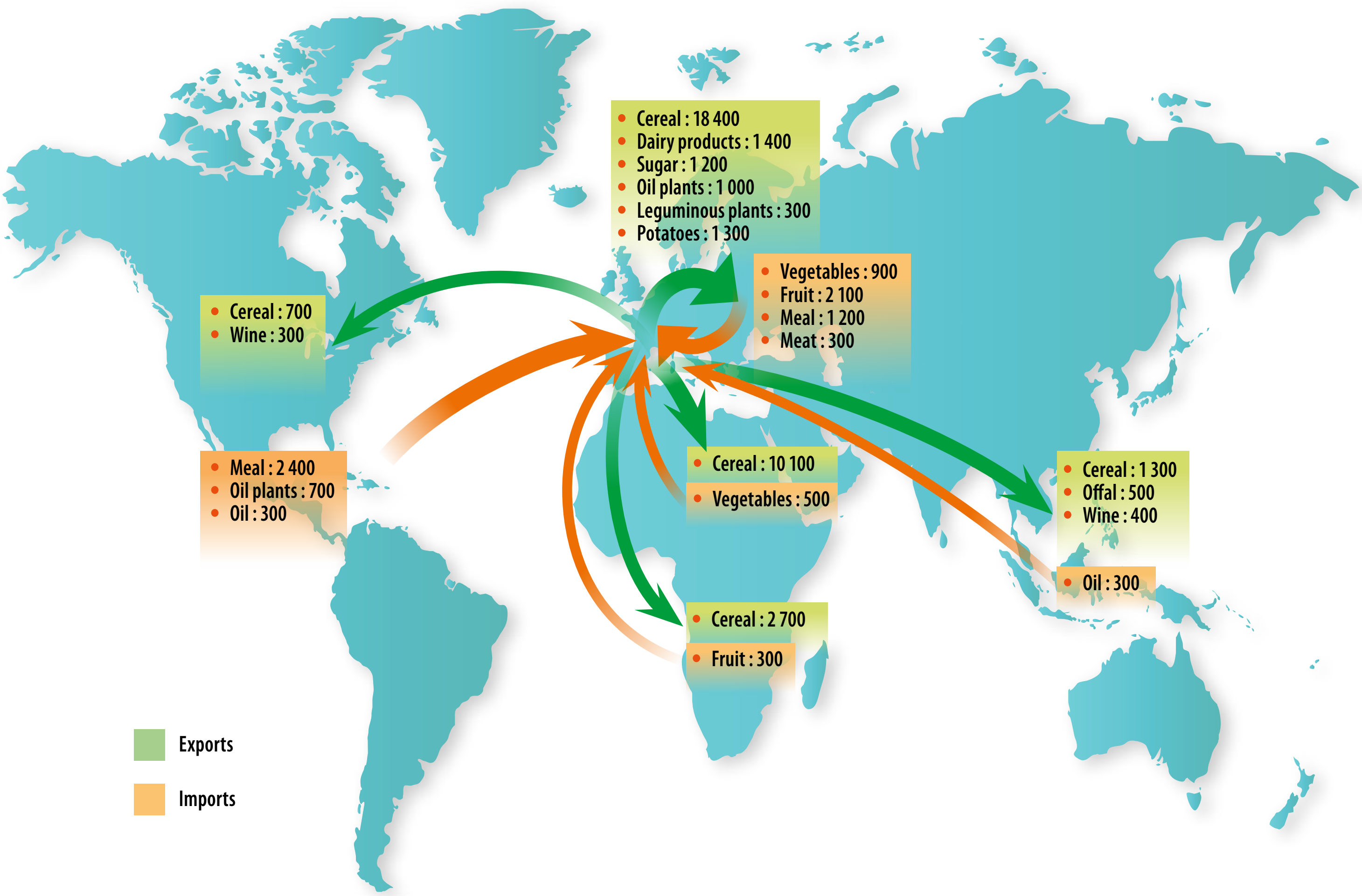
Playing our fair share in world food security

A great agricultural goods exporting power

France counts amongst the top 5 world exporters of food products, exporting 59 million tons of agricultural products and importing 28[32]. The positive balance reaches 31 million tons, with cereals representing the main part: 33 million tons[33], 56% of which go to other parts of Europe and 30% to North Africa and the Middle East.

The other significant items are:

- Co-product imports (soybean meal) from America and Europe
- Fruit imports from Europe (Spain, Italy)
- Vegetable imports from Europe and North Africa (Morocco)
- Milk, sugar, potato exports to Europe
- Oil plant exports to Europe (rapeseed) and imports from the Americas (soybean)
- A positive balance of alcoholised beverages (wines, Champagne)
- A negative balance of stimulants (coffee, tea, cocoa)
- A globally stable balance of animal products (meat, offal, animal fats) with contrasted situations depending on world regions
- A negative fish balance
- A negative balance of forest products (wood and paper) can also be added.



- Exportation balance (exportations minus importations) by product category and region - thousands of tons per year. *(Cf. detailed table page 98)*

The *«top 21»* of the main accounting items (product x country representing over 500.000 tons in 2011, either export or import), that alone represent one third of the exchange flux in one direction or the other (29 million tons out of a total of 86 million tons either exported or imported), underline the importance of wheat exports to Algeria, Morocco and Egypt, but also the different European countries, and the imports of soybean meal from Brazil.

[32] Averages over the 2007-2011 period. This data is issued from the FAO Trade data base and is expressed in quantities of commercialized products «as is», and not in «primary equivalent». See chapter «Within the accounting intricacies of the bioeconomy».

[33] The balance on cereals alone is higher than the total balance: this is not an error as the total balance includes negative components.

Country	Product	Thousands of tons	Export / Import
Algeria	Wheat	5 772	Export
Morocco	Wheat	2 326	Export
Brazil	Soybean meal	2 179	Import
Italy	Wheat	2 091	Export
Spain	Corn	2 080	Export
Belgium	Wheat	1 535	Export
Holland	Corn	1 427	Export
Belgium	Barley	1 380	Export
Holland	Wheat	1 289	Export
Holland	Barley	1 072	Export
Italy	Cattle	1 021	Export
Germany	Colza	996	Export
Egypt	Wheat	908	Export
Germany	Wheat	805	Export
Spain	Wheat	799	Export
Germany	Barley	684	Export
Belgium	Corn	681	Export
Portugal	Wheat	610	Export
Spain	Potatoes	588	Export
Germany	Corn	568	Export
Cuba	Wheat	554	Export

- *«Top 21»* of main French export or import flux (above 500 kt), in 2011.

Feeding the world?

The export–import balance is positive or negative, depending on the indicator and the chosen perimeter. It is positive when considering the «agricultural products» perimeter and (but at varying levels) the «mass», «energy» and «carbon» indicators. The «economical value» indicator must consider whether the subventions are directly or indirectly allocated to exportations. It is negative if all products resulting from photosynthesis (including forest products, wood, rubber, cotton, etc.) are considered for the «surface» indicator. Our surface «footprint» in France exceeds our agricultural and forest areas and the rest of the world provides for us, despite fertile and productive lands.

The import and export question are thus a major one. The French agriculture «calling» to «feed the world» is not a consensual vision. International solidarity organisations have long been speaking up about the harmful role of subsidised exportations from rich countries to poorer countries, where they compete with local farming and subsistence crops. Subsistence crops currently feed 80% of the world population and must be supported rather than fragilized by our exportations. Half of the poor people in the world are farmers. The question of world food balance is above all a question of poverty. France must of course play its part in world food security, but not blindly.

Afterres2050 and world scenarios

Afterres2050 draws on global level prospective works to reason on the evolution of international exchanges. It aims to be coherent with the «AGRIMONDE 1» scenario elaborated by INRA and CIRAD[34]. Two versions have been elaborated:

- The AGRIMONDE G0 scenario, itself resulting from the Global Orchestration of the Millennium Ecosystem Assessment scenario[35], is a trend type scenario: it carries through the current diet trends, and is based on an intensification of conventional agriculture. This scenario leads to a certain number of dead ends, and its environmental consequences seem unsustainable.
- The AGRIMONDE 1 scenario describes a transition towards a food demand and an agricultural production that are sustainable (through the «doubly green revolution»). According to AGRIMONDE 1, global food demand will have increased by 40% by 2050 (instead of 68% in AGRIMONDE G0), with a stabilisation of the demand per person, including animal products (dairy and animals). This scenario points out the necessity for a food transition and raises the until now unmentionable question of controlling food demand.

[34] INRA, CIRAD, 2009, AGRIMONDE. Scenarios and Challenges for Feeding the World in 2050. http://institut.inra.fr/en/Objectives/Informing-public-policy/Foresight/All-the-news/Agrimonde. A new study, AGRIMONDE TERRA, exploring 5 world scenarios, was presented in June 2016. Also see the n°27 analysis report of the French ministry of agriculture's Centre of Study and Prospective, February 2011, that compares several world food scenarios within the same timeframe.
[35] www.millenniumassessment.org.

An export balance still largely positive

The net export balance result stems from modelling, as the difference between production on national territory, and domestic demand. It is expressed in quantities (weight), in energy values and in greenhouse gas values.

Net export balance, in thousands of tons of gross products	2010	2050			
		Trend	Afterres	BHF variant	PAR variant
TOTAL	27 000	15 000	22 000	9 100	32 000
Cereals and corn	31 000	28 000	20 000	12 000	31 000
Potatoes	1 300	1 300	310	-770	220
Dairy products	6 900	7 300	6 900	7 700	4 000
Sugar	1 500	1 600	2 200	1 100	2 100
Meat, offal, animal fats, eggs	-14	-2 200	-72	310	-1 400
Alcoholic beverages	1 500	600	1 000	390	1 200
Meal, oils, high-protein oil seeds	- 4 200	-7 500	560	-2 500	2 500
Coffee, cocoa, tea, spices, stimulants	- 640	- 650	- 630	- 630	- 630
Fruit and vegetables	- 8 500	-13 000	-7 600	-7 900	- 6 300
Fish and fishing products	- 2 200	- 670	- 640	- 640	- 640
Energy value (PJ)	370	260	310	120	470
GHG value of the balance (MteqCO$_2$)[37]	8	-7	5	2	4

• Evolution of net export balance .[36]

The Afterres2050 scenario manages to maintain the export balance at a slightly lower level than today's. The content of the export balance is different:

- Cereal exports decrease (production decrease),
- Dairy product exports remain stable,
- Sugar exports increase (decrease of non-food uses),
- The oilseed accounting item becomes positive (decrease of soya imports),
- The meat result globally remains almost stable,
- Fruit and vegetable imports decrease (important production increase),
- Tthe energy value of the balance varies little,
- The GHG value of the balance remains positive but decreases.

The trend scenario doesn't manage to maintain exports at the current level on account of the consumption increase and the production stagnation. Therefore, the outcome worsens, and the balance becomes negative in GHG value (although it remains positive in energy value). In the BHF variant, the export balance strongly decreases in quantities and in energy value, and the GHG value becomes almost null. The PAR variant offers the highest balance in energy value, whereas its GHG balance is comparable to the Afterres2050 one. The export balance for the main groups of products and countries sketches out the role that France could play in international exchanges and the paths to explore.

We can in particular point out the strong decrease of cereal exports to Europe, that are mainly feed grains, used as animal feed. Generally speaking, the exports to Europe follow the same logic as the evolution of French needs: fewer animal cereals, a lower meat and milk consumption and a stable fruit and vegetable consumption. Let's remember that Europe produces between 400 and 500 million tons of cereals every year, half of which is used as animal feed, and is a net exporter. A reduction of European domestic demand similar to the one that would take place in France would allow to manage without most of the exchanges between European countries.
Cereal exports to North Africa and the Middle East could then increase by 60%, whereas vegetable imports would decrease and pulse exports increase: the energy balance value towards the Mediterranean region would globally increase by 64%.
Inversely, cereal exports to Sub-Saharan Africa would decrease: the bias being that African farmers can and must feed their continent.
Finally, the high-protein oil seeds imports, including oils and meal, incoming from the Americas, drop dramatically. Oilseeds become the second export accounting item, under the influence not only of a decrease of the imports linked to livestock evolution, but also of the decrease of the use of oils for energy.
The other accounting items represent small volumes, as is the case today.

[36] La masse, le contenu énergétique et la valeur GES des produits ne sont pas proportionnels, aussi un bilan positif pour un indicateur ne signifie pas automatiquement qu'il soit positif pour un autre. En particulier, le contenu carbone des produits importés (fruits et légumes) est plus élevé que celui des produits exportés (céréales).
[37] Solde issu du bilan d'approvisionnement. Attention, ce tableau n'est pas comparable aux tableaux qui indiquent les soldes par régions du monde, qui sont quant à eux basés sur la nomenclature au sens du commerce. Voir en annexes « Dans les arcanes comptables de la bioéconomie ».

Export balance per main product group and per country, FAO	North Africa, Middle East	Sub-Saharan Africa	Americas	Asia, Ocea-nia	Europe	TOTAL
Cereals	16 000	1 000		1 000	3 000	22 000
Dairy products [38]	200	200		500	1 000	2 000
Sugar					1 000	2 000
Vegetables					-1 000	-1 000
Fruit					-2 000	-2 000
Oilseed plants and sub products (oils, meal)					1 000	1 000
Pulses	1 000				1 000	2 000
Total, Thousands of tons	16 800	1 200	-400	2 000	5 200	24 800
Export balance energy value (PJ)	230	18	-4	25	80	350
Weight of all French exports	66%	5%	-1%	7%	23%	100%

- A possible distribution of export balances per product category and per region (thousands of tons).

Key hypotheses

- Constant dairy product export balance
- Continued stable animal product balance
- Increase by 60% of exports to the Mediterranean region
- Constant global exports of dairy products to Asia (with a slight increase) and Sub-Saharan Africa (decreasing)
- Half the exports to the rest of Europe (forage cereals) and reduction by a third of imports (fruit and vegetables)

[38] Let us recall that we are speaking here of quantities «as is» and not of primary equivalents. The corresponding quantity of milk can be found by multiplying by approximatively 3.6 to obtain a correlation with the supply balance.

Afterres2050

Crops and trees

Rethinking crop systems

Thinking the agrosystem as an ecosystem

The practices and qualified systems that come under the generic term «agroecology» have in common a holistic or systemic vision of an agrosystem, that is above all considered as an ecosystem, that is to say that it is regulated by complex interactions between the soil and living organisms, plants, animals, microorganisms, that are in competition or in symbiosis.
The doxa dominating the second half of the 20th century considered an agrosystem as a physical medium. For example, soil defects (capping, compaction, absence of nutrients) can be compensated by exogen solutions: mechanical working, providing of synthetic origin (nitrogen) or of mined origin (phosphate), plant protection products, genetic engineering, drainage and irrigation. Other schools of thought consider that the soil should on the contrary be thought of as an ecosystem where complex phenomena occur, of interaction, balances, dynamics that are biological, chemical and physical, and that farming practices consist in piloting these mechanisms rather than dominating them.
These two perspectives can be placed on a scale ranging from «artificialisation» (the extreme being hydroponic cultivation for example) to «piloting», reflecting two diametrically opposed visions of agriculture and, more widely speaking, of the relationship between man and nature [39]. All grades of this scale can exist and even coexist with varying degrees of artificialisation or piloting.
The current trend is to find a new balance that favours piloting, that is included in the term «agroecology» for example, as a result of becoming conscious of certain limits of «conventional» agriculture: sanitary and environmental impacts, and dependency on inputs.

osaé
www.osez-agroecologie.org

Discover on OSAE farmers who practice agroecology every day. Designed and maintained by Solagro, OSAE is a video library of «field side» testimonies. It is also a collaborative platform that facilitates information exchanges and the dissemination of know-how. Cover crops, prairie seed mixes, dynamic rotational grazing, diversity of varieties: you will find all these practices and far more, as well as the results obtained both by early adopters and by those newly converted to agroecology…

Soil, a film of life on Earth

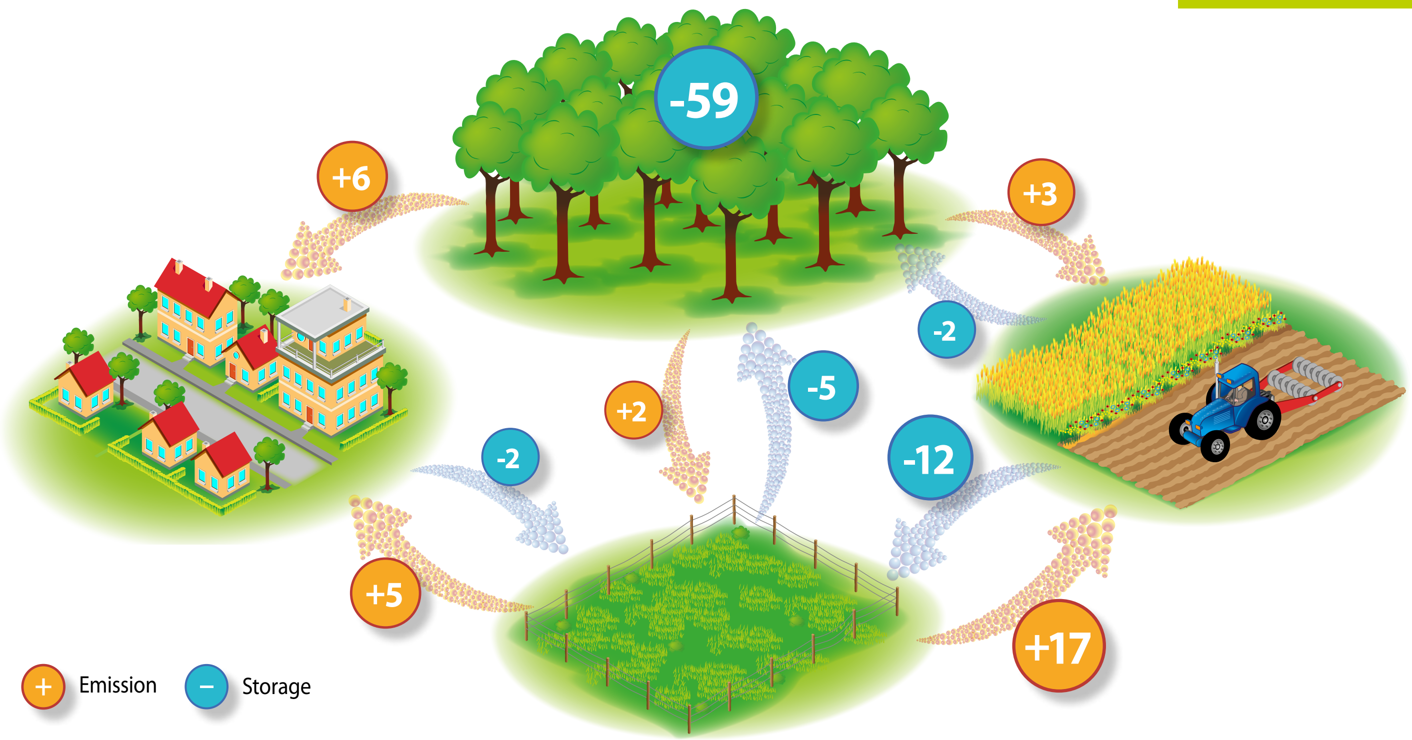
Making the conservation of soil fertility the linchpin of farming systems' sustainability

The soil is host to intense biological activity, that ensures the recycling of organic matter and represents a central link in the regulation of the great global cycles of carbon and nitrogen. It forms a complex living system that interfaces and interacts continuously with the other environments (atmosphere, lithosphere, hydrosphere).
Fertile farming soils are a natural resource that can only renew very slowly, because their fertility depends on properties inherited from long geological cycles. Their preservation is preoccupying and has become a crucial issue [40] in the face of their surface reduction (artificialisation), their quality deterioration (pollution by metal or organic elements, hydraulic or wind erosion, salinization, reduction of their organic matter content) or even their destruction (desertification, landslides).
In Europe, water erosion causes the loss of 2.46 tons of earth per hectare and per year (farming lands and forest), whereas only 1.4 t/ha.year [41] is created. Four million hectares are more particularly threatened. Farming policies have allowed to reduce these losses by 20% in a single decade, but the phenomenon remains of major concern. In France, the average for arable land is of 2.78 t/ha with no agri-environmental measures, that are capable of reducing this impact by close to 40%.

Soils, carbon sinks

Soils and ecosystems are also «carbon sinks»: in 2013, they stocked the equivalent of 47 MteqCO_2 [42] that is to say 10% of gross GHG emissions. This gain is mainly due to forests. Prairies stock carbon but their conversion to arable land, like artificialisation, leads to a net emission. Farming lands, in total, lose carbon because of affectation changes.

[39] Larrère Raphaël, Agriculture : artificialisation ou manipulation de la nature ? (Agriculture: artificialisation or manipulation of nature?) In Cosmopolitiques n°1, June 2002
[40] See the documents preparing the implementation of a future Framework Directive for Soils: Soil Thematic strategy – European atlas of soil biodiversity - 2010
[41] The new assessment of soil loss by water erosion in Europe, P. Panagos et al., Joint Research Center. Environmental Science & Policy, 54 (2015) 438-447. Published on August 25th 2015.
[42] Including CH_4, N_2O, mineral carbon (lime) additions and burning. The whole of France. Source: CITEPA inventory, UNFCCC format: United Nations Framework Convention on Climate Change. October 2015.



- CO_2 emissions per landscape type and when allocation changes occure (2013 values - Source CITEPA 2015). *(Cf. detailed table page 99)*

Completing the nutrient cycle

Nitrogen

Nitrogen, also known as azote that means «lifeless», is despite this name an essential component of life. Without nitrogen, there would be no proteins. Nitrogen is abundant: it makes up 79% of our atmosphere, but it can't be assimilated by plants in its gaseous form. Plants absorb nitrogen in its mineral form: nitrate and ammonium. Up until the Haber-Bosch[43] revolution, the only sources of nitrogen that could be used for farming were provided by leguminous plants. Symbiotic fixation still plays an important role in the French national nitrogen balance, with almost 400.000 tons of nitrogen fixed each year, but synthetic mineral fertilizers represent far more: 2.3 million tons per year.

The availability of industrial quantities of nitrogen was one of the major causes of yield increase in the 20th century. With as a counterpart water and air pollution. Part of the nitrogen spread on the soil volatilises as ammoniac, a forerunner of fine particles.

Another part ends up in water as nitrates. Ammoniac and nitrates are consumed by nitrification and denitrification reactions that take place in natural environments and end up returning to their initial state of atmospheric dinitrate. As this happens, small quantities, in the order of a few percent, escape as nitrous oxide, or N_20. N_20 is known for its medical applications, it is also called laughing gas, but it is above all the third main greenhouse gas, with a global warming power 300 times higher than that of carbon dioxide. Nitrogen fertiliser production is also a source of greenhouse gas emission, as natural gas is consumed.

The nitrogen cycle starts with the primary sources that are symbiotic fixation and mineral fertilisers, representing 2.7 million tons a year. The fluxes from the soil are far higher, at almost 6.1 million tons. Indeed, as well as these primary sources there are vast recirculation fluxes of 3.5 million tons of nitrogen: livestock manure and grazing animals' droppings, crop residues, and redeposits of volatilised ammoniac. Each of these fluxes generates losses by volatilisation or leaching, with associated N_2O leakage.

Net agricultural productions, used as human food or exported, represent 1.5 million tons of nitrogen, that is to say 8 million tons of proteins. The aim is not to reduce the production of proteins, but to reduce nitrogen loss throughout the cycle, and to replace, at least partially, synthetic nitrogen by nitrogen of symbiotic origin.

Phosphorus, a critical element

Phosphorus is relatively scarce in the lithosphere and absent from the atmosphere. It's a non-renewable geological resource, the reserves of which are estimated between 100 and 250 years. Phosphorus is listed as one of the 20 critical raw materials, and the only one that is related to food[44]. Phosphorus is not a very mobile element: with time, the fraction non-assimilated by plants can be lost through erosion and end up in surface waters, contributing to the eutrophication of aquatic environments, but mainly end up at the bottom of oceans, only to return to firm ground by the end of the next geological era.

Phosphorus conservation represents a crucial issue, both in fighting pollution and in the preservation of non-renewable resources: hence the importance of protecting soils from erosion and of entirely recycling phosphorus.

[43] Production of ammoniac by synthesis of atmospheric nitrogen and hydrogen from methane.
[44] «La planète a atteint ses limites» («The planet has reached its limits», Le "Monde" newspaper, 15th January 2015

Crop diversity, a production factor

Lengthen rotations, diversify crops over time

Diversifying productions and lengthening rotations, on a farm scale or on the territory scale, is the heart of a strategy to optimise photosynthesis and soil resources (biodiversity, mineral resources) over time and space.

This strategy allows both to reduce the addition of chemical and/or energy inputs and to add value to the associated natural resources by reducing:

- Weed pressure and thus the necessity to weed because of the alternance between grasses and dicotyledons, and of the alternance of crop periods...,
- Pest pressure by reducing soil related illnesses and by interrupting pests' cycle as they depend on a crop or a family
- Fertiliser needs thanks to more efficient recycling of mineral elements (in particular K_2O but also P_2O5).

Today, a typical crop plan in the case of a large-scale cereal crop is composed of two thirds of cereal grass and one third of high-protein oil seeds, hence a rotation over 3 years, sometimes less. Crop plans and rotations of high performing systems stretch over 6 to 8 years (so with 6 to 8 main productions), with legumes representing at least a third of the crop plan.

Associating crops and varieties on a single plot

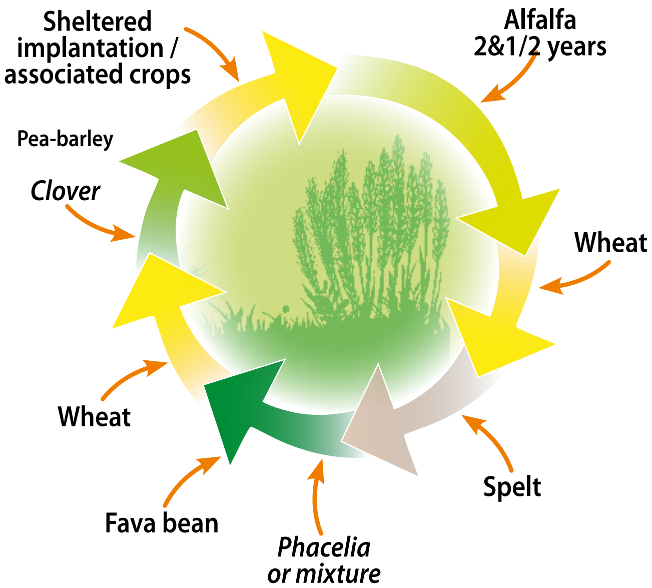
High performing systems associate different crops on a single plot, either over time (intercrops), or over the same area (intercropping), or over a vertical plane (agroforestry).

Associating several varieties (of wheat for example), including old or so-called farmers' varieties within a same plot is a path that is currently being explored to consolidate and stabilise crop yields, and make the agrosystem more resilient.

In intercropping systems, the yield of the main crop is lowered in comparison to it occupying time and space alone (pure crop).

But the global yield of the plot (that is measurable with the Equivalent Yield Coefficient) is increased as a result of:

- Optimising photosynthesis: there is always a plant (or a tree) in place to capture CO_2 and stock carbon,
- Generating synergies between productions that favour nitrogen and nutrient transfers, erosion prevention, recycling organic matter in the soil,
- Reintroducing ordinary biodiversity to the agrosystem, that favours the natural regulation mechanisms of pest populations and weeds in connection with the diversification of crop plans.



- Example of long-term rotation and balanced crop plan, the pillars of integrated production (Viaux, 2009).

Measuring the impact of the association of productions: Equivalent Yield Coefficient (EYC)

The Equivalent Yield Coefficient, defined as the relative surface necessary to obtain the same production in a pure crop as in the association, is used to compare the performance of crop associations to that of the same species cultivated separately. An EYC above 1 indicates that the association is more performant than the pure crops.

For example: when adding the production of a 1 ha plot of wheat to that of a 1 ha plot of peas, the result is 7 tons of wheat and 3 tons of peas, that is to say 10 tons in total. If wheat and peas are associated on the same 2 hectares, the pure wheat yield will be lower, for example 5 tons per ha, that of the peas also, at 2 tons. However, the total result is 10 tons of wheat and 4 tons of peas. That is to say a total production of 14 tons, that is higher than the total of the system planted with pure crops. The EYC is 1.4: 40% extra surface would be necessary to obtain the same production.

Mobilising live production factors

Biological control

Biological control is based on the presence of populations of predatory or parasite animals that are capable of limiting the population of crop pests. The term for the former is crop auxiliaries or pest-fighters, and pest for the latter.

Historically, the main biological control means was invented in California in the 1930's. It consisted in introducing species such as ladybird larvae to fight aphids: this is called augmentative biological control. Unlike augmentative biological control, conservative biological control and habitat management (CBCHM) presents a more permanent and sustainable character, as no animal species are introduced. The idea is instead to preserve and stimulate the natural enemies of the pests already found in the environment, and on the contrary to disadvantage the latter. This biological control means mainly looks into the non-cultivated plants that can be found in the crop environment (the HERBEA website presents over fifty) and are apt to offer a habitat and food to helpers and to pollinators. The agroecological infrastructures (AEI), also called semi-natural habitats, that host these plants are diverse: hedges, grass strips, fallows or flower grasslands, copses or traditional orchards, and are often related to landscape elements, that ensure the continuity and the spatial and temporal integration of these infrastructures on the scale of the territory. In order to work properly, the AEI must represent at least 5% of the UAA, the plots mustn't be too wide so as to ensure the connectivity between the cultivated area and semi-natural habitats. The semi-natural habitats mustn't receive crop protection products: even if pesticides are an agricultural production factor, they conflict with another production factor: biodiversity.

herbea
habitats à entretenir pour la régulation biologique dans les exploitations agricoles

Just like OSAE, HERBEA is an online platform that is maintained by Solagro. Its purpose: promoting biological control through the conservation of habitats. Biological control puts into practice the saying: *«the enemies of my enemies are my friends»*. HERBEA indicates what plants should be planted near crops in order to favour their helpers and to recreate food chains that are able to regulate pests. Designed for farmers, for counsellors and for teachers, HERBEA collates the observations of 200 technical and scientific references. www.herbea.org

Legumes and mastering fertilisation

Nitrogen, a key element of agricultural productivity, comes essentially from two sources: synthetic fertiliser production, that combines atmospheric nitrogen and hydrogen from naturel gas, or symbiotic fixation: from annual legumes such as peas, chick peas, green beans, dry beans, runner beans, fava beans, lentils, soya, clover, lupin, alfalfa and broom, but also trees and shrubs such as locust, acacia, alder or sea buckthorn… These plants fix atmospheric nitrogen and constituted the main nitrogen source for plants grown before nitrogenated fertilisers were introduced. All other nitrogen sources, whether livestock waste, crop residues or compost, are recirculation fluxes, not primary sources.

Reducing synthetic nitrogen consumption without reducing the associated protein production requires the application of three principles:

- Using legumes massively –as a main crop, an associated crop, an intercrop, or a crop interplanted with trees (Agroforestry)
- Maintaining permanent soil cover and deep root systems, that limit volatilisation and nitrogenated matter leaching, and in general limit losses using appropriate practices.
- Recycling the nitrogen contained in crop residues, livestock waste and biowaste generated by businesses, homes and local communities.

Crops in Afterres2050

FOCUS

The regionalisation of this scenario has allowed us to describe «basic farming units» in detail based on test cases, that is to say based on representative farms in 2010, that we have projected through to the year 2050. Some of these test cases are described below, and in the chapter «raising animals».

A large-scale crop farm in the Picardie region

A conventionnel system that is performing but that can be improved

Picardie. Guillaume Rocquecourt cultivates 170 hectares of good fertile land, and like all his neighbours, he grows cereal grass, rapeseed, beetroots, potatoes and sometimes leguminous plants. The soil remains bare in the winter, except before beetroot. An altogether conventional rotation, over 6 years: agrochemical consumption is quite high, especially for beetroot. Energy consumption and greenhouse gas emissions are around the average national level.

Switching to conservation agriculture

Guillaume Roquecourt understands that the system is improvable. The crop rotation makes little use of leguminous plants and the nitrogen record is far from being balanced. Some measures have been taken: reduced tillage, permanent cover, creation of flower strips, and implanting at least one leguminous plant in the rotation, or even two. The outcome: the plant production remains identical, at 7.5 tons of dry matter to the hectare, all crops included, agrochemical consumption is divided by two, and energy consumption and greenhouse gas emissions are reduced by a third. Because they host lots of beneficial organisms, the flower strips have allowed the reduction of treatments against potato aphids, whereas the rapeseed yield has increased, due to the higher number of pollinating insects.

Organic: alfalfa, fava beans or compost

His neighbours, the Delacher brothers, have switched to organic farming. They have added two years of under contract alfalfa to their 8-year rotation plan. On average, half of the crop rotation periods are occupied by cover plants, mustard or clover. Unlike Guillaume Rocquecourt's crop system, theirs doesn't generate a nitrogen surplus. However, the proportion of production that is for human food is of only 42%, compared to 61% for their neighbour. Indeed, the nitrogen supply comes only from legumes, and the main part of the legumes grown by the Delacher brothers is commercialised for animal feed, starting with alfalfa, which also allows to cover the soil and fight weeds. Variant: alfalfa could be replaced by other legumes, such as peas or fava bean, that can be easier to sell on the market.

The Delachers, only produce 5.4 tons of dry matter per hectare, but energy consumption and greenhouse gas emissions, considering the production, are far lower than Guillaume Roquecourt's. A major constraint: having to purchase external organic nitrogen, such as compost for example, as the nitrogen from the legumes isn't sufficient to fertilise the cereal areas correctly. Sometimes part of the alfalfa crop is composted in order to increase the system's nitrogen autonomy.

Room for improvement in each case

In 2025, legumes cover a third of the cultivated area for Guillaume Roquecourt and a half for the Delacher brothers who also grow peas intercropped with durum. For Guillaume Rocquecourt as for the Delacher brothers, improvement comes first through an increase of legumes for human consumption: lentils and soya beans, to meet the increased demand.

Second prerequisite: reducing tillage, which means in particular generalising cover plants. Guillaume Rocquecourt has now switched to direct seeding over cover crop, with no tillage, and still uses some agrochemical treatments for emergencies. The Delacher brothers don't till, but mechanical weeding remains necessary.

Guillaume Roquecourt and the Delacher brothers have joined forces to create a shared anaerobic digesteur, in partnership with the farming cooperative. The anaerobic digester is fed a mixture of straw and chaff, from green cover and cereals, that as well as biomethane, produces a local source of nitrogen that is more «organic». As an added bonus, anaerobic digestion lowers the germinating potential of weed seeds, that are collected with the chaff. The Delacher brothers save part of their alfalfa production to feed the anaerobic digester rather than exporting it and they have become completely autonomous regarding nitrogen.

Pest control based on recreating biodiversity stocks is also a pillar of the system. The Delacher brothers prefer flower strips and hedgerows, whereas Guillaume Roquecourt is an agroforestry adept. The plains in the Picardie region spring copses here, fallows there, elsewhere hedges or copses that create new shapes in the landscape.

2050: a generalisation

In 2050, the « integrated[45] production» system that Guillaume Rocquecourt applies, and the Delacher brothers' «organic farming» system, small minorities in 2015, have become the prevailing forms. An evolution that is both chosen, following the example of precursors, and imposed by the need to search for systems that are more resilient to climate change.

In 2050, the summer temperature has increased by 2°C in comparison to 2015, and rainfall between May and October has fallen by 17%. Only a tenth of farmers have stuck to old systems, more often because the land isn't a good candidate for these practices, sometimes by refusal of this form of progress.

Guillaume Roquecourt was tempted by irrigation, but quickly backed out of it. Over a few decades, the low-water flow of rivers in the Picardie region has decreased by almost a quarter. Here the costs of irrigation outweigh the benefits. Indeed, the climate accidents due to a water deficit are relatively rare: one year out of 6 in average. Irrigation is now limited to springtime, only in severe problem cases, for cereal grasses and protein crops.

Seeding and harvesting dates are earlier and the diversification of crop varieties means that productions are less sensitive to climatic variations. The system has become significantly more resilient. Wheat yield has even increased by an average of 5% in 30 years: in the Picardie region, the growth factors compensate the decline factors. In the meantime, precursors such as Guillaume Roquecourt and the Delacher brothers have handed over the baton to a new generation. Louise Delacher, born in 2016, has taken over both her uncles' farm and Guillaume Roquecourt's, with several associates. They have entirely switched to organic farming and have generalised direct seeding over cover crop. Some of the first trees planted by Guillaume 35 years ago have been cut down, transformed into beams and granules, and replaced with nut trees that have already started to produce hazelnuts and almonds, that are transformed into flours in an artisanal mill.

[45] The agricultural system, integrated production and organic farming notions are set out in «The making of Afterres2050».

Modelling farming systems

Describing agronomical systems

In MoSUT[46], modelling plant growing is based on 3 contrasted agronomical systems:

- «Conventional agriculture», that represents the majority of today's situation (90% of cultivated areas), characterised by the use of synthetic inputs (fertilisers, agrochemicals) and evolving towards gaining better control of these agents (sustainable farming);
- «Organic agriculture», following the requirements specification of organic farming and characterised by the exclusive use of organic agents (organic fertilisers and integrated pest control) and the absence of synthetic products;
- «Integrated agriculture», that is also massively based on organic agents, with some synthetic inputs however, and focusing on soil conservation (superficial soil tillage, no ploughing).

These are simplified names used for modelling, that is necessarily reductive. The real situation is and will continue to be diverse and contrasted; there are both continuities and ruptures between these different systems. All the systems imagined in Afterres2050 mobilise certain common practices, with varying degrees: long rotation periods, diversified crop plans, intercropping, integrated pest control, development of legumes and organic fertilisation, simplified tillage, soil coverage and anaerobic digestion.

They differ however in the intensity of their use of these different practices.

- «Organic» agricultures favour «organic» production factors above all others, especially the use of organic input (legumes, organic fertilisers, pest control), and totally exclude the use of synthetic fertilisers and synthetic agrochemical products. Organic agricultures give importance to agroecological infrastructures, that favour the life of biological helpers, predators of crop pests. Fighting weeds is difficult, hence the need to resort to ploughing, that damages the soil, or mechanical or thermal weeding, that are costly operations.
- «Integrated» agricultures - a term under which can be listed families ranging from agroecology, as defined by CIRAD, to conservation agriculture - favour the soil, considered as the primordial production factor. They systematically practice direct seeding over cover crop, without ploughing or with superficial tillage. Through lack, amongst other things, of specific opportunities related to consumer visibility, as is the case for organic agriculture, integrated agricultures also aim to produce yields that are close to those of conventional agriculture. Hence the authorisation to use «chemical» production factors, used as a recourse however, not systematically:
  - mineral nitrogen, so as to not limit yield in under-fertilisation situations,
  - agrochemical treatments as a last resort, to avoid plant health incidents on plots and to avoid ploughing, otherwise compromising the whole long-term strategy of building up a soil that is full of life, structured and rich in organic matter.

Imagining what a cultivated plot would be in Afterres2050

The main crop is systematically intercropped. It shares the space either with trees, or with associated crops or with intercrops. Never bare, the land is always green, or at least covered (straw). Variety mixing is generalised.

Instead of the 2 productions in the current agricultural standard - a grain and straw - a plot can virtually deliver a widened range of productions:

- The main crop grain (wheat for example),
- The associated crop grain (peas for example),
- Crop residue that will be partially recycled or returned to the soil,
- Fodder or energy biomass derived from the harvesting of unrecovered plant covers,
- Softwood, fuel-wood and/or fruit from agroforestry rows (walnut trees for example) or hedgerows.

Furthermore:

- **Covers** between two crops (intercrops) are systematically sown on plots where the water constraints are not prohibitive;
- **Associated crops** occupy 20% of arable land; they are based on cereal/legume associations, that are particularly efficient in low input systems. The cereal grain is used for human food whereas the legumes are mainly used to livestock feed;
- **Agroforestry** is strongly developing, but with a «low density». With 50 trees per hectare, for a footprint of 12%, this density doesn't lower the yield of the annual crop. In 2050, agroforestry covers 10% of the utilised agricultural area (that is to say 3 million hectares);
- 5% of the UAA are reserved for **agroecological infrastructures** (semi-natural habitats) as diverse as the terroirs and landscapes: hedgerows, copses, riparian woodlands, fallows or flower meadows, grass strips… The length of hedgerows will thus have doubled by 2050, reaching 1.5 million km.

On the landscape (or the catchment) scale, this type of plot and its installations (associated with buffer zones), allows to reduce the risk of erosion, to decrease the transfer of pollutants to water and to homogeneously spread out the agroecological installations.

[46] MoSUT: "Modèle systémique d'utilisation des terres" ("Systemic model of land use") is the scenario tool developed by SOLAGRO. See «The making of Afterres2050 – the approach».
[47] There are however some agrochemical products in Organic Farming, among which metal-based products (copper) such as Bordeaux mixture.

Creating scenarios for plant productions

Modelling consists in describing different agricultural systems (conventional, organic, integrated) and their variants according to practices (with associated or intercrops, agroforestry), describing their evolution over time, and varying the area occupied by each of these systems, for each of the 23 main crops. Each main crop is characterised by its productions, production factors, and impact indicators, forming a whole coherent system. The productions include not only the main crop, but also the associated or intercrops, and the wood from the wooded elements. The production factors - consumption of energy, nitrogen, water, agrochemical products, etc. - also evolve over time. The simplified culture techniques allow to reduce the use of machines; nitrogen fertilisation control leads to a reduction of the use of synthetic fertilisers, and pest control to a reduction of the use of agrochemical products.

The impact factors stem from the chosen orientations -for example the proportion of agroecological installations, carbon storage in the soil, the treatment frequency index (for agrochemicals)- and the indirect consequences of these choices: the nitrogen surplus is calculated for each system as the difference between plant requirements and inputs, considering the proportions of nitrogen really used.

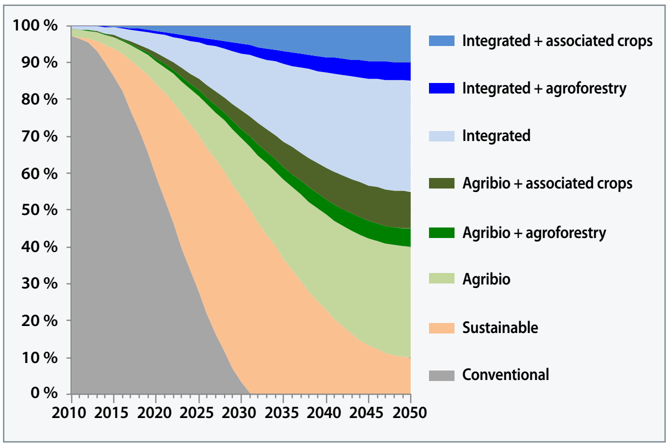
Detailed modelling deals essentially with 23 main plant productions, representing over 95% of cultivated areas: cereals, oilseed, protein crops, natural meadows, orchards and vines and industrial crops. The other crops (in particular vegetables) exist in the model, but are not detailed.

Soft wheat	Grain corn	Field peas	Natural less productive grasslands and meadows
Durum	Forage corn	Fava beans	Apples
Barley	Rapeseed	Productive natural grassland	Vine
Triticale	Sunflower	Temporary grassland	Sugar beet
Oats	Soya	Temporary legume grassland	Potatoes
Rye	Sorghum	Temporary mixed grassland	

- The 23 modelled productions.

Bringing cultivation systems to evolve

The agricultural production scenarios are based on generalising the current systems that are considered the most performing ones. The agricultural transition rhythm proposed in Afterres2050 defines a continuum in which conventional agriculture progressively gives way to sustainable agriculture, that disappears around the year 2030. At the same time, integrated production and organic agriculture progress, representing 90% of cultivated areas in 2050. Several variants can aggregate around these systems, depending on the agronomical potential of territories: agroforestry, intercropping…



- Evolution of different plant production systems.

Estimating yield evolution and the impact of climate change

Climate changes are going to impact the behaviour of crops, which will also be submitted to stronger intensity extreme hazards. Plant growth, that is to say the successful completion of plant cycles, from germination to death, is indeed determined by accumulated temperatures, whereas plant development and «productivity» depend on water availability.

Given the diversity of climatic situations in France, climate changes (temperature increase and rainfall decrease) will be detrimental for some zones but will offer new opportunities to others. An uncertainty remains on the extreme hazards that will have an impact on biomass production, that we can't currently evaluate however. Let us underline that the 1976 and 2003 heat waves reduced French agricultural production by 25% and showed just how vulnerable we are.

The prospective works carried out in France over the last years have been regrouped in the CLIMATOR[48] project. The scenarios created with MoSUT are based on the integration of these different works and on the research of average yield per culture and per region, so as to consider differentiated climate evolutions, while remaining cautious concerning the potential yield improvements.

The scenario selected as a model is the RCP 6.0[49], that corresponds for France to an average temperature increase of 1.6°C for 2020-2050 and 3°C for 2070-2100. It is not a very optimistic scenario, leading to a world average of +2.2°C, that is higher than the intended target, and that is detrimental to agricultural production and to the forest. Let us consider the example of soft wheat, that is an emblematic culture and

[48] http://www.avignon.inra.fr/projet_climator
[49] These are scenarios created by GIEC in its 5th evaluation report

remains the most widespread, with a third of arable land. From 1960 to 1985, the yield progressed by nearly 1.5 quintal per year. Between 1985 and 2010, progression was down to 0.5 quintal per year. Over the last 15 years, the soft wheat yield in France was 72 quintals per hectare. The average yield per hectare of the worst 5 years was 67 quintals, compared to 74 quintals for the other 10 years. This yield decrease (-10%) during these 5 years is estimated to be due for 60% to summer conditions (flower blast, lack of water) and for 40% on the contrary to temperatures that were too low, or to an excess of water.

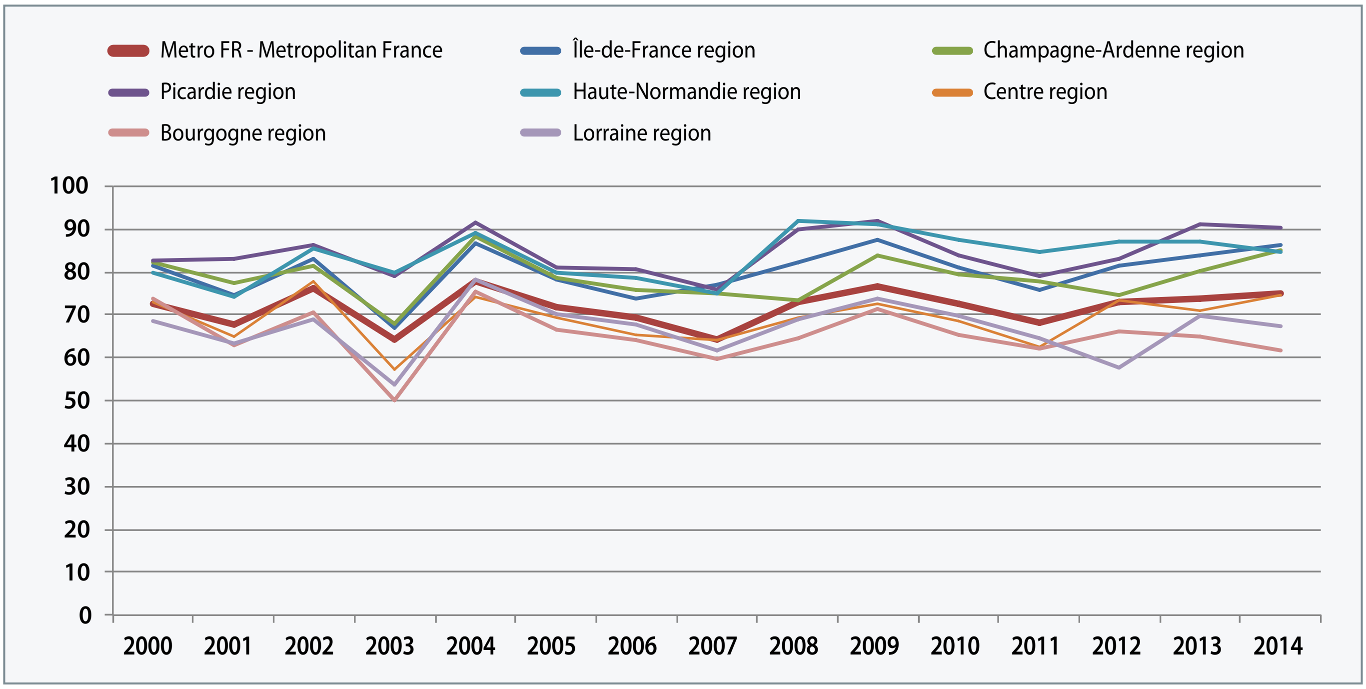
With climate change, these incidents would not repeat once every three years, but in 2 years out of three. In other words, today's «incidents» would become tomorrow's norm.

North of the Loire, these changes could benefit certain cultures because of a reduction of soil waterlogging phenomena and of freeze periods; the yield would increase, by 4 or even 5% in the Parisian Basin.

South of the Loire, the changes should accentuate the existing constraints, that are already strong: a pronounced lack of water especially in the summer, a more strongly erosive climate and reduction of organic matter in the soil. Over all the southern half and up to Britany and the Bourgogne region, the average yield of soft wheat will tend to decrease, with an accentuated fall in the Mediterranean region (-15%), but also in Aquitaine and Midi-Pyrénées regions (around 10%). Irrigation would only allow to improve this yield by 2 quintals on pluriannual average.

The approach developed here is a cautious vision. Several yields increase factors are not considered, for example longer rotations and crop diversification provide a positive impact on yield, but it is hard to quantify. Furthermore, the effect of climate change could turn out to be more severe, as there is no guarantee that the world greenhouse gas emission trajectory may be contained within acceptable limits.

These effects are partially integrated in the case of organic agriculture, that provides ample margins of yield improvement: today's yield is at about half of the yield reached by conventional agriculture, the difference would be reduced to about a third in 2050.



• Multiannual variability of soft wheat yield in several French regions (quintals per hectare).

Primary plant production quantity preserved and diversified in the long run

The combined evolution of the proportion of each cultivation system and the evolution within each system leads to significant changes of the main crop characteristics.

For tender wheat for example, wheat production per hectare drops from 7.1 to 5.2 tons of wheat grain per hectare, on average and on a national scale. An evolution due to switching to 50% organic, to the presence of other associated or intercrops, and to the decrease of the sown surface because of the implantation of agroecological infrastructures. These other productions compensate the wheat yield decrease. In total, the biomass production of wheat lands (that is to say the plots having wheat as a main annual crop) increases slightly from 14.4 to 14.8 tons of grain or dry matter per hectare. By mobilising all the agroecological practices adapted to these types of systems. there are important effects: the quantities produced remain close to their current level or even increase and the impact indicators are all significantly improved. Agrochemical product consumption, measured by TFI (Treatment Frequency Index) drops from 6 to 1.4 [50], representing 100% reduction in «organic agriculture» and from 30 to 50% in «integrated production». The agroecological infrastructure surfaces (AEI) increase from 1.9% to 4.7%. Energy consumption decreases by a third.

[50] The hypotheses of agrochemical pressure reduction are taken from the INRA-ECOPHYTO R&D study.

1 ha de parcelle «blé tendre» en culture principale, moyenne nationale		2010	2030	2050
Main crop yield	t grain	7.1	6.0	5.2
Associated crop yield	t grain	0.0	0.2	0.4
Intercrop yield	t MS	0.1	1.8	3.5
Wood production (agroforestry)	t	0.0	0.06	0.1
Industrial wood/ energy wood (hedgerows + agroforestry)	t	0.1	0.2	0.3
Crop residues	t	7.1	6.1	5.3
TOTAL AERIAL BIOMASS	**t**	**14.4**	**14.4**	**14.8**
Nitrogen exports [51]	kg N	181	212	254
Nitrogen symbiotic fixation	kg N	2	34	69
Nitrogen requirements	kg N	179	175	177
Energy consumption	GJ	95	71	63
Carbon Stock	t C	51	58	70
Agroecological infrastructure surface (semi-natural habitats)	%	1.9	3.3	4.7
Treatment frequency index (agrochemicals)	Number	6.0	2.9	1.4

- Result example: synthesis of the main characteristics of a one-hectare soft wheat plot (integrating agroforestry and associated crops).

Key hypotheses

- All arable land is permanently covered, no soil remains bare: cover crops are generalised when possible, stubble and straw are left in otherwise
- All agricultural land is equipped with agroecological infrastructures (hedgerows, agroforestry…).
- Intercropping is practiced on 20% of arable land, and agroforestry on 10%
- No ploughing is generalised, with direct seeding when possible, or with superficial tillage otherwise
- Half of the arable land is managed with organic agriculture, the other half with integrated production. Conventional agriculture has become marginal in 2050
- The proportion of protein crops significantly increases, while cereals decrease
- Irrigation is only used in the spring

Trees and forests

A productive and sustainable silviculture

Preserving forest multifunctionality

As with agriculture, the Afterres2050 scenario is based on the development of a silviculture that is both productive and sustainable. The economical function of the forest must be increased, while improving its ecological, landscape and societal functions.

Agroecology principles can also be applied to the forest. The aim is to maintain a high production level while increasing the ecological value and the resilience of forest systems, in a climate context that will probably become less and less favourable.

In the French trade balance, the agglomerate «wood, paper, paper pulp» is the second highest deficit accounting item, the first being the agglomerate «petrol, gas, coal». One exception to this: the accounting item «used papers» is in excess, with the poor excuse that Germany was the country to invest in the recycling plants while France exports its paper to be recycled.

Reducing imports, especially of uncertified wood from deforestation, while increasing the proportion of construction wood is possible: the French forest must play a central role, the challenge being to significantly increase harvest, while also increasing the eco-systemic services provided [52].

Resilience and adaptation to climate change

The adaptation constraints are much stronger regarding the forest than they are for agriculture. The forest's response both to extreme events and to general evolutions -water stress, storms, increase of water requirements because of longer vegetation periods and the emergence of new illnesses– is difficult to predict. The French national adaptation plan to climate change recommends to re-establish diversity in

[51] Nitrogen exports represent the quantities that are fixed by plants: it increases thanks to legumes. The nitrogen requirement is the balance between exports and symbiotic fixation, it represents what is necessary to provide to the plot. It remains stable because legumes provide as much nitrogen as they export.[53] Construire une société soutenable : quelle production pour quels usages du bois des forêts françaises ?

[52] Construire une société soutenable : quelle production pour quels usages du bois des forêts françaises ? (Building a sustainable society: what production for what uses of the wood from the French forests?) Les Amis de la Terre (The Friends of the Earth), May 2009.

populations, to favour the most resistant species, and to modify interventions (thinning, tree spacing) so as to put the water resources, that could become a limiting factor, to their best use. The introduction of more southern species is also suggested. The migration of the distribution zones of tree species is considered unavoidable, provided that the species have the time to migrate before dying out. Foresters are now thinking about modifying reforestation species to better anticipate climate change.

Forest, wood and carbon footprint

Wood's carbon neutrality in question

Wood as a material has the reputation of being «neutral for the climate» as it stocks carbon. Energy wood was up until now also considered neutral for the climate, since its combustion reemits the carbon absorbed during the tree's growth phase. This reasoning is valid for annual crops and short cycles. Where the forest is concerned, it only applies if the forest has reached its climax, that is to say a stable state in which regeneration compensates mortality. Harvesting wood, when the forests are sustainably managed, does not modify the standing stocks. Substituting energy with wood reduces the carbon dioxide emissions due to the carbon destocking brought about by the combustion of a fossil resource.

Yet our forests haven't all reached the climax stage: proof of this is that the French forest as a whole stocks carbon in massive quantities. The non-harvest of wood constitutes a form of carbon storage, that can be compared to the different ways of using wood. The net balance is based on the notion of cycle length. Using wood in the long term (framework) allows to stock carbon over several decades, generations or even centuries. Using wood in the medium term (paper, furniture) or the short term (energy) constitutes a shorter cycle, of several years on average, and doesn't constitute a sustainable form of storage.

Evaluating the carbon footprint of wood uses, either as a material or as energy, amounts to comparing several silviculture and wood use scenarios, and these comparisons generate numerous debates and controversies[53]. The «sequestration» effect (carbon storage in forest ecosystems or in wood products) and the «substitution» effect (replacing energy and material with a high carbon footprint - fossil, aluminium, concrete…- by bio-sourced products) are generally in opposition. Depending on the scenario, the «carbon return time», that is to say the time required to obtain a positive balance with an increased harvest, varies between 10 and 50 years.

Favouring itineraries with a low carbon return period

There is a quite wide consensus to prioritise wood as a material for construction, that offers the longest storage periods. In this context, the energy valorisation of «bonded wood», that is to say wood parts that are not suitable for construction use, presents a neutral balance, as this is the by-product of a main activity that would have decomposed on location if it hadn't been used.

Conversely, a purely energetic use of wood can present a high carbon return period, when harvesting from a growing forest. This is the case for coppices for example: this traditional form of silviculture turns out to be quite intensive, harvesting 8 to 10-year-old offshoots. It could be compared to other scenarios, in particular to high forest conversion. However, for this comparison to be relevant (and the carbon footprint balance computable), the markets for timber would have to exist.

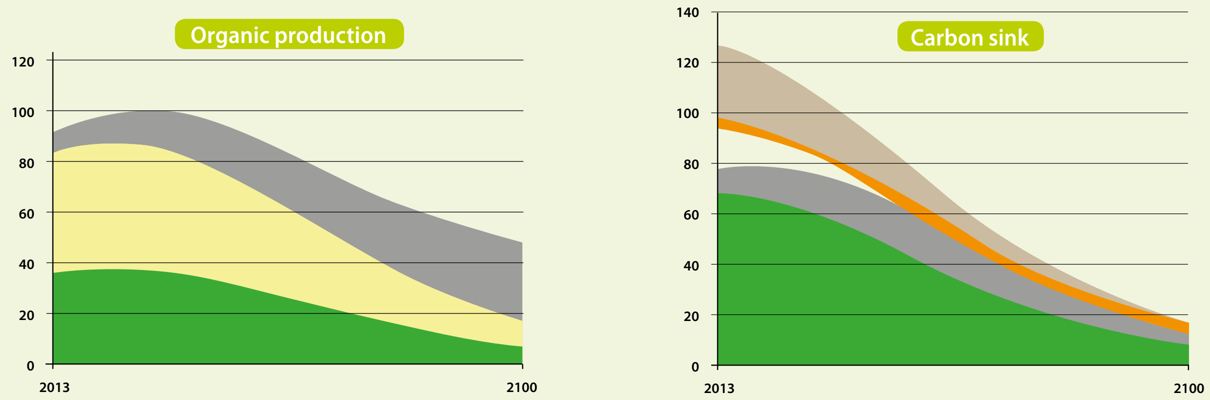
That is not currently the case for hardwood timber. The French forest currently consists mainly in deciduous trees, whereas the demand is mainly on resinous trees. Increasing the wood used in construction could paradoxically lead to an increase of softwood import while the French deciduous forest would remain under-used.

Increasing the uses of hardwood timber is the main pivot of future forestry policies. It isn't the only one: substitution policies can go hand in hand with a dynamic silviculture that allows to increase the sequestration potential. The two logics are not systematically opposites. The challenge is on the contrary to maximise the possible synergies.

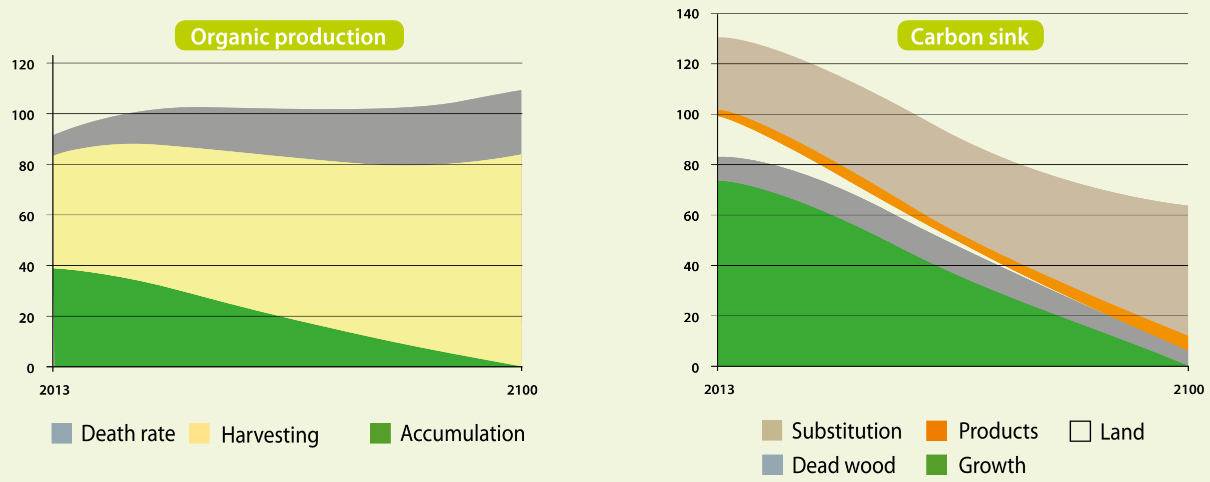
[53] See the ADEME notice: Forêt et atténuation du changement climatique (The forest and attenuating climate change), June 2015.

Jean-Luc Peyron, director of ECOFOR, recently set the first figures of the long-term future of the French forest, according to different climate and forestry scenarios [54].
In the «constant forestry» scenario (top graph), the annual organic production (left hand graph) eventually decreases, and mortality takes away the most of the increase. The harvest drops, as does the accumulation of forest biomass. In the « dynamic forestry» scenario, the harvest is in line with «100% of net annual increase». Organic production remains constant or even increases. The net accumulation ends up becoming null. The «carbon sink» function (right hand graph) – the sum of storage in the forest (growth, dead wood and soils) and in bio-sourced products (material and energy), combining the effects of sequestration and of substitution for the French forest in 2100, drops dramatically in the constant forestry scenario in 2100, and is divided by 2 in the dynamic scenario. These still exploratory works can be credited for underlining the importance of taking lengthy time periods into account, and for reasoning beyond 2050: the diagnosis is different when reasoning in short, medium or long term.

Constant forestry scenario: dieback through mortality



Scenario where harvesting is aligned with 100% organic production in 2100



[54] Mentioned in « climat, forêt, société – livre vert » («climate, forest, society –green book») Y. Caullet, Nov 2015.

Afterres2050

Raising animals

Three dilemmas

Intensive or extensive? Monogastrics or ruminants? Grass or grain?

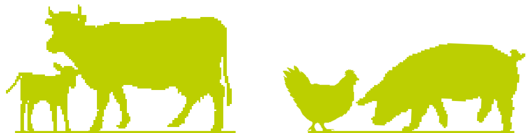
Conciliating food performance, greenhouse gas emissions cuts and animal well-being

The «food performance» of farm animals can be measured using as main parameter the ratio between ingested food and production. The term consumption index is used to express the quantity of meat produced from the quantity of grain consumed for example, or the ration of fodder or concentrate ingested per litre of milk produced.

The lower the index, the more the animal «makes the most» of the ingested food. Some foods, such as grain, are very digestible, whereas others, such as grass or fodder, can only feed ruminants which have a digestive system capable of decomposing the cellulose and the hemicellulose. The current French cattle herd is fed with 68 million tons of grass (dry matter) from permanent grassland (as hay or in the pasture) and from annual (corn, sorghum) or pluriannual forage crops (mixed temporary grassland, alfalfa, clover) and 12 million tons of concentrated feed (cereals, rapeseed or soya meal, co-products of food industries, etc.). It produces 1 million tons of protein as meat and milk.

As for monogastrics (pigs and poultry), they ingest 16 million tons of food and provide 0.6 million tons of protein in the form of meat and eggs.

The energy balance for monogastrics is thus better than for ruminants: globally 3 times less plant food is necessary for the same quantity of proteins, and as a consequence less space also. The same applies for the greenhouse gas balance: the enteric fermentation, that represents the main methane emission accounting item in France, is mainly due to ruminants.



		Bovines	Monogastrics (pigs + poultry)
Grass and fodder	millions of tons (of dry matter)	68	-
Concentrated food	millions of tons	12	16
Meat	millions of tons	1,5	1,5
Milk	millions of tons	25	-
Eggs	millions of tons	-	0,8
Protein	millions of tons	1	0,6

• Consommation d'aliments et productions animales (synthèse, moyenne France 2008-2012).

Conversely, French cows are still for the main part grass fed (in the pasture or with hay, silage, alfalfa pellets). Admittedly, dairy farms consume grain and meal, and veal is fattened with grain, when not exported to Italy. But unlike American feed-lots (fattening parks) for example, French cattle spend half their time in grasslands –a little more for meat cattle and a little less for dairy cattle.

Furthermore, grasslands offer essential functions: biodiversity, carbon sink, protection from erosion, landscape… Altogether, natural grasslands, including low production grasslands and high-altitude grasslands, stock 8.5 million tons of equivalent-CO_2 per year, which partially compensates the 34 million tons of equivalent CO_2 enteric methane produced by ruminants.

On another note, monogastrics consume grain and so come directly into competition with human food. This competition is far harsher than the competition brought on by the biofuel industry for example, as almost 50% of the cereals and high-protein oil seeds consumed in France are used to feed animals. Conversely, ruminants allow to make use of natural grasslands, without any competition with human food.

White meat to fight climate change?

However, «white meat» doesn't offer only advantages. Monogastrics are mainly produced through intensive farming, in an environment where the animals are battery farmed with a very optimised diet.

Livestock farms that are based on this model often rely on imported feed, with no link to the land -hence the nitrogen and phosphorus excess problems in intensive farming regions- on the massive use of pharmaceutical substances (antibiotics), and according to a fragile economic model that is submitted to fierce international competition.

What arbitration when facing today's challenges?

To synthesise, from a natural resource use and climate change point of view, ruminants and monogastrics both present a series of advantages and inconveniences, and arbitration between these two vast animal categories must consider contradictory criteria. In all cases, animal farming systems will have to take new phenomena into account.

First of all, the rarity of natural resources will push us to seek out the best efficiency and thus favour the lower consumption indexes. Today grain is abundant and cheap, it is used in vast majority to feed «monogastric» animals (pigs and poultry), but also ruminants. In olden days (before the generalisation of tractors and fertilisers), the main function of livestock animals wasn't to produce meat, but to provide driving power (oxen and draft horses) and milk and eggs. Hens and pigs were farmyard animals fed with kitchen leftovers and whey, and grain was only sparsely given. Cattle mainly provided energy (animal power); milk was only in second place in the services provided by cattle, and meat in third. The «meat breeds» essentially describes ploughing breeds. Conversely, questions of public health, of animal wellbeing, favour quality productions, with in particular increased rearing periods and as a corollary, an increase of the consumption index (and of the portion of grass in ruminants' fodder rations).

Back to grazing

De-intensifying dairy farming to preserve natural grassland

The discourse about the role of ruminants in the preservation of pastures -with the questions of biodiversity and of carbon storage in the associated grasslands- often ignores the fact that the intensification trend leads on the contrary to «no grazing». Seeking maximal milk productivity means using concentrated feed, that as its name indicates, allows to provide more digestible energy for the same stomach volume. The large size of herds allows at the best access to an exercise area, not to pastures with a balanced storage rate per hectare[55]. Preserving pastures thus means a limit both to the size of herds and to the storage rate[56].

Returning to mixed breeds

Dimensioning both dairy and meat herds stems from two main factors. Milk production needs determine the size of the dairy herd, by dividing the global production demand (billions of litres of milk per year) by productivity (litres of milk per cow). As for the meat cattle herd, it is not solely dimensioned by the cattle meat production needs, as the meat produced by the dairy cattle herd must also be considered: veal calves and cull cows. The meat cattle herd is thus dimensioned by the difference between the meat production needs and the meat production of the dairy herd.

Yet the evolution of different animal farming systems on the one hand and the evolution of milk and meat consumptions on the other leave little room in the end for bovine meat systems. Hence the priority given to the scenario with «mixed breeds», that produce both quality milk and quality meat.

Cattle farming would thus evolve towards mixed breeds, putting an end to the dichotomy between milk and meat herds. Its geographical distribution would be profoundly changed, the central question being the balance between the vast dairy regions of Western France and the mountainous animal farming zones.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[55] The storage rate is the number of cows per grassland and forage crop area.
[56] See the dossier « Pâturage des grands troupeaux » («Large herd grazing»), Britany Agriculture Chamber, Nov. 2012. It describes farms that practice grazing, however the animal farms of the observation network had less than 150 dairy cows.

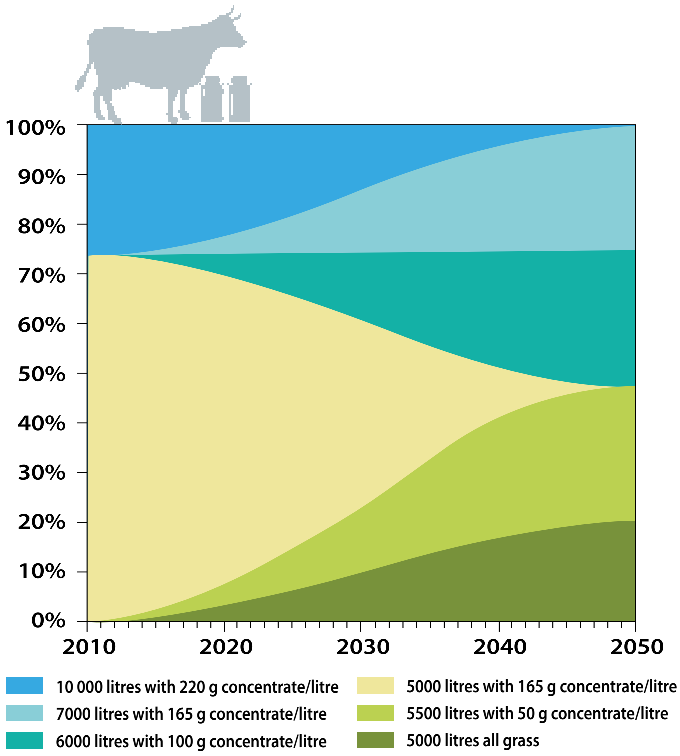
Modelling animal farming systems: ruminants

Cattle

The dairy cattle herd is described according to 6 animal farming types that are mainly differentiated by their milk productivity and their diet. A dairy cow currently produces an average of 6, 500 kg of milk per year. The most productive produce over 10, 000 kg: in this case they are fed mainly with concentrates and silage, graze little, and are submitted to extensive genetic selection. Conversely, rustic breeds capable of making good use of more difficult environments such as high-altitude grassland or grasslands and that can be fed only grass (pasture and hay), produce 5 000 kg of milk, or even less.

The scenario proposes a general evolution towards less intensive systems[57]. The 10, 000 kg dairy cow would disappear, whereas on the contrary, the extensive systems become even more so, with an «all grass» herd that would occupy a significant place in 2050 (20% of headcounts), and would widely substitute themselves to bovine meat farming.

The key factors are the concentrate feed consumption, that directly impacts the milk productivity per cow, and the grazing time that impacts the relative portion between pasture grass and fodder, and directly influences the capacity to maintain permanent natural grasslands or not. Other relevant factors are also modelled, for example food digestibility, the attenuation coefficient of enteric fermentations, or the farm animal waste management system, factors that count in greenhouse gas emissions for example.



- Distribution of milk producing cattle systems in Afterres2050.

The zootechnical characteristics of an «average» dairy herd evolveas indicated in the following table:

Type	Average grazing time	Concentrate (g/l milk)	Milk production per cow	Pasture grass	Fodder	Concentrate
				tMS per cow (including followers)[59]		
10 000 litres no grazing	10%	220	10 000	0.86	8.53	3.1
5 000 litres – current	50%	165	5 000	4.03	4.79	1.7
5 000 litres all grass	80%	0	5 000	5.97	2.85	0.8
5 500 litres – very economical	75%	50	5 500	5.60	3.22	1.1
6 000 litres with 100 g concentrate	60%	100	6 000	4.48	4.34	1.4
7 000 litres with 165 g concentrate	50%	165	7 000	4.01	5.38	2.1

- Main characteristics of current and future dairy cattle systems (grass, fodder and concentred feed consumption, also includes follower feed[58]).

Today's bovine meat herds are quite extensive, with a lot of grazing: overall almost two thirds of the time. They retain their characteristics in Afterres2050, grazing time increases slightly; the main modification is the headcount.

Characteristics of an average dairy herd		2010	2050			
			Trend	Afterres	BHF	PAR
Milk production	Litre / cow	6.300	7 400	5 900	5 800	5 800
Grazing time		40%	36%	66%	68%	62%
Fodder ration	Tons of dry matter per cow and per year	5.8	6.3	4	3.8	4.3
Concentrate consumption	g/litre of milk	179	184	83	70	101

- Characteristics of a dairy herd.

[57] These systems would be coherent with the specifications of numerous AOC cheeses, based on a stronger autonomy and a more important portion of grass in the ration.

[58] All this data relates to cow headcounts, but it includes the feed and the production of what is called «followers», that is to say the other animals that accompany the cow, usually classified according to the following names: calves of less than a year, heifers 1-2 years, heifers over 2 years, yearlings 1-2 years, bulls over 2 years.

[59] Pasture: tons of grazed dry matter. Fodder and concentrate: tons of dry matter consumed in the stable. Fodder combines conservation forage (hay, alfalfa granules, etc.) and all forage crops (silage, collard, etc.).

Sheep and goats

Sheep farms are mainly located in rather challenging areas: 80% of sheep meat farms are eligible for the CAP ANC[60] allowance. Sheep can make good summer use of low production areas such as mountain pastures, high-altitude grasslands, Causses. In France, lactating ewes (intended for meat production) are fed at least 63% by grazing, and at least 80% by grass when counting hay.
Ewes are essentially present in the Alpes and the Pyrenees (collective pastoral systems), the Massif Central (extensive grassland systems), and in the Poitou region (more intensive feed system). Sheep pen systems, where the animals go out less and consume 40% of their feed as concentrates, represent a small minority. Dairy systems, whether with sheep or goats, are more intensive, with less grazing and more concentrates. There is an important proportion of milk produced in France with a quality label or in direct transformation (cheese). Sheep farms will have to face the impacts of climate change in these particularly fragilized regions, especially in the Southern half of France. They will furthermore persist in plain regions, and even, according to the Afterres2050 hypotheses, progress, as they allow to make good use of poor lands or small areas. There are lots of possible improvements[61]: for example, managing lambing in a better way, dynamic grazing rotation (or «techno grazing»[62]), more low input systems, etc.
In Afterres2050, the main characteristics of sheep and goat systems are not modified: the possible improvements simply allow to compensate both the consequences of climate change and the trend to increase concentrate feed consumption.

Modelling animal farming systems: pigs and poultry

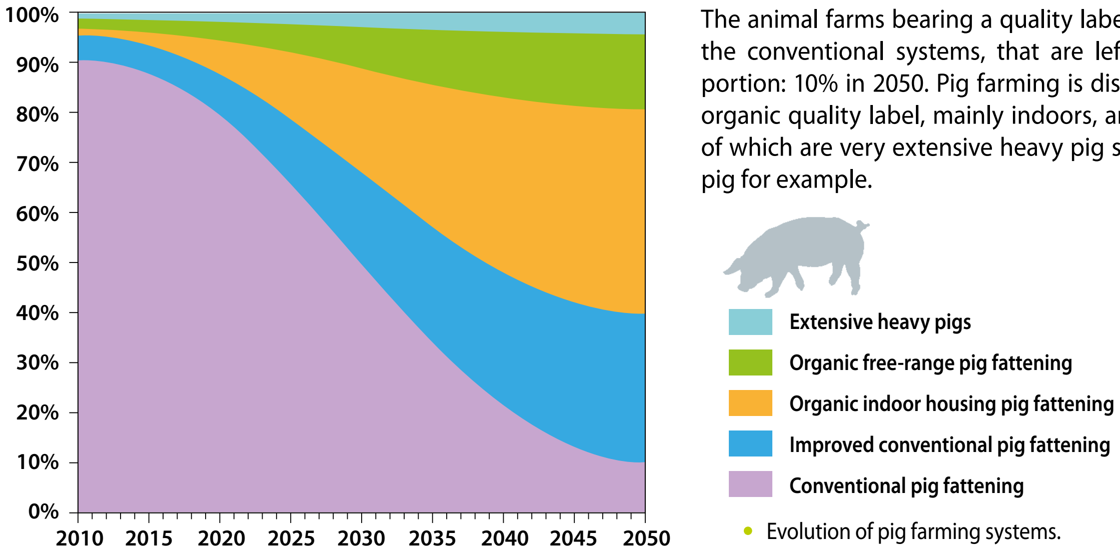
For monogastrics (pigs and poultry), the key factors are the available surface per animal, access to outdoor areas, the fattening period, the consumption index and body weight. The model includes a mortality rate that can vary according to the nature of the animal farm.

Porcine production

In porcine production, the current conventional system is largely dominant. The animals bearing an official quality label represent 3% of French slaughter. The current organic systems stand apart in particular because of a far larger indoor surface and access to exercise areas. An «improved conventionnel» system appears in the Afterres2050 scenario, that would stand out from the current one in particular with a far bigger building area, almost double the conventional one.

Type	Fattening period (days)	Number of lots per year	Consumption (kg concentrate per kg body weight)	Building surface, m²/animal	Exercise surface, m²/animal
Conventional	120	2.7	2.7	0.73	0
«Improved» conventional	133	2.5	2.8	1.21	0
Indoor organic	145	2.3	3.1	2.65	40
Free-range organic	145	2.3	3.2	0	84
Extensive (heavy pig - Gascon black pig for example)	365	0.9	3.9	0	212

- Characteristics of porcine productions.



The animal farms bearing a quality label progressively replace the conventional systems, that are left with only a residual portion: 10% in 2050. Pig farming is distributed between 60% organic quality label, mainly indoors, and 20% free-range, 4% of which are very extensive heavy pig systems – Gascon black pig for example.

- Evolution of pig farming systems.

[60] Common Agricultural Policy Compensatory allowance for areas facing natural constraints. Source: « Comprendre les enjeux environnementaux dans l'élevage ovin » («Understanding environmental issues in sheep farming»), IDELE and INTERBEV, Sept. 2014.

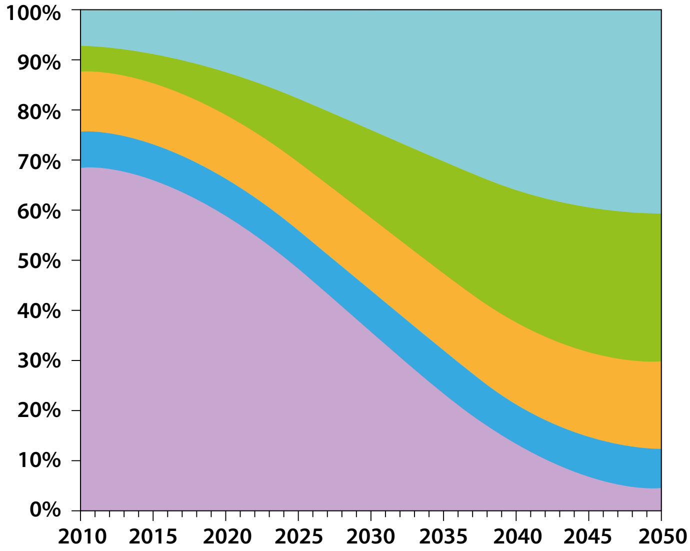
[61] F. Boquier et al., Innovations et performances environnementales en production caprine et ovine : Expertise Elevage-Environnement à l'INRA (Goat and sheep environmental innovations and performance: Animal farming-Environment Expertise at INRA), Agronomical Innovations 12 (2011), 29-52
[62] See http://www.osez-agroecologie.org/delpech-paturage-tournant

Laying hens

Standard egg production represents 68% of the total production, organic production 8% and the rest (Red Label, free-range, barn) 24%. In the quality label or organic systems, performance is almost the same: egg production is under 12%, but the hens have twice as much space.

Type	Number of eggs per year	Mass (g/ egg)	Feed consumption g/ day	Length of stay, days	Building density, hen/m^2
Standard caged hens	293	63	112	350	13
Standard barn hens	257	59	110	333	9
Standard free-range hens	259	61	115	332	9
Quality label hens	263	59	118	336	9
Organic hens	257	61	112	334	6

• Characteristics of laying-hen farms.



In Afterres2050, organic layer hens represent 40% of the workforce, labels and outdoor 47%, and standard farms 13%.

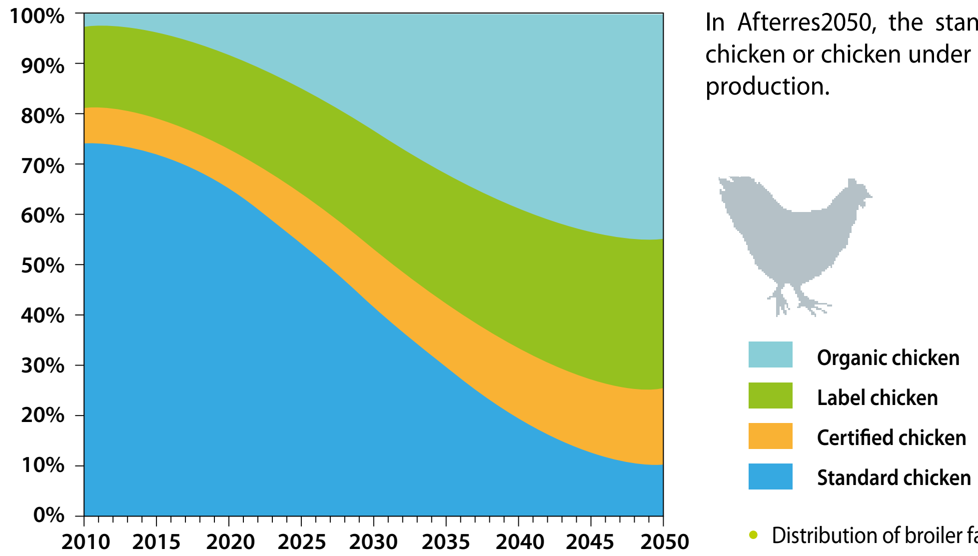
• Evolution of laying hen farming types

Broiler poultry

Standard chickens are reared in 40 days, or even less. The consumption index is now at 1.7 kg concentrate per kg of body weight. The productions bearing a quality or origin label (SIQO) represent 15% of poultry meat production, including organic. In the label-bearing or organic systems, the rearing length has almost tripled, at the cost of a higher consumption index, almost double the standard one.

Type	Type	Rearing length, days	Number of lots per year	Consumption index (kg concentrate per kg body weight)	Body weight, kg
Chicken	Standard chicken	37	6.7	1.7	1.9
	Certified chicken	58	5.2	2.2	2.2
	Label chicken	81	3.3	3.1	2.2
	Organic chicken	95	3.0	3.3	2.3
Turkey	Medium turkey	116	2.6	2.3	8.8
	Label turkey	140	2.1	2.4	4.3
	Organic turkey	140	2.1	2.4	4.3
Guinea fowl	Standard guinea fowl	79	3.6	2.9	1.6
	Label guinea fowl	102	2.9	3.8	2.0
	Organic guinea fowl	94	2.5	3.7	1.7
Duck	Ready to roast duck	85	3.4	2.8	3.4
	Ready to force-feed duck	86	3.6	4.0	4.1
	Fattened duck	12	19.0	6.1	1.6

• Characteristics of poultry farms.



In Afterres2050, the standard chicken gives way to organic chicken or chicken under label and represents only 10% of the production.

• Distribution of broiler farming types.

Key hypotheses

- The cattle herd is massively redirected towards a grass system, concentrate consumption falls
- Milk productivity per cow decreases as the feed changes
- The headcount of mixed breeds is stable, the proportion of breeds specialised in milk or meat strongly drops
- Milk production is rebalanced over the whole territory
- The «standard» level in monogastric farming becomes residual (10% of farms), profiting productions that bear a quality label, half having an organic agriculture label and other labels (for example Red Label or Certified).

Animal farms according to Afterres2050

FOCUS

A bovine meat farm in the Centre Val de Loire region

A classic polyculture animal farm

With70 Charolaise cows on 125 ha of crops and grassland, Aurélie and Nicolas Robin's GAEC ("Groupement Agricole d'Exploitation en Commun": a jointly run farm) is typical of the bovine meat farms that can be found in the Val-de-Loire region. Permanent grassland represents a third of the UAA, temporary grassland another third, the rest is allocated to cereal crops -wheat, barley and rapeseed- that are partly self-consumed. Summer grass growth is sufficient to allow grazing in the summer and autumn. The spring stock generally lasts through the winter with no particular problems. The farm is autonomous regarding cereal and hay, but buys meal.

Diversify, work on the after-production, radically reform the fodder system

Robin GAEC is part of the Terres-Étangs EEIG - including about twenty other animal farmers - that practices short circuit transforming and selling. This approach is based on a contract concluded with the Châteauroux central kitchen. The farm first passed under a quality label, then under an Organic Agriculture label. Its goal is to become autonomous regarding feed and to diversify its productions. The constraint: the summer growth is becoming less reliable with climate change; the ration sometimes needs completing. More and more often, all of the permanent grassland is grazed in summer, leaving less potential to build up fodder stocks.
Aurélie and Nicolas have chosen to reduce the lactating herd by half and to convert the forage crop areas to cereal and high-protein oil seeds. The rotation is much more diversified, the proportion of agricultural land for human consumption has tripled thanks to legumes. The crops that are sold have increased significantly, the transition to integral no ploughing was progressive.
The 42 ha of permanent grassland are entirely preserved. Grazing only consumes part of the grass and allows to build up hay stocks. In a normal year, part of this hay is used for the cattle and another part is used for biogas production in digester managed collectively by the Terres-Étangs EEIG. The biogas plant is also fed the manure

produced in winter. The quantity that is transformed into methane represents a quarter of the grass production. If it is a difficult year, the farmers have two options: on the one hand give the animal feed priority by using some of the hay stock, or on the other hand to preserve the energy production by reducing the herd. The biogas plant allows to both spread out the nutrients and organic matter near to the farms and to provide new income sources: biomethane is sold under contract with Châteauroux city via the naturel gas network: it provides the consumption of half of the city's bus fleet. The energy production adds to the electricity produced by the 300 m^2 photovoltaic panels implanted on the buildings. This diversification and quality upgrade approach has provided real room for manoeuvre, and makes the GAEC far more resilient.

Switching to mixed breeds

Maxime Bonnin, an associate of the same EEIG, has chosen differently. He has indeed reduced the herd, but above all, he has chosen the Nantaise cow, a mixed and rustic breed, to produce both milk and meat, which allows him to make use of his poor and humid lands in winter. With an associate, he also owns a little herd of Berrichon du Cher, a cattle breed that is appreciated for the quality of its meat. This activity allows him to provide services to his neighbours, lots of whom have neglected or remote plots, for which cattle can be an interesting solution. Maxime has adopted the Dynamic Rotational Grazing (DRG) practice, an imperative for his herds to coexist and to optimise grass valorisation. Maxime has also invested in pisciculture: the ponds in the Brenne are experiencing an unprecedented dynamism, due to the maritime fishing fall. The star product: royal carp, bred extensively and fed with aquatic insects and zooplankton, produced using digestate from the production of methane as a nutrient source.

A cattle dairy farm in the Rhône-Alpes region

Resisting abandonment

Thomas Morel breeds Montbéliarde cows on 59 hectares, of which 32 ha are natural grasslands, 18 ha are temporary, 8 ha are planted with barley and triticale and 1ha with potatoes. The milk production is of 200, 000 litres per year, at a rate of 6, 200 litres per cow. The temporary grasslands are mown in the spring and the autumn. The permanent grasslands are partly mown, partly grazed in the spring, and entirely grazed from August onwards. Cereals cover the farm needs; the system is autonomous. In this region, animal farming has evolved a lot between 2000 and 2010: the average size of farms has increased by 40 %, the dairy herd has decreased by 12% over the same period, and the number of dairy farms has decreased by 37%. The mountain breeds such as Abondance or Tarentaise have resisted better than the Prim'Hosltein or the Montbéliarde.

Conversion to organic

Thomas Morel has preserved his herd, but doubled his UAA with his neighbours' departure. His visit to Maxime Bonnin, in the Indre department, has convinced him of the validity of the system. He has chosen to strongly reduce concentrate feed consumption, from 240 to 80 grams per litre of milk. This solution is made possible in particular because of the installation of a barn dryer (what is more, a solar one) that has strongly improved the value of fodder. The productivity per cow has dropped by 25%, a loss compensated by the sales of crops, and especially by a better selling price of the milk. With such a grassland system, the conversion to organic agriculture doesn't present any particular difficulty. It was even a necessity in order to satisfy the requirements of the local dairy that has decided to completely switch over to the organic market.

Increasing the total surface of the farm and helving the temporary grassland and forage crops allows to diversify production with cereals and high-protein oil seeds, and to lengthen rotations. The natural grasslands are entirely preserved, including alpine pastures. The mechanisable grassland are mown in the spring. Surplus grass is used in a methane digester, also fed with manure, and a with a third (in a normal year) of the intercrops produced on arable areas. In draught years, the hay and intercrop stock goes first and foremost to the animals.

The anaerobic digester belongs to a local company, comprised of half a dozen associates. It fuels a small cogeneration power generator, that provides the communal heating network, and allows to dry hay, wood chips, cereals and legumes.

Afterres2050

Land use

Non-agricultural areas

The artificialisation of lands

Fighting land artificialisation

The utilised agricultural area is forever receding: from 34.5 million hectares in 1960 it was down to 29.1 million hectares in 2010. Over the same time period, wooded areas gained as much surface as the moors and wastelands lost. This movement greatly benefits artificialized lands population increases and spreads out differently over the French national territory, the surface per inhabitant progresses to satisfy the needs in roads and carparks, in secondary residences, or because of the living apart phenomena.

The agricultural area per inhabitant has thus decreased by 56% in 50 years. Each person in France has the equivalent of 46 ares to provide food for them today, that number will be down to 36 in 2050 if the current trend continues. This decline in agricultural areas is all the more worrying as it has been coupled since the beginning of the year 2000 with a yield stagnation. Thus, the peak of production per inhabitant registered in 1992 will certainly never again be topped.

Artificialisation and population

In 2010, artificialized areas represented 4.9 million hectares, and were gaining 60 000 ha a year[63]. The phenomenon is very heterogenous over the French territory. If the main causes are known, there is no predictive model[64]. One can but observe that artificialized areas are tightly correlated with population density: with 1.022 inhabitants per km^2, the Ile-de-France region has the lowest artificialized area per inhabitant, that is to say 21 ha per thousand inhabitants. On the contrary, in the Limousin region, the density is of 44 inhabitants per km^2, and artificialisation is up to 160 ha per thousand inhabitants.

The increase of artificialized area isn't correlated to the population increase: the Ile de France region has seen its population increase by a million inhabitants since 1992 and has only consumed 10.000 ha. Conversely, the Rhône-Alpes region has artificialized 120.000 ha to accommodate 800.000 extra inhabitants. The Languedoc-Roussillon and PACA (Provence-Alpes-Côte-d'Azur) regions have artificialized no more than the Bourgogne region where the former have accommodated 500.000 extra inhabitants, whereas the Bourgogne region very little.

Containing artificialisation

The increase of artificialized areas depends on two parameters: an effect that is linked to population increase, and a spreading effect with equal population. The population will have increased by 15% by 2050 according to INSEE. The projection of observed past trends for the «artificialized area per inhabitant» ratio leads to an increase of the artificialized area per inhabitant of 29% on average in France.

The aggregation of these two factors leads to an increase of 48%, that is to say 2.3 million hectares, and a total of 7.2 million hectares of artificialized areas.

The urban planning policies tend to contain land artificialisation within urban areas, whereas in the countryside, the sprawl of allotments over farm lands is becoming a major preoccupation. The Territorial Coherence Schemes (SCOT) and the local urban planning that results from them now fix target figures for densification and for the fight against urban spreading, the difficulty being to avoid creating zoning that shifts artificialisation to urban peripheries.

Even if we permanently need to build infrastructures, buildings and equipment, it is possible to slow down this artificialisation rate, that is 4 times faster than demographic growth.

Afterres2050 assumes of a halving of the spreading effect: the area per inhabitant only progresses by 14%. The artificialized areas progress to 6.4 Mha. that is to say an increase of 1.5 Mha, and an almost 0.8 million hectares difference with the Trend scenario. The regions that undergo the effects of artificialisation the most are Rhône-Alpes, Midi-Pyrénées, Pays de Loire and Aquitaine, mainly for demographical reasons.

Thousands of hectares	1990	2010	2030	2050	2050	2050	2050
			Afterres	Trend	Afterres	BHF	PAR
Artificialized lands	3 700	4 900	5 600	7 200	6 400	6 300	6 300

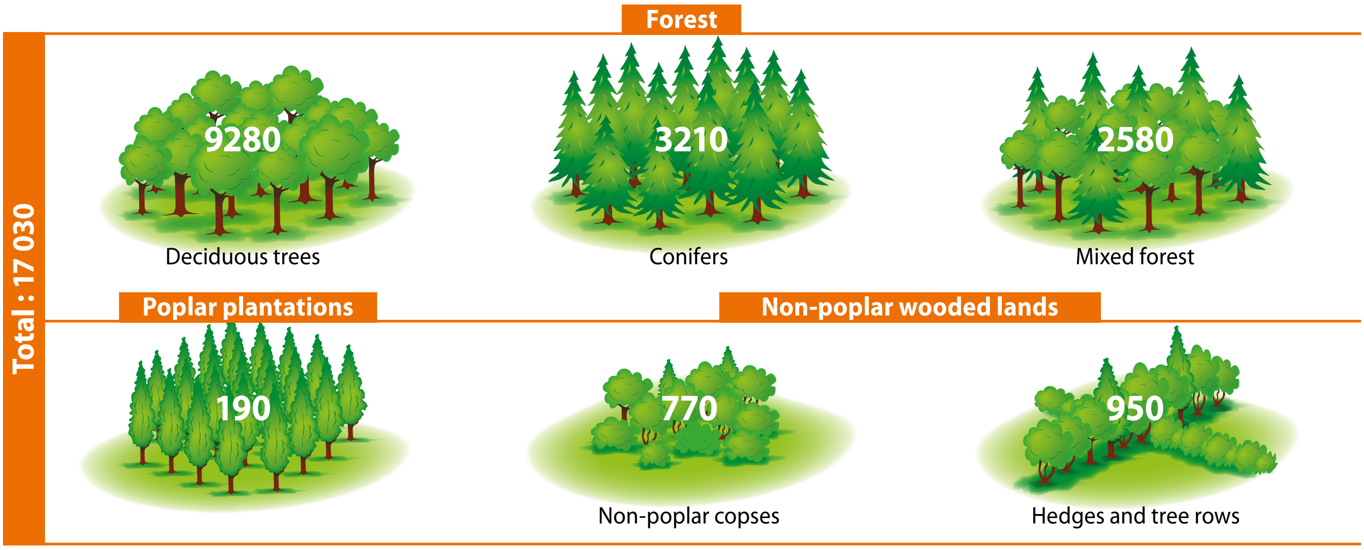
- Evolution of artificialized areas per scenario.

The forest

The French forest area has significantly increased since the middle of the 19th century and continues to do so, even if this evolution seems to have been slowing down significantly over these last few years (33.000 ha per year between 2006 and 2014). The forest has gained on agricultural areas and on wastelands and moors, also generated in part by agricultural abandonment since the 1950's. The transition from the «moors» category towards the «forest» category can still be seen today: a retard effect of the agricultural abandonment of past decades, that sees fields shifting to moor status before turning into a real forest.

The TERUTI-LUCAS survey on French territory occupation offers a global vision of wooded environments. The «production» forest totalises 15.4 Mha, and the wooded areas other than forests (copses, hedges and tree lines) about 2 million, that is to say a total of 17 Mha of wooded areas, that has been stable since 2006: the increase of forest areas compensates the loss of copse and hedge areas, that continues.

[63] Average over 20 years. Over the 2006-2014 period, the average was even up to 77.000 ha a year.
[64] It is in fact impossible to trace the regional level long-term trend, because of discontinuities in the TERUTI (French national land occupation survey) data.



- Wooded land in France (thousands of hectares in 2014). *(Cf. detailed table page 99)*

In the Trend scenario, artificialisation gnaws both at agricultural areas and at the forest, and the latter is regressing slightly. In the Afterres2050 scenario and its variations, on the contrary, it progresses slightly.

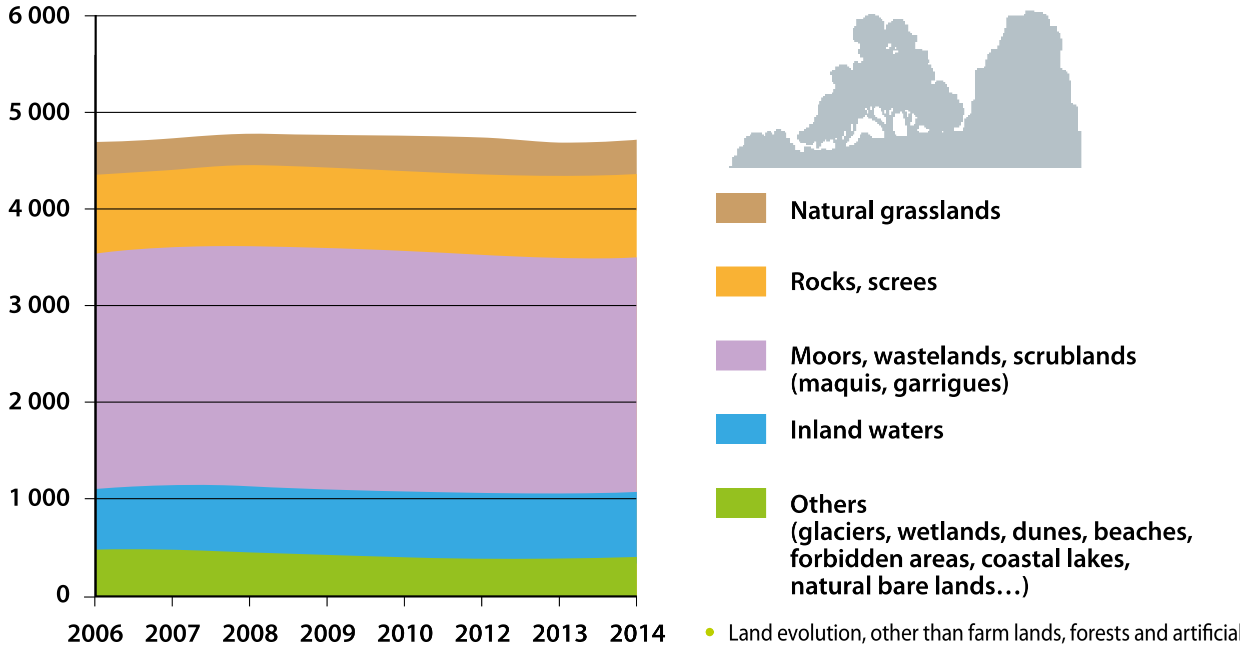
Thousands of hectares	2010	2030	2050	2050	2050	2050
		Afterres	Trend	Afterres	BHF	PAR
Forests, poplar groves and other wooded areas	17 000	17 100	16 800	17 200	17 200	17 200

- Evolution of wooded areas per scenario.

The numbers provided do not reflect the role of trees in the Afterres2050 scenario: 10% of agroforestry agricultural areas should be added, as well as the generalisation to all agricultural areas of agroecological infrastructures, the majority of which include wooded elements. Afterres2050 multiplies both country trees and city trees freely.

Other areas

The «other areas» group is an aggregation of diverse elements that mainly includes natural or semi-natural environments: moors, scrubland and garrigues, lakes, ponds and rivers, mountains, rocks and screes, beaches, glaciers and permanent snow… These areas represent 4.8 million hectares and variations from one year to another are minor. They remain stable and identical for each scenario.



- Land evolution, other than farm lands, forests and artificialized lands.

Agricultural areas

From local to regional, from regional to national

Arable lands

The test cases studied in each region[65] allow first of all to «rebuild» the regional crop plan: for example, in the Ile-de-France region, the «conventionnel cereal colza» system represents 41% of the region's agricultural area, compared to 20% for the conventionnel system, including a protein crop, and 35% including beetroot. The current organic and integrated production systems represent less than 5% of the total area in 2010. The table below indicates the rotation length and the proportion of each type of crop in the rotation for each test case: for example, 2 wheat and 1 rapeseed over 3 years for the simplest systems.

Ile de France - 2010	Conventional cereals - rapeseed	Conventional cereals peas rapeseed	Conventional - cereals rapeseed beetroot	Autonomous Agribio N	Importer Agribio N	Integrated production	TOTAL
Proportion of the system in the crop plan	41 %	20 %	35 %	1 %	1 %	2 %	100 %
Rotation length (years)	3	5	5	9	7	5	
Cereals	2	3	3	4	3	2	67 %
Oilseed	1	1	1	1	1	1	20 %
Protein crops		1		1	2	1	5 %
Alfalfa				2			< 1 %
Industrial crops			1	1	1	1	8 %

- Description of the main rotation systems in the Ile-de-France region in 2010.

In the 2050 vision, all systems evolve. The point is not only to simply increase the proportion of organic and integrated systems, but also to take care of the coherence of the nitrogen balance for organic systems for example, to avoid making them dependent on other systems for their nitrogen supply. The proportions of protein crops and alfalfa increase very significantly, which necessarily occurs at the expense of other crops, in particular of cereals that represent two thirds of the land use in 2010. In the «Autonomous» Agribio system, part of the alfalfa is kept in situ.

Ile de France - 2050	Conventional cereals peas rapeseed	Conventional - cereals rapeseed beetroot	Autonomous Agribio N	Importer Agribio N	Integrated production with beetroot	Integrated production, no beetroot	TOTAL
Proportion of the system in the crop plan	5%	5%	30%	15%	30%	10%	100%
Rotation length (years)	5	5	8	6	6	5	
Cereals	3	2	4	3	3	3	51%
Oilseed	1	1	1	1	1	1	16%
Protein crops	1	1	1	2	1	1	19%
Alfalfa			2				8%
Industrial crops		1			1		7%

- Description of the main rotation systems in the Ile-de-France region in Afterres2050.

The work carried out over the different regions led to fixing the following rules:

- Protein crops must represent 25% of the COP (Cereals, Oilseeds and Protein crops)
- The total legume crop, including alfalfa, must represent 25% of the total arable land area, including annual forage crops.

Cereal areas thus necessarily decrease in large-scale crop regions, as well as oilseed areas, benefiting legumes in general.

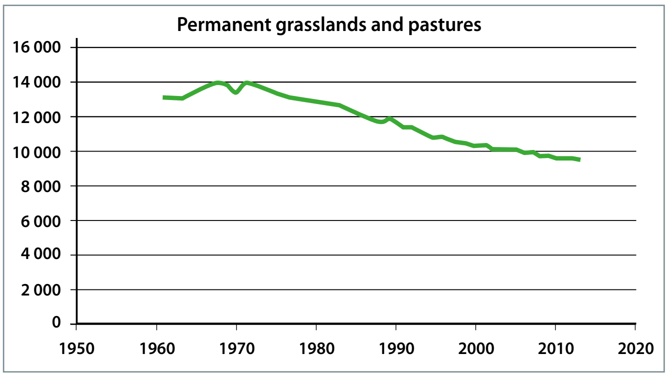
[65] See «The making of Afterres2050» chapter for questions relating to the work method and the work on the regionalisation of scenarios.

Cows and grassland

Priority to natural grassland-rich regions

Re-dimensioning the cattle herd, with the aim to make it better suited to our future milk and meat needs, implies completely revising its geographic layout.

The first parameter is the notion of a relationship with natural grassland. The aim is to preserve permanent grasslands as much as possible and to put an end to their decrease. Their area has dropped from 14 million hectares in 1970 to 9.5 million in 2013.



- Evolution of permanent grassland and pasture areas since 1960, in thousands of hectares.

The «always grassy area[66]» (AGA) of farms represents 7.7 million hectares, to which collective environments should be added. This AGA is divided between «productive» grassland, that produce 5 tons of dry matter per hectare on average, and « low production» grasslands composed of rangeland, alpine pastures and moors, producing on average 1 ton of dry matter per hectare. In 2050, 6.4 Mha of productive grasslands will remain in Afterres2050, and 2.4 Mha low production grasslands, corresponding to 6.9 Mha of productive grasslands, to feed a herd of 3.7 million cows and 8.5 million ewes and goats in 2050. Placing the priority on natural grasslands equates to linking the herd to natural grassland areas.

All the other forage areas are per definition arable lands, that can have other uses than grass production. Conversely, a large portion of permanent grasslands cannot be used for anything else than grass production, the only alternative being conversion to moors then to forests.

If the cattle herd were homogenously spread out over the entire territory according to natural grasslands areas, the «average storage rate»[67] would be of 0.55 cow per hectare. This indicator is today of 1.2, and varies between 0.17 in the PACA region to 7.2 in Britany. The PACA region grasslands can only uphold a low storage rate, and Britany has chosen annual forage crops rather than permanent grasslands.

Another geographical distribution

Britany and the Pays de Loire region alone house a quarter of the national cattle herd. They also have a high storage rate, meaning that arable land is massively used to produce fodder. It is easier to convert them to cereal land than it is in the case of mountain grasslands, and the herd reduction is stronger there than in mountain regions. Without however exceeding a factor 3, proposed as a limit value not to be exceeded for socio-economic reasons.

The dairy herd decreases in all regions, except the Ile de France and PACA regions, in order to increase their milk autonomy level. They have however no hope of becoming totally autonomous: that would require the Ile de France region to convert 80% of its wheat land to grasslands, and the PACA region to import fodder massively. The herd increase has been limited to a factor 2 in these regions.

The new proposed balance strives to respect the character of each region, with a more or less pronounced dairy orientation. Hence the Bourgogne, Limousin or Midi-Pyrénées herds remain in vast majority lactating herds.

	1970	2010	2050
Prim'Hosltein	4 000	2 500	Strong drop
Montbéliarde	810	590	Stable
Normande	1 900	500	Stable
Simmental and other dairy breeds	560	190	Stable
Total dairy herd[68]	**7 280**	**3 800**	**2 300**
Charolais	1 110	2 100	Strong drop
Limousin	460	1 100	Strong drop
Blonde d'Aquitaine	170	570	Strong drop
Aubrac, Salers and other breeds	1 100	450	Stable
Total lactating herd	**2 800**	**4 200**	**1 300**
Milk production (billions of litres)	22	23	15
Meat production (millions of tons)	1.6	1.5	0.7

- Cattle breeds in 1970 and 2010, and an Afterres2050 possible vision.

[66] In the Trend scenario, the decrease of natural grasslands areas is more important than in the Afterres2050 scenario, partly because of a worse control of artificialisation and of a weaker link to natural grasslands. The conservation of a cattle herd at 6.6 million cows, dairy or lactating, leads to a strong rise in storage rate, increasing from 1 cow per ha of natural grasslands today to 1,56. This indicator means that animal farming in the mountain regions intensifies, without however reaching the levels in the dairy regions of the Ouest region.

[67] Only considering permanent grasslands here. Usually the storage rate is relative to the total forage areas, that is to say the grasslands (permanent, temporary or artificial) and the forage crops (silage corn, cabbages and forage turnips, etc.). Moreover, we have used the notion of equivalent productive meadow areas here: 1 ha less productive meadow (LPM) corresponds to 0.2 ha equivalent productive meadow. In certain regions, especially in the PACA and Languedoc-Roussillon regions, the proportion of LPM is actually significantly higher than in the other regions, and the «storage rate» indicator would be falsified without this correction.

[68] Mixed breeds are partly classified in the dairy herd (Normande, Montbéliarde, Simmental), partly in the lactating herd (Aubrac, Salers, Tarentaise).

We have sketched out what these herds could become in terms of cattle breeds; the point is mainly to visualise the current situation, compared to that of 1970. The milk production has hardly changed between 1970 and 2010, whereas the headcount has been divided by two. The productivity per head has considerably risen. The Prim'Holstein breed lost 1.5 million heads between 1970 and 2010, and is to lose as much again between 2010 and 2050 according to Afterres2050. It would still represent half of the total dairy herd however. The mixed breeds such as the Montbéliarde or the Normande, should see their headcount remain constant. The lactating herd on the other hand has considerably increased since 1970, growing from 2.8 million cows to 4.2 in 2010. In 2050, the dominating breeds – the Charolaise, Limousine and Blonde d'Aquitaine – would see their headcount strongly drop in all regions, even mountain ones, to a level at half the 1970 headcount. The mountain breeds would preserve their current headcount, for terroir adaptation and breed diversity improvement reasons.

Limited natural grasslands loss

The storage rate remains at a level close to the current one. It remains stable in the mountainous regions in 2050; the herd has decreased, slightly in the case of the dairy herd and significantly in the case of the lactating herd. It balances out in the Ouest region, that maintains its natural grasslands and where the herd decrease allows to de-intensify dairy herds.

	2010		Afterres2050	
	Dairy cows	Lactating cows	Dairy cows	Lactating cows
Mountain regions *(Auvergne, Limousin, Rhône-Alpes, Midi-Pyrénées, Franche-Comté)*	1600	900	500	700
Grand Ouest region *(Britany, Pays de Loire, Basse Normandy)*	1000	1800	200	800
Mediterranean region *(PACA, Languedoc-Roussillon, Corsica)*	140	50	100	30
Other regions	1800	1100	500	800
TOTAL	3 800	4 200	2300	1 300

- Herd distribution per region type.

	2010		Afterres2050		TREND 2050	
	Permanent grasslands *(thousands ha)*[69]	Storage rate *(cow/ha eq. PM)*	Permanent grasslands *(thousands ha)*	Storage rate *(cow/ha eq. PM)*	Permanent grasslands *(thousands ha)*	Storage rate *(cow/ha eq. PM)*
Mountain regions *(Auvergne, Limousin, Rhône-Alpes, Midi-Pyrénées, Franche-Comté)*	3 200	0.79	2 600	0.77	2 500	1.48
Grand Ouest region *(Bretagne, Pays de Loire, Basse Normandie)*	1 400	1.95	1 400	1.29	1 300	1.77
Mediterranean region *(PACA, Languedoc-Roussillon, Corsica)*	2 800	0.91	2 400	0.88	2 300	1.57
Other regions	400	0.41	300	0.33	200	1.00
TOTAL	7 800	1.02	6 700	0.90	6 300	1.56

- Storage rate and natural meadow areas per region type.

Natural grasslands continue their decline trend: the loss of 1.1 million hectares is however significantly less than the 4 million hectares lost between 1970 and 2010.

In the Trend scenario, the decrease of natural grasslands areas is more important than in the Afterres2050 scenario, partly because of a worse control of artificialisation and of a weaker link to natural grasslands. The conservation of a cattle herd at 6.6 million cows, dairy or lactating, leads to a strong rise in storage rate, increasing from 1 cow per ha of natural grasslands today to 1.56. This indicator means that animal farming in the mountain regions intensifies, without however reaching the levels in the dairy regions of the Ouest region.

[69] The storage rate is defined here as the number of cows per hectare of equivalent productive permanent meadow (so without forage areas, that are arable lands), low production grasslands being counted with a 1 to 5 equivalency.

The evolution of agricultural areas in Afterres2050 and its variants

The total Utilised Agricultural Area decreases by about 1 million hectares in all scenarios, under the pressure of artificialisation. The Trend scenario stands out with the conservation of forage crops and a more important loss of permanent natural grasslands. On the other hand, the Afterres2050 scenario preserves slightly more natural grasslands, and loses 2 million hectares of forage crops, half of which is converted to grain crops, fruit and vegetables. The BHF variant is characterised by a larger pasture area at the cost of grain crops, and the PAR variant follows the opposite scheme.

Areas, in thousands of hectares	2010	2030	2050	2050	2050	2050
		Afterres	Trend	Afterres	BHF	PAR
Soft wheat	5 000	5 000	5 600	5 000	4 700	5 300
Barley	1 700	1 500	1 400	1 300	1 200	1 300
Durum and rice	500	600	800	600	600	600
Grain corn	1 600	1 300	1 200	1 100	1 000	1 100
Other cereals	500	500	400	400	400	500
Oilseed	2 200	2 300	2 400	2 300	2 100	2 300
Protein crops	300	1 300	400	2 300	2 200	2 300
GRAIN SUB TOTAL	11 900	12 500	12 200	13 000	12 100	13 500
Forage corn	1 400	900	1 300	400	400	500
Legume temporary grasslands	300	700	300	1 200	2 200	700
Mixed temporary grasslands	2 400	1 500	2 200	700	700	700
Grass temporary grasslands	600	400	600	200	200	200
Other non-feed annual crops	0	200	200	200	200	200
FORAGE SUB TOTAL	4 700	3 800	4 600	2 700	3 600	2 200
Productive natural permanent grasslands	7 400	6 900	5 800	6 400	6 500	6 400
Less productive grasslands	2 400	2 400	2 300	2 400	2 400	2 400
NATURAL GRASSLANDS SUB TOTAL	9 700	9 200	8 100	8 700	8 900	8 800
Sugar beet	380	390	450	390	340	390
Potatoes	160	160	210	160	140	160
Vines	790	750	740	700	690	750
Arboriculture	140	230	120	320	210	200
Vegetables	260	390	210	530	530	520
Others	140	140	130	140	200	210
FRUIT, VEGETABLES, INDUSTRIAL OR PERMANENT CROPS	1 900	2 100	1 900	2 200	2 100	2 200
TOTAL	28 200	27 500	26 800	26 800	26 800	26 800

• Evolution of main crop and grasslands areas.

The play on areas, losses and gains

The reorganisation of land areas is a vast game of communicating vases: what is gained by cities is lost by the countryside, the forest eats on pastures and grain crops compete with forage crops. But these transfers are not always very fluid. The land characteristics dictate their requirements: mountain grasslands and meadows, if they happen to be machine accessible, rarely make good wheat lands, but evolve more spontaneously towards forests. One should hesitate to tarmac arable lands, even under strong pressure, or to fell forests. It is often easier to convert silage corn to cereals, and vice versa.

Our area evolution hypotheses obey several different logics, sometimes independently. For example, artificialized area evolution results from the (non-)management of urban spread policies, and not from diet nor agricultural system modifications. Others are the consequence of «all the rest» and serve as adjustment variables: this is the case for the forest, that is not today a part of intentional expansion policies. There are deforestation slowing mechanisms, that limit encroachment phenomena. As for afforestation, it mainly results from the abandonment of agricultural lands. The forest can thus develop where agricultural areas –concretely that is to say grasslands- are decreasing faster than artificialisation is progressing [70].

	Thousands of hectares		Δ Artif	Δ AGA	Δ Other	Δ Forest	Δ Arable	Δ *FRG*	Δ *COP*
Champagne-Ardenne	Loss of permanent grasslands higher than gain of artificialized areas	Stable forest	12	-77	7	0	59	-28	87
Corsica			6	-11	16	-13	1	1	1
Bourgogne		Forest gain	30	-295	8	52	168	-51	219
Lorraine			21	-111	1	18	77	-36	113
Franche-Comté			22	-113	2	31	75	-38	113
Auvergne			26	-239	10	72	112	-126	237
Limousin			28	-75	6	40	-37	-111	74
Midi-Pyrénées	Loss of permanent grasslands lower than gain of artificialized areas	Stable forest Forest gain	165	-10	32	0	-197	-324	127
Rhône-Alpes			167	-131	71	0	-94	-124	29
Haute-Normandy			23	0	0	0	-23	-34	11
Basse-Normandy			39	0	9	0	-49	-145	96
Pays de la Loire			146	0	25	0	-172	-411	240
Britany			140	141	58	0	-253	-402	149
Poitou-Charentes			63	0	10	0	-73	-158	85
Languedoc-Roussillon			133	-14	-56	0	-64	-46	-18
Provence-Alpes-Côte d'Azur			92	-55	2	0	-39	-28	-11
Nord-Pas-de-Calais			36	0	19	0	-55	-34	-21
Alsace			39	0	-5	0	-34	-7	-27
Aquitaine			134	0	68	0	-202	-131	-71
Île-de-France			30	2	26	0	-59	20	-79
Centre		Forest gain	96	0	34	21	-152	-38	-113
Picardie			23	0	32	8	-63	12	-75

Δ : gain or loss in surfaces – **Artif :** artificial surfaces – **STH :** always grassy surfaces – **FRG :** forage production – **COP :** cereals and oilseed crops

- Evolution of areas per category and per region, in thousands of hectares (Afterres2050 vs 2010).

Working on a regional scale, there are 4 types of situations.

If the loss of permanent grasslands is higher than the artificialized area gain, arable lands progress.

- ***A type situation.*** In certain regions, these grasslands are entirely converted to arable land: this is the case in the Champagne-Ardenne region.
- ***B type situation.*** In other regions, part of these grasslands is gained by the forest: this is the case in mountainous regions such as Auvergne, Franche-Comté, Bourgogne and Lorraine.

If the artificialisation rate is higher than the loss of natural grasslands it also gains over arable land in this case.

- ***C type situation.*** In the majority of regions, the forest then remains stable: it doesn't regress, but it doesn't progress either, so as not to lose more arable lands.
- ***D type situation.*** In the Picardie and Centre regions, the work group meeting for regionalisation decided to adopt a forest progression hypothesis, that means a higher decrease of arable areas.

[70] The reasoning here is of course in «net balance», considering opposite and indirect fluxes: artificialized areas can gain on arable lands that themselves impinge on grasslands, that are also taken over by forest. Locally, opposite phenomena can be seen, where arable land is converted to grasslands or to forest.

There are some particularities: for example, Britany is the only region where natural grasslands progress, a consequence of Forage crop areas are calculated so as to correspond to the herd's needs on a regional level (the calculation is in reality slightly more complex, because it also considers nitrogen needs provided by dedicated legume crops).

This then results in a variation of the COP – cereals, oilseed and protein crop areas– equalling the difference between the arable areas and the forage crop areas.

Thousands of hectares	2010	2030	2050	2050	2050	2050
		Afterres	Trend	Afterres	BHF	PAR
Cereals, high-protein oil seed	11 900	12 500	12 200	13 000	12 100	13 500
Fruit, vegetables, vines, industrial or perennial crops	1 900	2 100	1 900	2 200	2 100	2 200
Forage crops and temporary grasslands	4 700	3 600	4 500	2 500	3 500	2 100
Natural grasslands	9 700	9 200	8 100	8 700	8 900	8 800
Total UAA	28 200	27 300	26 600	26 500	26 600	26 600
Forests, poplar groves and other wooded environments	17 000	17 100	16 800	17 200	17 200	17 200
Moors, wastelands, fallows	3 000	3 000	2 500	3 000	3 000	3 000
Waters, rocks, others	1 800	1 800	1 800	1 800	1 800	1 800
Artificialized lands	4 900	5 600	7 200	6 400	6 300	6 300
TOTAL	54 900	54 900	54 900	54 900	54 900	54 900

- Evolution of areas per main categories.

Producing

Crops

The energy value of the primary agricultural production (excluding crop residue), expressed in Petajoules (PJ), increases from almost 2 800 PJ today to 2 900 in 2050[71]. These values include the production of associated and intercrops in addition to the main crops. The Afterres2050 scenario thus isn't a plant production decrease nor extensification scenario.

In all scenarios, including the Trend one, the grain production decreases, because the yield decreases under the effect of climate change. The decrease is more marked in the scenarios with a high organic proportion (Afterres2050 and its BHF variant), although it is attenuated by the presence of associated crops.

Production, thousands of tons	2010	2030	2050	2050	2050	2050
		Afterres	Trend	Afterres	BHF	PAR
Soft wheat	35 600	30 200	37 000	25 800	19 700	32 800
Barley	11 600	8 100	8 200	5 500	3 900	7 200
Durum and rice	2 500	2 300	3 700	2 100	1 600	2 600
Grain corn	15 000	10 400	8 200	6 900	5 700	7 200
Other cereals	2 800	2 000	1 700	1 400	1 000	1 900
Oilseed	7 000	6 000	6 400	5 200	3 800	5 300
Protein crops	1 200	4 400	1 400	6 800	4 500	7 400
GRAIN SUB TOTAL	75 800	63 400	66 700	53 800	40 100	64 400
Forage corn	16 900	9 900	14 400	4 100	3 300	4 700
Temporary legume grasslands	2 400	5 900	2 300	9 200	18 600	5 100
Temporary mixed grasslands	14 300	9 200	13 800	4 300	4 300	4 300
Temporary grasslands	3 700	2 300	3 800	1 000	1 000	1 000
Other forage crops	1 000	600	700	300	300	300
FORAGE SUB TOTAL	38 300	27 900	35 000	18 900	27 400	15 500
Permanent natural productive grasslands	38 400	34 100	28 900	30 300	32 500	30 000
Less productive grasslands	2 800	3 200	3 500	3 600	3 600	3 600
GRASSLANDS SUB TOTAL	41 200	37 300	32 400	33 800	36 000	33 500
Beetroot	33 500	31 900	38 300	31 200	24 000	29 600
Potatoes	7 500	6 300	8 600	5 400	3 800	5 600
Vine	6 000	5 000	5 700	4 200	3 500	4 900
Orchards	2 800	3 100	2 300	3 500	3 000	3 100
Vegetables	5 900	8 900	4 800	12 000	12 000	11 700
Others	2 100	2 100	1 800	2 000	3 500	3 500
FRUIT, VEGETABLES, INDUSTRIAL OR PERMANENT CROPS	57 800	57 400	61 500	58 400	49 800	58 500
Production of associated crops	0	1 500	0	2 900	4 200	4 800
Production of intercrops	1 900	27 300	15 900	52 900	52 000	33 800
TOTAL	214 900	214 900	211 500	220 800	209 500	210 400
TOTAL ENERGY VALUE (PJ)[72]	2 800	2 810	2 690	2 900	2 870	2 690
Productivity (GJ/ha)	99	103	101	109	108	101
Total grain including associated crops	75 800	64 900	66 700	56 700	44 300	69 200
Total forage, grasslands and intercrops	81 400	92 500	83 300	105 600	115 400	82 800

- Evolution of the main plant productions according to each scenario.

[71] The equivalent of respectively 67 and 69 million tons of petrol.
[72] The energy value compatibility allows to add productions with very different characteristics. The Petajoule is worth 1018 Joules (1 billion billion). 42 PJ is equivalent to 1 million tons of petrol. A Gigajoule is worth 109 Joules. 42 GJ is equivalent to 1 ton of petrol.

The production of fodder matter–grazed grass, forage crops and intercrops–significantly increases in both the Afterres2050 and the BHF variant scenarios, whereas it remains globally unchanged in the Trend and PAR variant scenarios: the intercrops more than compensate the decrease of fodder and grasslands areas.

Yield	2010	2030	2050	2050	2050	2050
		Afterres	Trend	Afterres	BHF	PAR
Soft wheat	7.1	6.0	6.6	5.2	4.2	6.2
Barley	6.8	5.4	5.9	4.2	3.3	5.5
Grain corn	9.4	8.0	6.8	6.3	5.7	6.5
Other cereals	5.6	4.0	4.3	3.5	2.5	3.8
Oilseed	3.2	2.6	2.7	2.3	1.8	2.3
Protein crops	4.0	3.4	3.5	3.0	2.0	3.2
GRAIN SUB TOTAL	6.4	5.1	5.5	4.1	3.3	4.8
Forage corn	12.1	11.0	11.1	10.3	8.3	9.4
Temporary legume grasslands	8.0	8,4	7.7	7.7	8.5	7.3
Temporary mixed grasslands	6.0	6.1	6.3	6.1	6.1	6.1
Temporary grass grasslands	6.2	5.8	6.3	5.0	5.0	5.0
FORAGE SUB TOTAL	8.1	7.8	7.8	7.6	7.8	7.4
Permanent natural productive grasslands	5.2	4.9	5.0	4.7	5.0	4.7
Less productive grasslands	1.2	1.3	1.5	1.5	1.5	1.5
Grasslands SUB TOTAL	4.2	4.1	4.0	3.9	4.0	3.8
Beetroot	88.2	81.8	85.1	80.0	70.6	75.9
Potatoes	46.9	39.4	41.0	33.8	27.1	35.0

- Yield of the main agricultural crops according to each scenario[73]. The data is expressed in gross tons (including beetroot and potatoes), except for grasslands, forage crops and intercrops, for which the production is indicated in tons of dry matter.

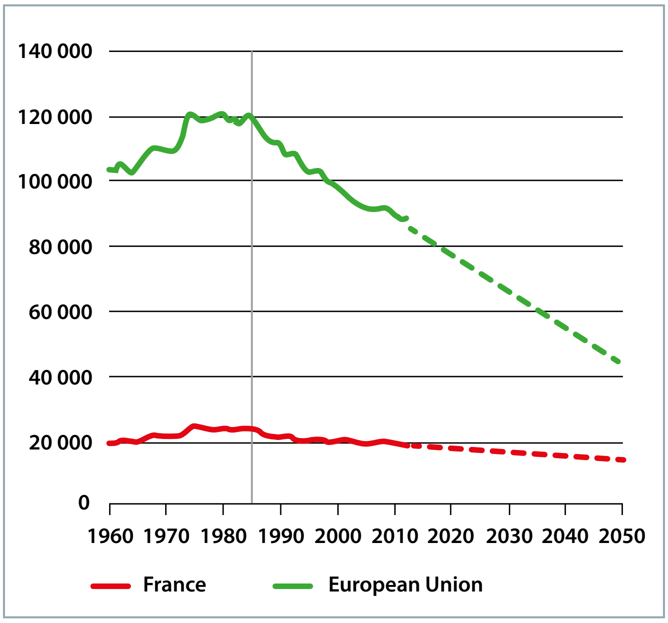
Herds and animal productions

Ruminants

A cattle herd in a preoccupying situation

The cattle herd reached its maximal headcount in France as in Europe in the 1970's. Since 1985, it has continuously decreased. It has dropped from 120 million heads (total headcount) down to 90 million in 2010 according to EUROSTAT. If this rhythm continues, it will be down to 45 million in 2050. In France, the trend is also a decline, although it is less pronounced. The maximum headcount was reached in 1976 with 24.1 million heads, it is of 19 million today. Continuing this trend would lead to a headcount of 14,3 million heads, that is to say a ¼ less than today.

In the Rhône-Alpes region for example, the dairy cow headcount over 10 years was reduced by 12%, the number of farms with dairy cows was reduced by 37%, whereas the number of cows per farm increased from 25 to 35, that is to say by 40%. This evolution is mainly due to the drop in Prim'Holstein herds, whereas mountain breeds such as the Tarentaise or Abondance have resisted well, with the help of the Reblochon, Beaufort and Tome des Bauges cheeses.



- Evolution of cattle population in Europe and France since 1960, with a trend projection for 2050. Total number of heads.

[73] Main crop only, not including the other productions on the same plot: associated crops, intercrops, trees.

This trend is not limited to the Rhône-Alpes region, as the dairy herd decreased by 14% over the same time period at the national level, the number of dairy farms decreased by 36%, whereas the headcount per farm increased by 38%[74]. The same observation may be made in each region, the trend is the same all over, whether in the Grand Ouest region or in mountainous regions. If the reduction of total headcount and the increase in herd size continue in the same way, there will only be 2 million dairy cows remaining in metropolitan France in 2050, distributed over 14.000 farms with headcounts of 144 cows: that is to say respectively a drop by 46% of the dairy herd and by 83% of the number of farms.

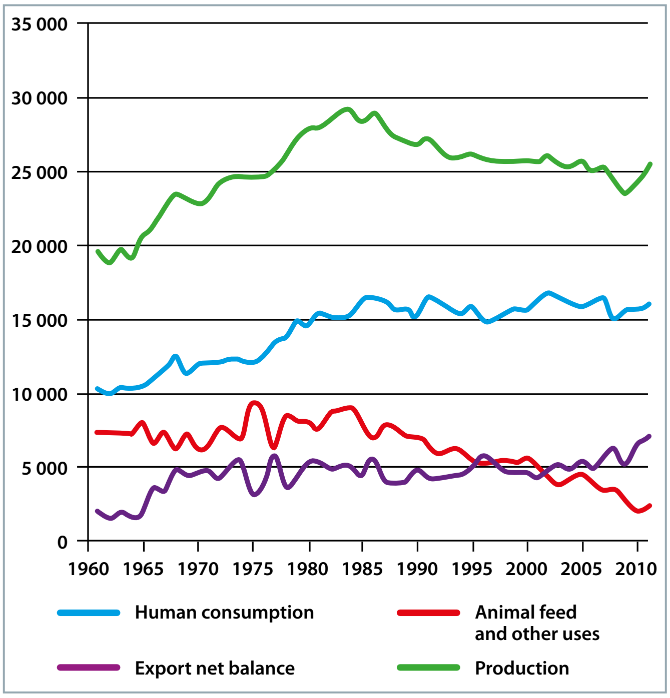
	2000	2010	Différence	Evolution, annual %	2050 trend	2010-2050 evolution
Thousands of dairy cows	4 324	3 712	-612	-1,5%	2 016	-46%
Dairy cows per farm	34	45	11	2,9%	144	219%
Number of farms with dairy cows	128 336	82 427	-45 909	-4,3%	14 027	-83%

- Trend evolution of cattle dairy farms.

A «trend» scenario that isn't really one ...

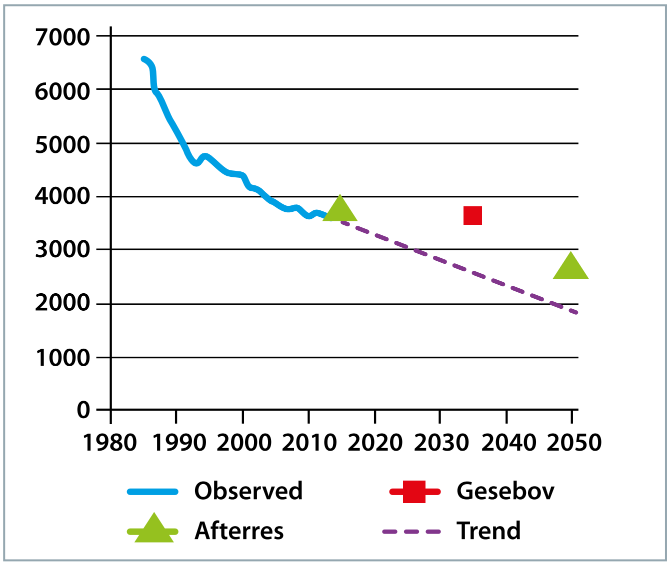
Can the increase in world milk demand counteract this evolution? The increase in gross exports (export – import balance) observed over these last years remains modest, and stems less from the production increase than from the decrease of uses other than for human consumption, particularly for animal feed. At a world level, milk production increases by 2.2% per year and the export and import fluxes by 3.1%. This situation is a priori favourable for a big milk exporting country such as France. Although is this quite so certain?

The GESEBOV prospective, «greenhouse gas emissions and energy consumptions of French cattle farms», with a 2035 timeframe, conducted by IDELE, Institut de l'élevage (French Animal Farming Institute), considers that the «Trend» scenario is governed by the world milk demand increase. In 2035, the dairy herd only decreases by 2%, milk production progresses to 9.000 litres per cow on average, that is to say 32 million litres of milk per year. Our so-called «Trend» scenario is close to GESEBOV's: both are very close as far as headcounts are concerned, and our milk production is of 7.700 litres, half way between the current level and GESEBOV's hypothesis. In actual fact, this scenario isn't really a «Trend», with the meaning that it would carry through to the future the trends observed over the last years.



- Main components of the milk supply assessment, in thousands of tons, 1960-2013 (FAO Stat).

Indeed, these trends would lead to a drastic decrease of the herd and even more so of the number of animal farms. With a high risk of a strong regression of natural grasslands, as it is harder to lead larger herds (144 cows on average) to pasture. This evolution leads to an intensification of dairy farms, an increase of corn silage consumption that would mean increased water resource problems in certain regions, and also an increase in concentrates, diverting important quantities of cereals from export markets. The intensification of dairy farms also leads to a lower quality and quantity of meat from this herd, that would thus have to be compensated by an increase of the lactating herd[75].



- Evolution of dairy cattle population in France since the 80's and projections: continued trends, the so-called GESEBOV «Trend scenario» and the Afterres2050 scenario.

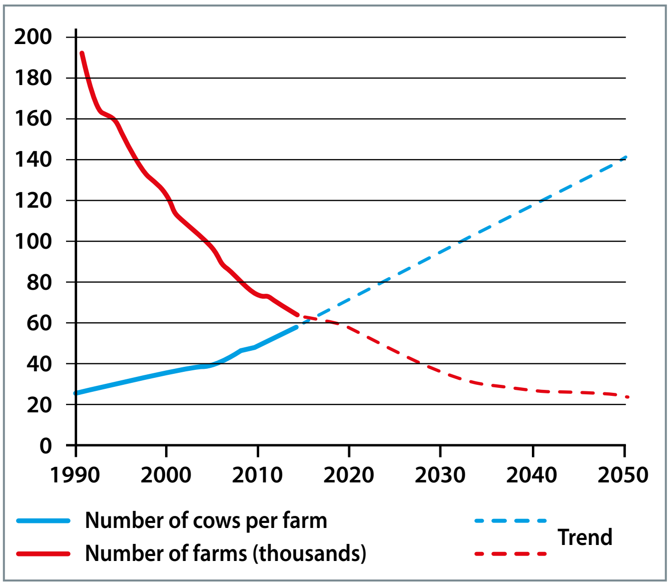
The Trend scenario used in both the Afterres2050 and GESEBOV prospective exercises is in reality a scenario in rupture with

[75] Puillet L., Agabriel J., Peyraud J.L., Faverdin P., 2014. Modelling cattle population as lifetime trajectories driven by management options: a way to better integrate beef and milk production in emissions assessment. Livestock Science, July 2014, Volume 165, Pages 167–180.

current tendencies. Stabilising the herd at -2% in 2030 whereas the current rhythm is of -1,6% per year, that is to say -33% over 25 years, does suppose an inversion of the curve, and more importantly mechanisms to allow this inversion: in particular a double long term stability, in both the price of milk[76] and of cattle feed.

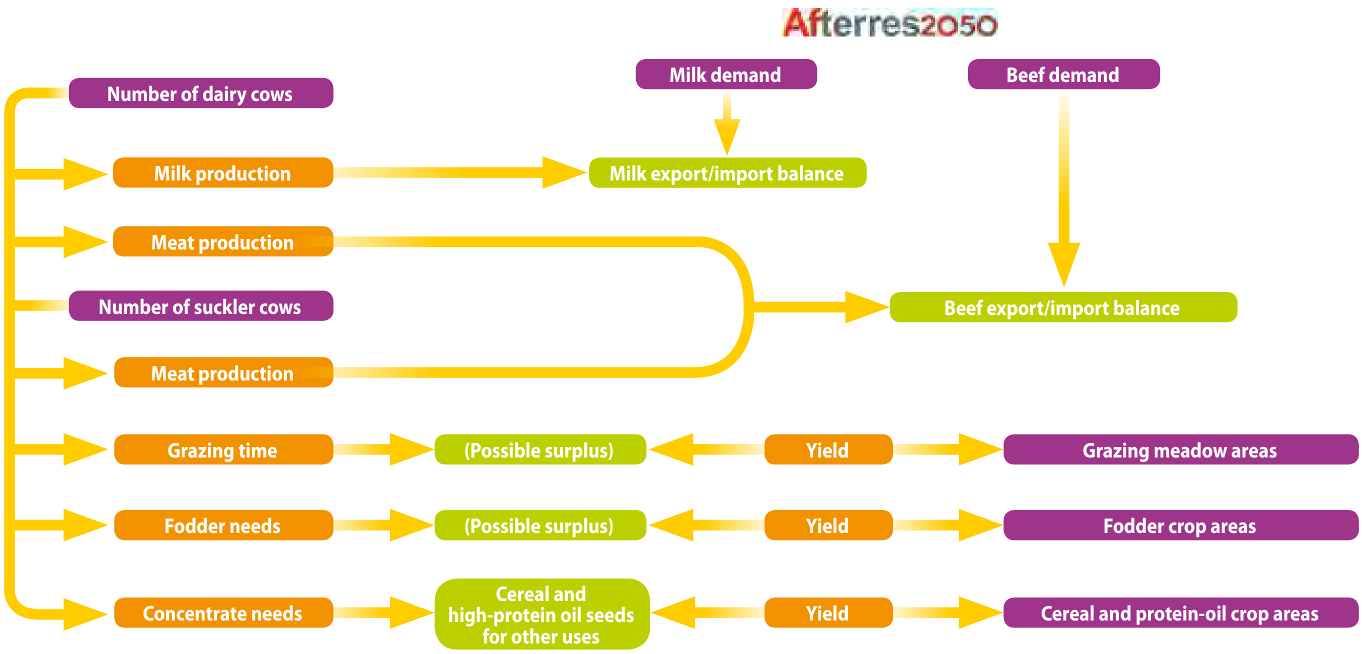
Cattle

Afterres2050 adopts some intermediate hypothesis between what would be a continuation of the current tendency scenario and the so-called «Trend» scenario.
The dairy cow herd, including mixed breeds, drops from 3.7 million heads to 2.7 million. Milk production drops from 25 to 18 million tons, the export balance remains stable however, as domestic demand also drops sharply.
The lactating herd is dimensioned so as to satisfy the domestic bovine meat demand, dropping from 4.2 to 1.9 million cows.
The diagram below allows to visualise the reasoning. Milk and bovine meat demands are determined by the consumers' plate and the hypothesis on international exchanges (stable milk export balance and improved commercial meat balance). The dairy herd is dimensioned by milk demand and produces meat. The lactating herd is dimensioned by the remainder to provide, considering the meat production of the dairy herd.
The changes in animal farming, with less concentrates and more grazing, allow to preserve a large part of natural grasslands.
Meat production drops from 1.5 to 0.9 million tons. Both the Trend and the PAR variant scenarios present a large bovine meat deficit. The production has fallen more sharply than consumption, in different proportions, but the final balance is similar. The Afterres2050 scenario and its BHF variant allow on the contrary to lower the balance deficit.



- Evolution of the headcount of cows per farm and number of dairy cow farms since 1990, and trend projection.

The needs in fodder and in concentrates decrease more than the amount of grass grazed, as grazing time increases. The three variants, with BHF and PAR, don't present any significant differences: the PAR herd is a little more intensive than the others, whereas the grazing time is a little higher in BHF.
Enteric methane emissions are reduced by 40%, essentially thanks to the herd decrease, and secondarily (10% reduction) by putting on action the research directions currently being explored: genetics, feed rations and vaccination (methanogenic bacteria inhibition).



- Cattle herd dimensioning algorithm.

[76] The GESEBOV Trend scenario is based on a price of 350 €/ton.

		2010	2030	2050			
			Afterres	Trend	Afterres	BHF	PAR
Herd characteristics							
Herd present (mothers)	Thousands of heads	7 960	6 120	6 630	4 290	4 440	4 350
Of which dairy cows	Thousands of heads	3 730	3 190	3 220	2 660	2 820	2 710
Of which lactating cows	Thousands of heads	4 230	2 930	3 410	1 630	1 620	1 640
Milk production	Thousands of tons	24 830	21 000	26 160	17 320	17 650	18 580
Net export balance	Thousands of tons	6 900	6 600	7 300	6 900	7 700	4 100
Meat production (whole herd)	Thousands of tons (carcass)	1 520	1 200	1 340	850	860	880
Net export balance	Thousands of tons (carcass)	-110	-110	-520	-90	-10	-480
Dairy herd feed							
Fodder	Thousands of tons (dry matter)	35 000	24 500	32 000	15 500	15 500	16 500
Grazed grass	Thousands of tons (dry matter)	34 000	30 000	27 000	23 800	24 800	23 900
Concentrates	Thousands of tons	12 300	9 000	11 600	5 800	5 700	6 300
Methane emission through enteric fermentation	$MteqCO_2$	44	35	37	25	26	25

- The cattle herd according to scenarios.

Sheep and goats

France has an ovine meat deficit and imports half its consumption: mainly from Great Britain, in front of Ireland and New-Zealand. What is more, the herd is decreasing (by a third since 1990).
The sheep herd (dairy and lactating) would increase by about 20% by 2050[77]. The ovine meat offer would then allow to cover domestic demand. The goat herd would remain stable.

What will our green pastures become ?
Towards new agro-pastoral systems

What impact does the reduction of the cattle herd have on natural grasslands? Their fate is linked not only to the ruminants' headcount, but mainly and above all to their feed. By returning to grazing, the Afterres2050 scenario allows to put 90% of total forage resources to good use. Just like today, the Trend scenario makes good use of 95%. As for the PAR scenario, it uses the totality of the resource with optimised management.
The BHF scenario is the one where all surpluses are the highest. This high surplus is due to the importance of legumes that are necessary to ensure sufficient nitrogen supply, in a context where organic agriculture is generalised. The BHF scenario makes as good use of the natural grasslands as the other Afterres2050 variants.
The surplus fodder stock (from both temporary and permanent grasslands) can be used in several ways, other than feeding ruminants. In Afterres2050, it is used for the joint production of nitrogen and energy by anaerobic digestion, as a complement to

		2010	2030	2050	2050	2050	2050
			Afterres	Trend	Afterres	BHF	PAR
Natural productive grasslands	Thousands of hectares	7 400	7 000	5 800	6 500	6 600	6 500
Natural less productive grasslands	Thousands of hectares	2 400	2 400	2 300	2 400	2 400	2 400
Grass production in natural grasslands	Thousands of tons (dry matter)	41 200	37 700	32 400	34 600	36 400	34 200
Temporary grasslands	Thousands of hectares	3 300	2 600	3 100	2 100	3 100	1 600
Forage crops	Thousands of hectares	17 900	10 400	15 100	4 300	3 400	4 300
Temporary grasslands and forage crop production	Thousands of tons (dry matter)	38 300	27 700	35 000	18 500	27 000	14 400
Ruminant feed							
Grazed grass	Thousands of tons (dry matter)	36 400	33 600	29 000	28 800	29 800	28 700
Fodder	Thousands of tons (dry matter)	38 600	27 800	34 800	18 500	18 500	19 800
Grass and fodder balance = production - consumption	Thousands of tons (dry matter)	4 500	4 000	3 600	5 800	15 100	100
Balance in production %		6%	6%	5%	11%	24%	0%

- Evolution of grasslands and forage crops according to scenarios.

[77] An ambitious but possible goal. See «Des systèmes ovins confortés par la réforme de la PAC » («Ovine systems consolidated by the CAP reform»)- INOSYS network, Oct. 2014.

other substrates (manure, intercrops, crop residues and biowaste). The Afterres2050 scenario proposes to combine cattle farming systems with energy production via anaerobic digestion. It aims to preserve natural grasslands that are biodiversity reserves, for which the palette of possible uses is far smaller than those of arable lands. The scenario refuses to plough these grasslands and strives to preserve or even to increase their ecological, landscape and social value. The harvestable hay from hay grasslands is partly used to feed the livestock and partly used for anaerobic digestion. It can come from dedicated grasslands or from late mowing.

The digestate returned preserves the fertility transfer function from legume rich grasslands to arable land, in addition to the organic fertiliser provided by animal farming. We should underline here that animals don't «produce» nitrogen: the primary production of nitrogen is solely due to legumes and to nitrogenated fertilisers.

We thus reconnect with the driving power production mission that grasslands–rather than arable lands- used to have for horses and oxen, while preserving the agroecological functions of grasslands and without however reverting to animal traction.

Another solution consists in imagining new uses for herbaceous crops. Laboratories and industrials are already working on this «green biorefinery» concept. This is a variant of biorefinery, that consists in using plant matter to extract different components that could replace petrochemical derivatives. The plant matter is fractioned, separated and filtered, before going through more or less complex chemical, biological or physical transformations and providing either basic chemical components – organic acids, polymers, alcohols, resins… –or materials– fibre, paper, film…

This is still part of agriculture, just as the part of agriculture that provided -and still provides- textile matter (wool, flax and hemp), tinctorial or pharmaceutical plants to industries.

Monogastrics

Pigs

The number of pig spaces drops from 8.5 million today, almost all intensive, to 5.6 million in 2050, 60% of which will be non-conventional (organic, free-range or extensive) and 40% improved conventionnel (instead of 97% today). The associated meat production drops from 2.3 to 1.5 million tons.

In poultry farming, the number of broiler spaces drops from 141 million to 110 million. The standard chicken now only accounts for 10%, certified chicken for 15%, the other systems (label, AgriBio) represent ¾ of spaces. Poultry meat production, including here all types of poultry farming, ducks, turkeys, etc., drops from 1.7 to 0.9 million tons.

Eggs are produced in vast majority on farms with no cages, in aviaries and mainly, for 70%, either organic or bearing a label. The number of spaces drops from 50 to 31 million, egg production falls from 940 to 540 thousand tons.

All productions cover the domestic demand, as they do today, whether it be for pork, poultry meat or eggs.

		2010	2030	2050	2050	2050	2050
			Afterres	Trend	Afterres	BHF	PAR
Pigs							
Herd	Thousands	8 503	6 802	4 638	5 102	5 612	5 612
conventional	Thousands	8 163	4 625	3 989	2 041	673	4 377
non-conventional	Thousands	340	2 177	649	3 061	4 938	1 235
Meat production	Thousands of tons (carcass)	2 280	1 824	1 244	1 368	1 505	1 505
Feed consumption	Millions of tons	8 665	6 947	4 735	5 222	5 772	5 681
Broilers							
Flock	Thousands of chickens	141 206	125 673	141 206	110 141	110 141	110 141
standard	Thousands	105 057	53 034	84 724	11 014	7 710	27 535
labelised	Thousands	36 149	72 639	56 482	99 127	102 431	82 605
Meat production	Thousands of tons (carcass)	1 700	1 329	1 639	992	959	1 153
Feed consumption	Millions of tons	5 103	4 793	5 266	4 139	4 133	4 177
Laying hens							
Flock	Thousands of hens	50 299	40 742	50 299	31 185	31 185	31 185
cages	Thousands	34 706	15 075	25 150	1 559	624	4 678
no cages	Thousands	15 593	25 668	25 150	29 626	30 562	26 508
Egg production	Thousands of tons	940	731	917	536	535	545
Meat production	Thousands of tons (carcass)	71	58	71	46	45	45
Feed consumption	Thousands of tons	2 067	1 686	2 070	1 300	1 290	1 295

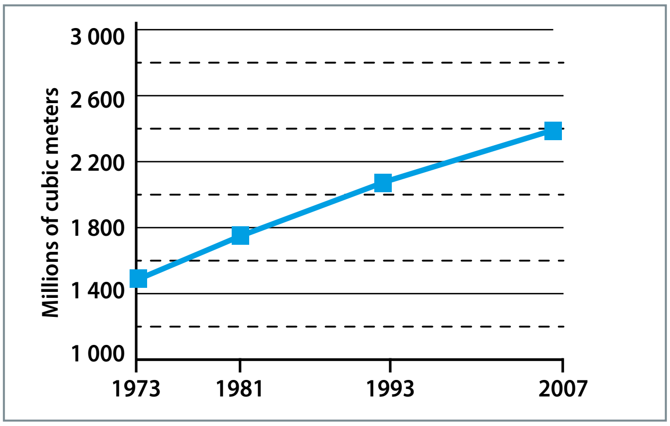
- Evolution of poultry flocks and pig herds.

Forest productions

Situational analysis and forest compatibility

Wood stock and annual organic wood production

The stock of standing timber[78] is estimated at 2.4 billion m^3 and grows by 25 million m^3 every year. The annual organic production is estimated at about 91 Mm^3.



- Evolution of the volume of standing timber in France over the last quarter of a century.

Current harvesting uses

The biological production is the quantity of wood produced yearly by the forest. Part is harvested and the net balance is capitalised and contributes to the growth of standing volume. Net growth takes mortality into account. Harvested quantities are commercialised; part is «lost» (in situ, as sawdust) and another part is used outside of classical commercial circuits (heating wood). Based on IGN data, harvesting amounts to 58 Mm^3 wood in total, counting a 10% loss during exploitation. The harvesting rate is of 43%[79] of the total annual organic production[80].

The uses outside of classical commercial circuits, that are more difficult to estimate, should be added to the commercialised quantities (38 Mm^3 per year on average during the 2010-2014 period).

Mm^3	Total woodl[81]	Small branch wood	TOTAL
Timber	20		20
Industrial wood	12		12
Energy wood (EAB: annual survey)	6		6
Total commercialised	38		38
Energy wood (non EAB)	10	5	15
TOTAL	48	5	53

- Organic production and forest harvest rate.

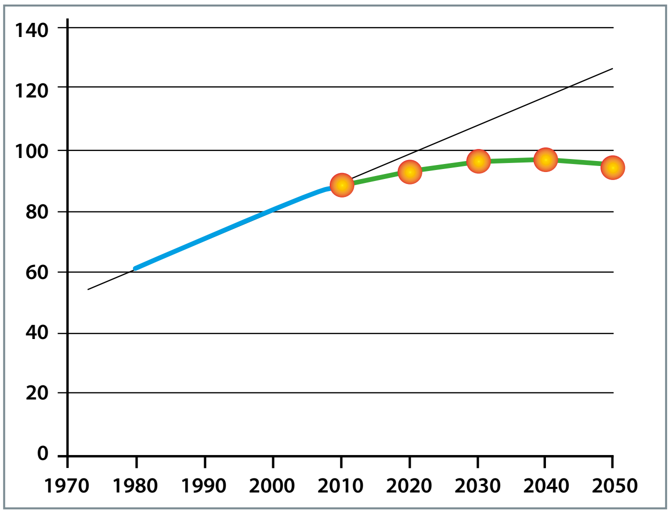
Prospective scenarios

Organic production and harvest

Because of an increase of forest areas but also because of the structure of the French forest, that is globally young, organic production has significantly increased over the last decades as forests have progressed by an estimated proportion of about 50% in 30 years.

This trend should continue, but there are uncertainties around medium term and long-term evolutions because of climate change. The forest does not withstand hydric stress very well, nor the multiplication of pests, nor increased fire and windfall risks. Organic production decrease phenomena (or even stand disappearance ones) can already be observed locally.

There are not many long-term prospective scenarios for the French forest. The works of the Conseil général de l'alimentation, de l'agriculture et des espaces ruraux (CGAAER – French High Council for Food, Agriculture and Rural Areas)[82] are worth mentioning. Their «sustainable development» scenario counted on a harvested volume of 129 Mm^3, for a 17-million-hectare forest.



- Organic production evolution scenario: observed evolution since 1970 and hypotheses adopted in Afterres2050, in millions of m^3 of trunk wood.

[78] Unless otherwise mentioned, forest wood volumes (stock, production and harvest) are indicated in Trunk Wood (TW). See the annexe «Within the accounting intricacies of the bioeconomy». To calculate the total volume of aerial wood, the trunk wood should be multiplied by around 1,5. Lots of publications forget to specify whether the unit used is TW or not, so caution should be used when comparing.

[79] This is the harvest rate of the gross organic production. The IGN most frequently indicates harvest over net organic production (mortality deduced), that is logically higher. Furthermore, storms interfere with this indicator, that should be interpreted over time rather than as an instantaneous value.

[80] It is of around 134 Mm^3 per year. It includes the total aerial wood and not only trunk wood.

[81] The total wood includes both trunk wood and branch wood. See «Within the accounting intricacies of the bioeconomy».

[82] La forêt française en 2050 – 2100 : Essai de prospective (The French forest from 2050 to 2100: a prospective essay). June 2008. Jean-Marie Bourgau, coordinator at CGAAER (Conseil général de l'agriculture, de l'alimentation et des espaces ruraux -– French High Council for Food, Agriculture and Rural Areas).
Presided by the minister of agriculture and agrifood, the CGAAER carries out audit, counselling, prospective and accompaniment missions for the ministers.

The IGN-FCBA 2015 study provides the most recent scenarios, within a 2035 timeframe. No other such prospective study exists for more distant timeframes. The Afterres2050 scenario supposes that small private properties will continue their mobilisation effort: in the IGN-FCBA study, only half of these proprieties are mobilised and so there is still quite some latitude, on condition that the necessary organisation is put into place. We have adopted a maximal harvest level hypothesis of 65%. Applied to an organic production in the order of 140 Mm^3 of total wood, the maximum mobilizable quantities are in the order of 91 Mm^3.

Mm^3 (total aerial volume)	2010	2030	2050
Organic production:			
- trunk wood	88	94	93
- total aerial volume	132	141	140
Harvest rate	46%	58%	65%
Quantities harvested	58	84	91

- Forest harvest hypothesis.

The Afterres2050 scenario works with the «dynamic scenario» values of the IGN-FCBA study for the 2030-2035 timeframe, that is to say an 84 Mm^3 harvest, loss included.

Uses and harvesting: timber

Different prospective studies carried out by IRSTEA[83] or FCBA[84] lead to an additional timber potential that is over 10 Mm^3 in 2020. Our hypotheses on timber demand stem mainly from the TERRACREA[85] research program, carried out by LRA (Laboratoire de recherche en architecture de Toulouse – Toulouse Architecture research Laboratory), the ambition of which was to estimate the potential opportunities for biosourced materials in construction. It is based on hypotheses that are close to the négaWatt scenario as far as the number of new constructions and rehabilitations are concerned, and on hypotheses close to those of the Afterres2050 scenario regarding biosourced material resources.
In these different scenarios, construction wood plays a significant part, both in new construction and in renovation. France imports tropical woods, participating to world deforestation, while the French wood sector is in difficulty, as the decline of sawmilling and the closing down of paper mills show, as far as industrial wood is concerned. The use of timber could however be strongly increased, especially hardwood.

The TERRACREA scenario is based on hypotheses of the distribution of biosourced materials in construction, relying on existing accomplishments: this scenario, just like the Afterres2050 and négaWatt ones, consists in fixing a rhythm to generalise the best techniques available. Thus, in new construction, the proportion of biosourced materials in walls would increase from 10 to 50% by 2050, in insulation from 10 to 75%, and in joineries from 20 to 30%. The main resource comes from wood, in the order of 26 million m^3 of sawn wood in the most ambitious TERRACREA scenario. Wood by-products such as cellulose wadding, wood wool and cork, represent 260.000 tons. Material from agriculture cereal straw, hemp wood, flax straw, cotton, sheep wool, etc.- doesn't exceed 150.000 tons per year. Insulation materials are light and contain more air than matter!

The project shows that a strong increase in construction wood demand can translate into both a strong increase in softwood imports and in a decrease of hardwood exploitation. Hence the choice of strong but realistic hypotheses to rebalance the demand towards hardwood.

Afterres2050 has chosen not to weigh the development of biosourced materials on imports, thus limiting the use of softwood to 17 Mm^3. Regarding softwood, the hypothesis adopted by TERRACREA is ambitious: the IGN-FCBA study only increases from 5 to 7 Mm^3. Afterres2050 has chosen a hypothesis of 13 Mm^3. Leading to a total of 30 Mm^3 of timber, with no imports.

Mm^3 (total aerial volume)	Net availabilities (IGN-FCBA study)	Maximum demand (IGN-FCBA study)	Maximum demand (TERRACREA study)		Value retained (Afterres, 2030)
	Logs	Logs	Sawn wood	Logs	Logs
Hardwood timber	15	7	11	18	13
Softwood timber	17		14	23	16
Total timber	32		25	41	29

- Comparison of various availability and demand scenarios, and choices retained.

[83] Biomasse forestière disponible pour de nouveaux débouchés énergétiques et industriels (Available forest biomass for new energy and industrial outlets), IRSTEA (ex-CEMAGREF), 2009
[84] Perspective de valorisation de la ressource de bois d'œuvre feuillus (Perspective for the better use of hardwood resources), FCBA, February 2011. This study reports an extra 10 Mm3 potential for hardwood timber in 2020.
[85] Synthesis of the TERRACREA research report - Matériaux de constructions biosourcés, ressources agricoles et forestières. Etat des lieux, prospectives et propositions à l'horizon 2030-2050. (Biosourced construction materials, agricultural and forest resources. Situation inventory, prospects and propositions for the 2030-2050 timeframe) P. Besse et al., Sept. 2014.

Uses and harvesting: industrial wood/energy wood

The available resource for industrial wood/energy wood uses, the 29 Mm^3 used as timber and the forest exploitation loss deducted, is thus of 52 Mm^3.
Energy and industrial wood belong in part to the same «part» of the tree, which is why prospective statistics concerning the forest refer to «potential IWEW» to differentiate this resource from «potential T». The available resource that is not used as timber can be mobilised as industry wood or energy wood.
Afterres2050 aims to increase the use of industry wood by 50%. Today 12 million m^3 are mainly used for making paper pulp. In the future, the materials derived from wood will replace the materials derived from petrochemicals. The négaWatt scenario plans to increase material recycling, to reduce needs through sobriety and efficiency actions both in construction and in industry. It also considers the re-localisation of certain industrial activities, and to substitute fossil origin or mined products by biosourced materials. With timber and industry wood uses removed, 35 Mm^3 would remain for energy wood. Timber production requires forestry operations and goes hand in hand with the production of kindling. It is this «related wood» that today constitutes the majority of the energy wood production (apart from copses that are traditionally harvested for heating wood). Timber allows to stock carbon on the long-term; this branch doesn't oppose the energy wood branch, it is on the contrary complementary.
The quantities harvested then increase for all uses, but mainly for energy. They reach an upper limit around the year 2040, then stabilise.

Mm^3 (total aerial vol.)	2010	2030	2050
Quantities harvested	58	84	91
Exploitation loss	5	8	9
Timber	22	29	29
Other wood materials	12	16	17
Energy wood	19	31	35

- Wood use hypotheses.

Biomass non-food valorisations

Renewable carbon for energy and materials

Energy, chemistry, pharmaceutics, cosmetics, plastic, paint, oil, pneumatiques, fertilisers, textile, paper, wood, and of course food: just by looking around us we can understand the extent to which carbon is the atom of the economy.
Substituting biomass renewable resources for fossil resources will however not be possible with an identical consumption level. The limiting factor of renewable resources isn't quantity, as by definition they are not limited over time, but instantaneous flux.
A really sober and efficient recycling strategy is essential in all domains: the négaWatt scenario, that is closely associated to the Afterres2050 scenario. The coherence is in the estimation of our energy and other carbonated matter needs (construction wood, paper, textile fibres, molecules for chemistry and pharmacology), in the renewable biomass production capacities, and in the agriculture and agrifood energy consumption.
The biomass represents the main energy resource in the 2050 «négawatt France» with close to 380 TWh primary energy.

The négawatt scenario, an energy transition scenario that is centred on a reform of energy needs, has popularised the levers of a policy that breaks free from the continuous consumption increase dogma: sobriety, energy efficiency and renewable energies.
It shows that France can halve its final energy consumptions, divide by 16 the energy CO_2 emissions, and radically reduce its dependence on fossil energy by 2050, by strongly mobilising renewable energies, while progressively abandoning nuclear energy over two decades.
Food needs are an entry point to our modelling work. The sobriety principle carries positive values: consume with moderation and sparingly, but in an epicurean way. It thus opposes acts of intoxication, gluttony, immoderation, waste, mortification, ascetism, austerity...

To find out more: www.negawatt.org

Producing bioenergies with the agricultural and forest biomasses

Today, the energy production derived from the biomass in metropolitan France represents close to 193 TWh HCV in primary energy: from wood (forest, hedgerows and green areas) and from wood by-products (sawmill residues, waste wood and paper mill black liquor), from agrofuels, urban waste (the fraction of renewable origin such as kitchen waste and papers and cardboard), biogas, and agricultural residues.

Ressources		1995	2000	2005	2010	2014
Ethanol	TWh HCV	0	1	1	5	5
Biodiesel	TWh HCV	2	4	6	26	33
Biogas	TWh HCV	1	1	2	4	6
Energy wood	TWh HCV	125	123	107	111	129
Other solid biomasses	TWh HCV	1	2	3	6	5
Urban waste	TWh HCV	8	10	12	15	15
TOTAL	TWh HCV	137	140	132	168	193
Uses						
Electricity production and cogeneration		5	7	10	19	18
Fuels		2	4	8	31	38
Thermal uses		130	129	115	117	137
TOTAL	TWh HCV	137	140	132	168	193

- Current biomass energy productions.

Wood

Energy wood from wooded areas

Today, the French forest provides 19 million m³ of energy wood. It will provide up to 35 million from 2040 onwards. That is to say a total of 95 TWh in HCV.
The wood other than from forest trees comes from hedgerows, urban trees, green areas, parks and gardens, vines and orchards, from agroforestry and from semi-natural habitats. All wooded elements are strongly developed in the Afterres2050 scenario, and each non-forest hectare would provide on average close to 0,5 m³ of wood per year, in the 2050 timeframe, almost 70% of which could be used as energy wood, and a third as material wood.

Sawmill residue by-products, waste wood, other wood by-products

The «saw-mill residues» (slabs, edgings, bark and sawdust) are partly used today to produce paper pulp, partly as energy. Their volume is increasing, due to the fact that sawmilling is increasing. «Wood waste» includes lumber rejects (shredded pallets and wrappings), wood from building demolition, and waste from wood by-products: non-recyclable cardboard, papermill black liquors, sludge…
All this matter stems from the use of timber and industry wood, materials that are destined to become waste after use, in the more or less long-term.
Today, a large part of the energy wood resource originates from these first or second transformations of wood.

Biogas

Biogas production increases and reaches 124 TWh in 2050. 90% of it comes from agricultural biomass sources.
Anaerobic digestion is considered to become a standard of all agricultural production, whether animal breeding or cultivation systems. Multiple forms will be available, as they are today: from farm-scale biogas units to collective territorial installations.
Anaerobic digestion is used both as an energy production tool using diverse agricultural resources available on a territory, and as a fertilisation optimisation tool. It contributes efficiently to organic nitrogen recycling, limiting the needs in nitrogen fertilisers. It also provides a diversification of farmers' income.

Biowaste, animal waste, crop residues

The main current biogas production comes from household and business waste: biowaste, sludge from waste water plants, industrial effluents, agri-food waste… In Afterres2050 a double phenomenon can be witnessed: an increasing part of this waste is transformed into methane, but the quantity of waste also decreases thanks to the reduction of loss and waste. Biowaste would provide 9 TWh in 2050.
Likewise, the quantity of animal waste decreases, due to the decrease of herds and the increase of grazing time, but the anaerobic digestion mobilisation rate increases. The estimated potential in 2050 is of 12 million tons of dry matter, producing 29 TWh. The mobilisation rate includes resources that are too scattered to feed a biogas plant, but it is high, at around 90%.
Afterres2050 plans to mobilise 30% of crop residues to feed biogas plants. The reduction of herds leads to reducing the amount of straw used as animal bedding. The straw mobilisation rate increases compared to today: anaerobic digestion preserves the entire humic potential of straw and its fertilising value (mineral elements). It transforms a little less than half of its total carbon to biogas, that is as much energy that is not available for the life in the soil. Harvesting should thus be limited, especially

as straw has a structuring effect on the soil. A straw harvest rate of 30%, 60% of which is contained as total carbon rendered to the soil, is compatible with soil conservation objectives. The generalisation of permanent cover practices and of shallow tillage contributes to maintaining soils that are rich in organic matter. The total potential is of 30 TWh.

Forage resources and intercrops

Afterres2050 proposes to use the forage resources that are not consumed by ruminants. For one part these are legume crops cultivated in large-scale crop regions to provide symbiotic nitrogen in these agrosystems, for another part they are the surplus grass in grassland systems. These productions would only become significant from 2030 onwards and would remain limited to under 15 TWh HCV. That would represent a global volume of 6 million tons of dry grass and forage matter, that is to say about 10% of total grass and forage production.

Intercrops -or EMSICs[86]- are generalised on nearly all arable lands by 2050. They can be left in place as a green fertiliser, or harvested, if the yield is sufficient to justify harvest fees, which depends on climatic variations, on the soil nature and on the EMSIC type.

In this second case, the EMSIC harvested can be used as animal feed and would then count in the calculation of the forage balance; the surplus can be used for anaerobic digestion, returning the digestate to the soil as a green fertiliser; or it can be exported to be used as biomaterial.

EMSICs present a forage value but never reach the maturation level that is necessary for human consumption: cereals for example are harvested green and contain little starch. These crops can be used for livestock feed. The estimation of the quantity of intercrops that can be harvested is based on the hypothesis that

	Non harvested	Harvested, methane produced, returned to soil	Harvested and exported
Animal feed			X
Green fertiliser	X	X	
Materials			X

• Possible uses of intercrops.

¾ of EMSICs are summer crops and ¼ winter crops[87]. The highest yield is considered to be of 7 tons of dry matter on average on the best third of summer EMSIC cultivated land (1.5 Mha), one year out of 5, and the lowest yield of 1 ton of dry matter on average on the poorest third of winter IC cultivated land (4.5 Mha), one year out of 5. The table below details the adopted hypothesis. The harvest threshold is considered to be of 4.5 t DM/ha. These hypotheses of yield variations are far higher than those of main crops, as EMSICs are sown at the end of spring or in the summer, with the hypothesis here that they are not irrigated, nor treated, nor fertilised.

Their harvest potential is estimated at 18 million tons of dry matter, that is to say a third of their total production, on 17 million hectares of arable lands. The corresponding potential is estimated at 43 TWh HCV.

The table shows that statistically, harvestable EMSICs are not produced 2 years out of 5, and that summer EMSICs are almost never harvestable on 2/3 of lands. To be able to feed the anaerobic digesters regularly, a 2-year stock is necessary, either as hay or as silage. If the harvest threshold changes to 4 tDM/ha, the harvestable quantity is of 27 Mt DM. The harvest hypotheses thus remain cautious.

	Summer EMSICs: ¾ of the COP			Winter EMSICs: ¼ of the COP			Total, Mt MS
Land quality	Good	Average	Poor	Good	Average	Poor	
Proportion	1/3	1/3	1/3	1/3	1/3	1/3	
Areas, Mha	4.3	4.3	4.3	1.3	1.3	1.3	
Yield, tDM/ha							
Best year out of 5	5	4	3	7	6	5	77
2nd quintile	4.6	3.6	2.6	6.2	5.2	4.2	68
3rd quintile	4.0	3.0	2.0	5.0	4.0	3.0	55
4th quintile	3.4	2.4	1.4	3.8	2.8	1.8	43

• Intercrop yield according to land quality, the nature of crops and climate variations.

86 Environmental multi service intercrop; this terminology is preferred to IEVC or Intermediate Energy Vocation Crop.

87 Summer EMSICs are harvested before implanting a winter crop. For example, sorghum or a buckwheat sunflower mix, that resist well to water stress. Winter EMSICs are harvested at the end of spring, they are frost resistant crops with regrowth of vegetation in the spring. Most grasses can be used mixed with legumes. Their yield is higher because they benefit from two growth periods. They precede spring crops: corn, sunflowers, beetroot and spring cereal.

Biofuels

The biofuels produced today in France represent 2.9 million tons of equivalent petrol: 86% as biodiesel and 14% as ethanol. The resources used represent respectively 2.5 million tons of oil and 1.3 million tons of cereals.
Their production decreases regularly in Afterres2050, reaching a half of their current production level, because of the competition with human food.

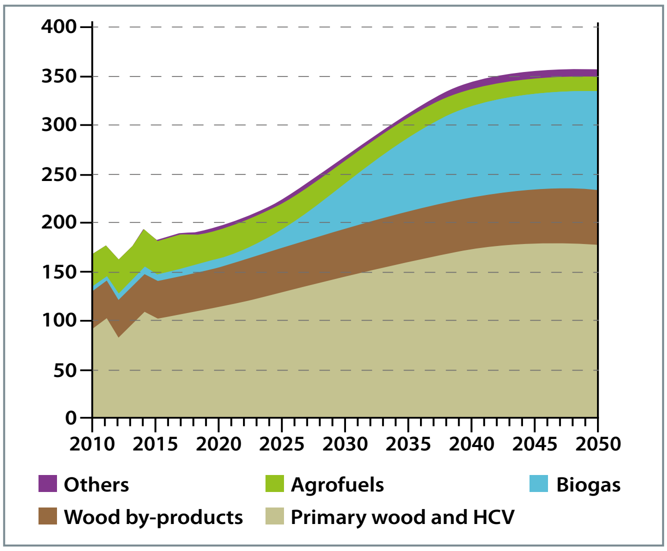
The methods to obtain fuel from plant matter will be significantly different from todays. Certain branches of so called 2nd generation will be available then, integrated to solutions such as «biorefineries», transforming plant matter into various biosourced products and generating co-products that can be used as combustibles or fuels.

Production and use of bioenergies

Fire wood used in its traditional applications for home heating is today the main way bioenergies are used. This progressively decreases in the négawatt scenario, in parallel with the decrease of the heating needs of buildings, benefitting collective installations (heating systems) or industrial ones.

The first use of biogas is through the cogeneration of electricity and heat, then more and more as biomethane injected into the public network. A part of the woody biomass is also converted to biomethane by gasification followed by a methanation reaction.

The biomass thus provides two substitution paths to natural gas with renewable methane. One of the new uses of gas is in transport: the négaWatt scenario plans to replace a strong proportion of fuels with methane, replacing petrol products.



• Evolution in the production of bioenergies, in TWh HCV.

GROSS RESOURCES (TWh HCV)	2010	2030 Afterres	2050 Trend	2050 Afterres	2050 BHF	2050 PAR
Wood –primary resources and sawmill residue by-products						
Forest energy wood	53	80	89	95	95	95
Sawmill residue by-product energy	15	22	26	26	26	26
Agroforestry and non-forest tree energy wood	10	24	6	36	43	40
Other solid biomasses -waste wood, waste and wood by-products, crop residues						
Wood waste (2nd transformation, waste wood, wrappings, demolition)	37	47	48	53	57	55
Other wood by-products, (papermill sludge, black liquors…)	16	18	18	18	18	18
Crop residues for combustion	0	3	7	5	0	6
Biogas						
Kitchen waste	3	5	9	9	9	9
Manure	1	14	13	29	27	33
Crop residues	0	17	5	29	15	33
intercrops	0	13	3	44	27	28
Grass and forage crops	0	3	1	13	22	-2
Other biogases	0	0	0	0	0	0
Liquid biomass						
Ethanol	5	3	5	2	1	2
Biodiesel	26	20	30	12	10	13
2nd generation biofuels	0	0	0	0	0	0
TOTAL	167	269	260	371	350	357

• Energy biomasses from now to 2050.

Afterres2050

Evaluating the impacts

Producing as much with to 2 to 3 times less inputs

A deeply modified nitrogen cycle

Synthetic nitrogen consumption drops from 2.3 million tons to 1 million tons by 2050. The nitrogen balance (uses/resources) was established on several levels: for agricultural lands (crops and grasslands), animal farms, food for humans, and on a global level. The total quantity of «soil inputs» is quite close to today's inputs, that is to say 6 million tons per year, but the balance structure is very different. The protein value of plant productions, represented by the «exports»[88] from forage and crops, is higher, at 5 MtN, than today's 4.3 MtN. The losses are lower, with a gain of 600 ktN over volatilisation and leaching. The soil balance, that is to say the difference between total inputs and outputs, also drops by almost 400 ktN.

Recirculation fluxes are overall identical, at 3.5 MtN. Redepositions decrease because volatilisation is better managed and return mainly occurs after anaerobic digestion for one part (1.3 MtN) and for the other by leaving 2/3 of intercrops in the field (1.1 MtN). The latter explains the increase of «exports»: this flux is entirely rendered and counts both as debit and credit, in «exports» and returns to the soil. The returns via grazing decrease less than the herd does, as grazing time increases. The nitrogen return decrease via droppings and crop residues can be explained by them being used in anaerobic digestion.

Primary needs decrease slightly, from 2.6 to 2.4 MtN. Indeed, exports increase but losses decrease, therefore there is less need for a primary nitrogen source, expressing an overall improved system efficiency.

	2010		2050	
«Agricultural land» nitrogen balance 2010	Inputs	Outputs	Inputs	Outputs
Primary nitrogen supply				
Mineral fertilisers	2 260		850	
Symbiotic fixation	380		1 520	
Nitrogen exports				
Forage exports		1 950		1 550
Crop exports		2 310		3 430
Recycling and recirculation fluxes				
Atmospheric redeposition	760		230	
Return via grazing	720		560	
Return via livestock manure	1 170		60	
Return via crop residue left in field	650		290	
Return via non-consumed plants	60		1 050	
Return via non-consumed grass and forage	120		0	
Return via digestates (droppings, meadow grass, crop residues, intercrops)	0		1 340	
Diffuse losses				
Losses through volatilisation and leaching		860		290
Soil balance		1 000		630
TOTAL	6120	6 120	5 900	5 900

- «Agricultural land» nitrogen balance, 2010-2050 comparison.

Symbiotic fixation allows to provide 1.5 MtN, thanks to the culture of protein crops for human or animal use (soya, peas, lentils, beans, broad beans, fava beans) and of forage legumes (alfalfa, clover), and to the presence of legumes in intercropped or associated crops, that alone contribute to half of the symbiotic fixation. Mineral fertiliser input is calculated as the difference between primary nitrogen needs and intake via symbiotic fixation. It is divided by 3 in comparison to today's, at less than one million tons, which happens to equal the French industrial production of nitrogenated fertilisers. An industry that would be entirely biosourced as the necessary methane (or hydrogen) would be of renewable origin.

[88] Export has the agronomical meaning here, that is to say what is produced in the fields.

	2010		2050	
	Area (kha)	Symbiotic nitrogen (kt)	Area (kha)	Symbiotic nitrogen (kt)
Soya	40	6	190	18
Peas, beans, lentils, protein seeds for human consumption	160	19	1.440	155
Fava beans, lupin, protein seeds for animal consumption	90	14	660	79
Alfalfa, clover and other legume grasslands	300	76	1150	282
Mixed grasslands	2.350	100	720	30
Intercrops or associated crops with cereals	9.380	18	9.480	680

- Table: Main sources of symbiotic nitrogen

Less energy, more renewable energies

The overall energy consumption of agricultural production is reduced by 40%, thanks to the changes in systems and in practices (fuel for ploughing, fertilisers), and to technical improvements (low consumption greenhouses, economical irrigation, tractor engines). Energy sources are 90% renewable according to the négaWatt scenario, including combustibles and fuels (bioNGV: Natural Gas for Vehicles produced from biogas). The energies used in input production processes are also of renewable origin: nitrogen fertiliser synthesis is achieved using biomethane or hydrogen of renewable origin.
It can be noted that the agricultural biofuel production corresponds exactly to the agricultural fuel consumption. And that the production of agricultural renewable energies amounts to around 165 TWh, that is to say twice the consumption of the agricultural sector.

Agricultural energy consumption, TWh	2010	2050	2050	2050	2050
		Trend	Afterres	BHF	PAR
Direct energy	63	48	44	45	45
Fuels	33	27	23	25	24
Electricity	11	9	6	6	6
Combustibles (gas, fuel)	18	10	6	6	6
Wood	-	2	9	9	9
Indirect energy	54	41	27	19	35
Nitrogen	34	23	10	3	17
Other inputs	10	9	7	7	8
Material	10	9	9	9	9
TOTAL	116	89	71	54	80

- Agricultural energy consumption, TWh, 2010-2050.

Pure air, clean water

The atmosphere breathes better

Strongly reducing agricultural emissions

Greenhouse gas emissions aren't the only atmospheric pollutants that considerably decrease. Agriculture is an important contributor to ammoniac emissions and to primary and secondary particles[89]. Pesticides are also present in the air.
The Afterres2050 approach integrates all the main practices recommended to lower these emissions.
Reducing the number of animals and increasing grazing time and the proportion of straw based systems strongly decreases ammoniac emissions, the three quarters of which animal farms are responsible for. In addition to that there is an improvement of spreading techniques and practices (weather forecast precision, spreading optimisation, equipment enhancement), and a better balance of nitrogenated inputs.
The nitrogen volatilisation risk of digestates is counterbalanced by a reduction of the direct spreading of animal waste and by the generalisation of covering the digestate storage pits.
The generalisation of simplified culture techniques, of non-ploughing, and of permanent cover are other major reduction factors of atmospheric particles. The soil is worked less, it is less submitted to erosion phenomena, there is less machine passage. Only the harvest stage has no alternatives for now.
It is hard to quantify these reductions: a factor 3 for ammoniac, and probably of the order of a factor 2 to 3 for the other emissions.

[89] Les émissions agricoles de particules dans l'air. Etat des lieux et leviers d'action (Agricultural particle emissions in the air. Situational analysis and leverage actions.) ADEME, March 2012. Secondary particles are generated by a chemical reaction, for example between nitrogen oxides and ammoniac.

	Fine particles, PM 2.5	Fine particles PM10	All particles	Ammoniac
Part played by agriculture in French emissions	10%	19%	48%	97%
Total agricultural emissions in kt				
Cultures (tillage, harvesting, residue burning, fertilisers)	3.4	26.5	417	107
Animal farming	4.9	20.9	46.5	364
Machines (fuel combustion, brakes and tyres)	16	23	41	

- Agricultural atmospheric emissions.

Regarding pesticides, the phytosanitary pressure[90] is divided by three.

Particle free combustibles and fuels

The bioenergies produced by agriculture and the forest also help to reduce air pollution in other sectors.
If the energy wood traditionally used in home heating is an important emitter of fine particles, in the négaWatt scenario this use decreases, replaced by far more efficient practices. The improvement of construction insulation and of the performance of heating appliances leads to far lower heating needs, and even if there is an increase in wood energy users, the total consumption decreases. Collective or industrial heating systems are under development, with emission levels 10 times lower than those of current individual appliances.
Transportation sobriety and efficiency actions also allow to reduce fuel demand. The pollution of this sector is significantly reduced by replacing liquid fuels with methane in almost all applications. As methane is composed of a single carbon atom, it is indeed difficult to generate pollutants containing several! This inherent asset of methane facilitates NOx and CO reduction techniques compared to those used for liquid fuels, that have long carbonated chains. NGV emits 30 to 70% less NOx and 95% less fine particles than diesel.

		Ammoniac	Particles
Culture	Simplified tillage	?	+
Culture	Intercropping soil cover	?	++
Buildings	Increased grazing time	+	++
Storage	Covering pits	++	
Spreading	Drop pipes, injection	+	?

- Main recommendations to reduce atmospheric emissions.

Water

Reconquering the quality of our water resources

In 2015, we haven't reached a good ecological and/or chemical state of water masses, that would conform with the 2000 European Water Framework Directive. This goal, enlightened by the failures registered in France since the 3rd of January 1992 law, would have required the implementation of efficient and constraining policies.
On the 3rd of January 1992, water became «common national heritage». Since then, the state of our resources has never cessed to deteriorate, as confirmed by the raw data review of the state of our resources before any depollution treatment.
Some examples:

- 400 drinking water catchments are abandoned each year in France;
- The government plan against green algae, launched in 2010 in Brittany, has an estimated cost of 2 000 to 4 000 € per hectare of watershed UAA;
- According to the French Ministry of Ecology (CGDD), water pollution by pesticides and nitrates adds a 1,7 billion euro cost a minima per year to the distribution of drinking water. If agricultural pollutants in the water were to be eliminated, the treatment would cost at least 54 billion euros a year to obtain «natural» water (and not simply water conforming to drinking water norms) .
- France was condemned by the European Court of Justice in February 2012 for its incapacity to fight nitrate pollution, mainly due to agriculture.

The national nitrate surplus (nitrate input to soils and not reexported as grain or forage) is estimated at 900 000 tons. It represents:

- 20% of all nitrate inputs in all forms (mineral, organic, linked to symbiotic fixation or stemming from atmospheric deposition);
- 50% of nitrogen fertilisers.

This «surplus» value is coherent in order of magnitude with the quantity of nitrogen that shows up annually in the estuaries of the great metropolitan rivers (almost 700 000 tons).
Concerning the use of pesticides, the aim is to halve it by 2018 (Ecophyto 2018), whereas the European «pesticide» Directive implies the generalisation of integrated pest control by the 1st of January 2014.
Lowering the nitrogen surplus on a national level (-40%), dividing ammoniac emissions by 3 (thus the volatilisation and associated redeposition risk), and dividing pesticide consumption by 3, are as many factors contributing to reaching these various goals in Afterres2050.

[90] The phytosanitary product pressure is measured with the number of unique doses (NOUD). The NOUD indicator, used within the French Ecophyto plan, is the sum of these «normalised» quantities for all the active substances sold. Our NOUD calculation also includes seed coating.

Modifying animal farming practices also contributes to considerably lower the consumption of antibiotic products, a part of which can also be found in surface waters.

Limiting irrigation in the summer

The climate change will generate new irrigation needs, in particular for cereals and high-protein oil seeds, as well as for grasslands. If nothing is done, these needs could increase by around 1.5 billion m^3 per year. In Afterres2050, the reduction of corn grounds, a consequence of herd evolution, allows to halve summer water consumption and to reserve irrigation use for cereals and high-protein oil seeds, mainly in the spring and autumn for starter or supplemental irrigations, and for vines and fruit and vegetables.

Water consumption, Mm^3	2010	2030	2050	2050	2050	2050
		Afterres	Trend	Afterres	BHF	PAR
Cereals, high-protein oil seeds (except corn)	-	300	200	700	600	1000
Corn	2000	900	2000	400	300	500
Grasslands, forage crops	100	100	600	100	100	100
Fruit and vegetables	-	-	100	100	100	100
Others	600	1000	800	1400	1100	1100
TOTAL	2700	2300	3700	2700	2200	2800
Of which summer consumption:	2000	900	2000	400	300	500

- Water consumption Mm^3, 2010-2050.

The climate & carbon equation

Taking the whole food chain into account in the fight against climate change

France has committed to reducing its greenhouse gas emissions[96] by 20% by 2020 and by 75% by 2050. This goal is called the «factor 4 goal». The factor 4 in 2050 means that within that timeframe, each French inhabitant will emit the equivalent of 2 tons of CO_2 per year, as opposed to almost 9 tons today.
These are minimal goals. The international scientific community states the necessity to reach «negative» emissions (that correspond to withdrawing CO_2 from the atmosphere) by 2070.
France (metropole + overseas departments and territories) emitted 496 million tons equivalent CO_2 ($teqCO_2$) in 2010 (considering the 33 $MteqCO_2$ fixed by the agricultural land and forest «carbon sinks»). With over 170 $MteqCO_2$, agriculture and food production -from the plot to the treatment of food waste- are responsible for 36% of emissions, which is more than the transport or construction sectors[97].
Agriculture emits 86 $MteqCO_2$, 108 if indirect emissions linked to nitrogen fertiliser production, crop protection products and imported livestock feed are included. Agriculture is responsible for 80% of methane and nitrous oxide emissions.

M t eq. CO_2	CO_2	CH_4 eq. CO_2	N_2O eq. CO_2	TOTAL
Direct emissions	9	42	35	86
Agricultural land nitrogen input, leaching and NH_3 volatilisation	1		32	32
Enteric fermentations		34		34
Animal farming effluents		8	3	12
Energy consumption	11			9
Indirect emissions	16	0	5	21
Nitrogen fertiliser production	9		5	14
Energy production	1			1
Other inputs[99]	6			6
TOTAL	25	42	40	108

- Greenhouse gas emissions via agricultural activities (CLIM'AGRI®[98] format) - 2010

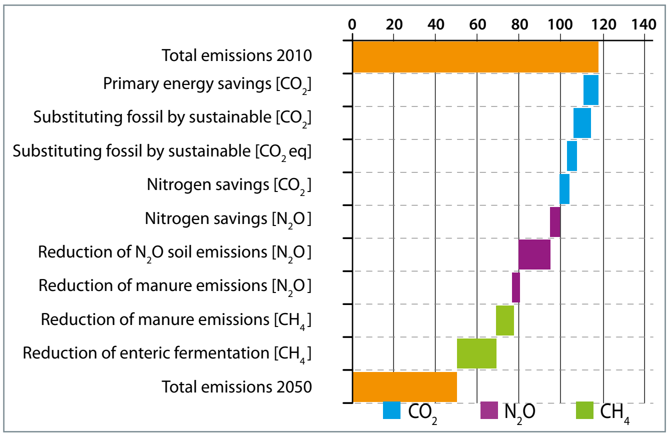
[96] In conformity with the European Union «energy/climate package»: 4 texts, and particularly the «renewable energies» directive 2009/28/CE that fixes production goals for each country (23% for France) by 2020, concerning the proportion of renewable energies in the final energy consumption. The transportation sector must use at least 10% of energy produced by renewable sources. The 406/2009/CE decision fixes the limitation of GHG emission goals in each state in comparison with 2005 (- 20% for France). The Grenelle laws and the French 2015 Law on Energy Transition for Green Growth transcribe these European laws into French national laws.
[97] «Households have a role to play in reducing greenhouse gas emissions». IFEN, number 115, Nov. Dec. 2006.
[98] See «Within the accounting intricacies of the bioeconomy».
[99] Lime and dolostone, other fertilisers, crop protection products, «grey energy» of agricultural buildings and machines.

Halving our climate footprint

A significant drop of emissions on the French territory

The agricultural greenhouse gas emissions are halved compared to todays. The main reduction factors are related to the reduction of the cattle herd and to better control of nitrogen fertilisation. The latter has an effect both on N_2O emissions and on fossil gas consumption, with amongst others technical progress on fertiliser production, that allows to lower the energy consumption (20%) and to emit less N_2O [100].

The strong reduction of direct emissions of CO_2 is due for 1/3 to a lower energy consumption, and for 2/3 to the substitution of fossil energies with renewable ones.



• Reduction of the GHG emissions per item in MteqCO_2.

M t éq. CO_2	CO_2	CH_4 eq. CO_2	N_2O eq. CO_2	TOTAL
Direct emissions	**2.9**	**25.3**	**17.3**	**45.5**
Nitrogen input and other inputs[101] on agricultural lands. leaching and NH3 volatilisation	1.2		16.0	17.2
Enteric fermentations		24.9		24.9
Animal farming effluents		0.4	1.3	1.7
Energy consumption	1.7			1.7
Indirect emissions	**4.7**	**0**	**0.4**	**2.7**
Nitrogen fertiliser production	2.3		0.4	2.7
Energy production	0.5			0.5
Other inputs[102]	2.4			2.4
TOTAL	7.6	25.3	17.7	50.1
Reduction rate / 2010	69%	52%	55%	54%

• Emissions of greenhouse gasses –Clim'Agri® format– Afterres2050.

A carbon footprint that takes exports and imports into account

This GHG emission reduction isn't a simple transfer as the GHG balance remains positive in 2050; the carbon footprint[103] is also divided by 2.4 compared to today. In the Trend scenario. on the opposite. the balance becomes negative and the footprint decreases little. The PAR and BHF variants are not significantly different from the Afterres2050 scenario. with footprints also close to 50 MteqCO_2.

M t eq. CO_2	CO_2	CH_4 eq. CO_2	N_2O eq. CO_2	Total emissions	Export	Import	Balance	Footprint
Current situation	24.7	52.5	39.5	116.7	+ 29.3	21.4	+ 7.9	108.8
Trend	17.8	42.2	28.8	88.8	+ 14.7	29.0	- 14.2	103.1
Afterres	7.5	25.3	17.8	50.6	+ 14.1	9.4	+ 4.6	45.9
PAR	9.2	26.0	14.7	49.9	+ 12.5	10.4	+ 2.1	47.7
BHF	9.2	25.9	21.0	56.1	+ 14.7	11.7	+ 3.1	53.0

• Greenhouse gas emissions according to scenarios.

Carbon sinks remain important

The main carbon sink effect is due to the continuing increase of the biomass stock in forests. The main difference between scenarios lies in the forest harvest rate. The «constant forestry» scenario of the 2015 IGN-FCBA study indicates a forest carbon sink effect increasing from 70 MtCO_2 per year today to 86 MtCO_2 per year for the 2031-2035 period, compared to 62 MtCO_2 for the «progressive dynamic management» scenario. The carbon sink effect thus continues, increasing significantly in the constant forestry scenario and decreasing slightly in the dynamic scenario. The differential between both scenarios is of 24 MtCO_2. This difference is compensated by carbon storage in forest biosourced materials, that is higher in the dynamic scenario, as well as by the fossil energy substitution effect. Above all, the dynamic scenario allows to rapidly renew stands and to favour their adaptation to climate change. The volumes exposed to variations–storms, fires–are lessened and the accidental carbon loss risk is lower.

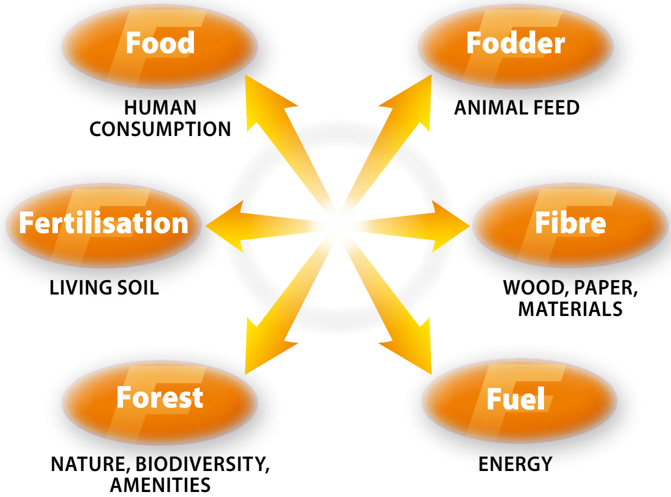
[100] Producing nitrogen fertilisers (excepting urea) generates N20 emissions, that could be very quickly reduced by 75 %.
[101] Carbonated matter like lime and dolostone emit carbon dioxide.
[102] Producing fertilisers and inputs other than nitrogen, crop protection products, emissions liked with the construction of agricultural buildings and the production of agricultural machines.
[103] See «Within the accounting intricacies of the bioeconomy»

In fine, arbitrating energy fluxes

The land and bioresource «hexalemma »[104]

The Afterres2050 scenario aims to favour synergies rather than antagonisms, between the «6Fs» that constitute the 6 poles of the biomass «hexalemma»:

- «Fertilisation», that symbolises the needs in stable carbon, humus and fresh organic matter for rich and inhabited soils;
- «Fibre», and in general all biomass matter uses;
- «Fuel», for energy production;
- «Forest», in its etymological meaning of an area free from anthropisation, and that represents the eco-systemic amenities, nature protection and biodiversity preservation;
- «Fodder», for animal feed;
- «Food», for human consumption.



- Afterres2050 and the 6 «Fs»

The «energy flux» indicator provides a global vision of arbitrations

The studied scenarios can be compared by identifying energy fluxes or carbon fluxes, which amounts to roughly the same thing. This approach consists in evaluating the final energy destinations of various matter, that stem directly or indirectly from the primary production, that is to say the quantity of energy fixed by photosynthesis in the agricultural biomass.

For example, there are the fluxes left in the field: crop residues, grass and non-harvested intercrops, droppings in the pasture, or rendered: manure and slurry, digestates. This flux feeds the living organisms in the soil, and thus conditions its biological activity.

The «food» flux is the one that ends up in our plates. The «food» flux is considered here as a final flux, but in reality, human metabolism should be considered. The exploitable fluxes, losses through metabolism (sludge from wastewater treatment plants) deduced, are low compared to the total. The circuits are direct as far as plants are concerned, losses and transformations not taken into account, but they are much more complex regarding animal feed. The quantity of energy of the primary plant biomass used to feed animals is in part transformed into meat, but also lost in animal metabolism (heat and movement), and in animal waste. On the national level and in energy value, the edible animal productions represent about 10% of the energy value of their feed, metabolism loss a half, and animal waste a third. Added here is the mass loss, and thus energy loss, linked to waste stockage.

The «export» flux represents the quantity of agricultural wares exported, that are destined to animal or human consumption abroad.

The «energy and materials» flux includes the energy contained in biogas (and not in the digestate, that is counted as a flux returning to the soil), as well as the straw used as material.

PJ/year	Current	Trend	Afterres	BHF	PAR
Primary plant production	4 400	4 200	4 400	4 200	4 300
Food	450	500	450	450	440
Exports	580	500	440	270	610
Energy + material	40	160	790	680	780
Animal metabolism losses + animal waste losses	1 270	1 030	690	700	700
Soil	2 090	1 980	2 010	2 120	1 790

- Destination of the energy fluxes from primary plant production, in PJ [105]

[104] Hexalemma is a neologism coined from trilemma, itself derived from dilemma.
[105] The PétaJoule (PJ) is worth 1018 Joules (1 billion billion).

Reducing losses, increasing energy and materials

Primary production is at 4.400 PJ in the Afterres2050 scenario. The total amount of energy left on the ground or returned is of 2.000 PJ, that is to say half the primary production. Human food represents 450 PJ, that is to say 11% of primary production, and exports almost as much at 440 PJ. The energy and material flux are multiplied by 20, at 790 PJ. The livestock metabolism losses are halved and drop to 690 PJ [106].

In fine, in comparison with the current situation and, in a lesser measure, in comparison with the Trend scenario, the Afterres2050 scenario establishes a significant transfer of carbon fluxes by reducing animal metabolism loss and increasing energy and material production. The other fluxes remain comparable.

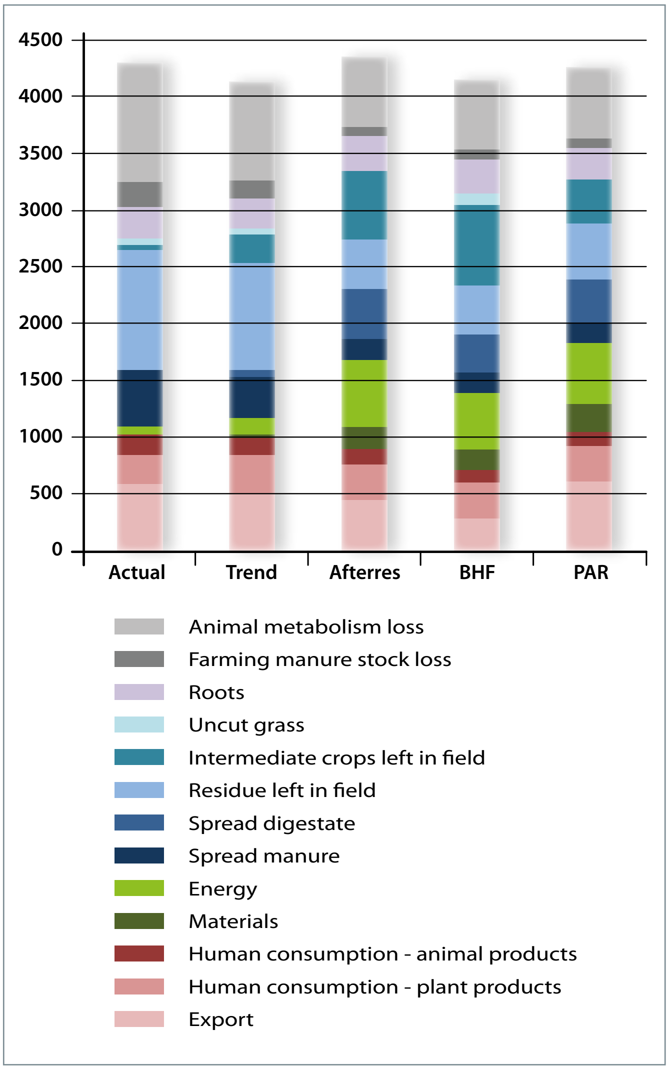
The two variants differ on the arbitration chosen: BHF preserves a higher energy flux towards the soil with an export decrease, whereas PAR represents the exact opposite.

The carbon fluxes towards the soil aren't significantly different within the studied scenarios nor the current situation. The soil carbon stock increase doesn't come from a modification of input fluxes, but from changing practices with non-ploughing and simplified culture techniques.

The arbitrations appear through the identification of energy fluxes. Primary energy (from primary plant productions) ends up either in consumed food products, including exports, or in the matter returned to the soil, possibly after passing through animals' digestive systems, or through methane digesters. The trophic chains thus end with 4 types of digestive systems: humans', animals', methane digesters' and the ones in soil microorganisms.

These fluxes allow to discuss arbitrations and for everyone to be able to express their preferences. A scenario aiming for a higher export level could be desired: as a consequence, soil life would risk being penalised (PAR scenario). Inversely, a scenario that favours the soil must reduce exports and energy and material productions.

The importance of non-food productions, representing 20% of the primary production, should be noted. They are energy productions - mainly through anaerobic digestion - and material productions, from intercrops, wooded elements, crop residues and animal waste. The quantity of carbon returned to the fields is however comparable to the current level, representing around half of the primary plant production.



• Detail of the energy flux from primary plant production.

The carbon indicator is all the more favourable to the Afterres2050 scenario that the most stable fractions of organic matter are considered, always with relatively close levels according to the considered scenarios, only the PAR scenario is less well rated than the others. This indicator is of prime importance; however, it is rarely considered in this type of exercise: its calculation method is uncertain, as is its interpretation.

Scenario		Current	Trend	Afterres v. Oct. 2015	BHF	PAR
Year		2010	2050	2050	2050	2050
Total carbon	PJ	1 770	1 820	1 930	2 020	1 670
Carbon > 1 month	PJ	1 290	1 280	1 390	1 370	1 230
Carbon > 6 months	PJ	940	930	990	980	890

• The carbon returned to agricultural lands.

[106] 4400 PJ is equivalent to 100 million tons of petrol, that is to say two thirds of our current final energy consumption. The losses due to animal metabolism are equivalent to 30 million tons of petrol.

Biodiversity and ecosystem resilience

Ecosystems that are more resistant to climate change

Beyond respecting the fundamental agronomical principle that consists in choosing crop plans and crops that are coherent with climate availability (sum of temperatures and rainfall), with its choices and options, Afterres2050 plays on global resilience by increasing or restoring agrosystems' capacity to «withstand» important climate differences over a short period (droughts, storms).

This higher resilience mainly stems from:

- longer rotations and diversifying crop plans: also leading to varietal diversity over time and space, this strategy «which amounts to not putting all of one's eggs in the same basket» and secures farmers' income;
- adopting new crop management practices that take into account climate availability (through other work methods – non tillage for example);
- «permanent» soil cover, partly ensuring a constant high level of organic matter, better water reserve management, and the control of erosion phenomena…

Preserved biodiversity, restored ecosystems

In 1992, at the Rio summit, France committed to putting a stop to all biodiversity loss by 2010. This goal has not been met and has been deferred to 2020, with the additional commitment to restore the ecosystemic services provided by natural environments.

The implementation of the Natura 2000 network (1979 «Bird» and 1992 «Habitat» directives) was an important but insufficient step towards biodiversity preservation.

Planned within the Grenelle laws (2008) the creation of «green» and «blue» frames intended to recreate ecological continuities must consolidate this measure.

Be it through fighting against the progression of fallows, delayed mowing to preserve certain species or preserving rangelands: a third of the Natura 2000 network areas are in agricultural zones, and preserving biodiversity depends on farmers adhering to their preservation.

Actions that are too disparate, a lack of ambition and of means on a national scale: most «naturel habitats» situated in agricultural areas are in a bad conservation state[107]. Many species, in particular the so-called specialist ones, because they depend on agricultural areas, are declining strongly[108].

Afterres2050 ensures the recovery of biodiversity: reduction of pesticide use, of nitrogen fertilisers, of wetland drainage, of irrigation; safeguard, restauration and increase of semi-naturel habitats such as hedgerows or tradional orchards. The scenario favours the forms of agriculture that are recognised for their ability to generate biodiversity and to provide quantities of ecological services, also called ecosystemic services (high nature value farming, HNV). These services represent the «benefits » that we gain from the proper functioning of ecosystems, and of agrosystems in particular: nutritive element recycling, soil fertility reconstitution, carbon fixation, pest population regulation and pollination are all «benefits» that improve agricultural productivity.

Saving biodiversity also allows us to protect, or even restore, our genetical library, these banks of genes that increase the adaptive capacities of life in a climatic environment that is susceptible to brutal change, and that may contain new molecules to heal us, new varieties to feed us.

The «high natural value» (HNV) agricultural area, that receded by close to 70 % between 1970 and 2000, with a loss of 14.4 million hectares[109], is maintained: the loss of natural grasslands is compensated by the generalisation of AEI and especially by the diversification of crop plans.

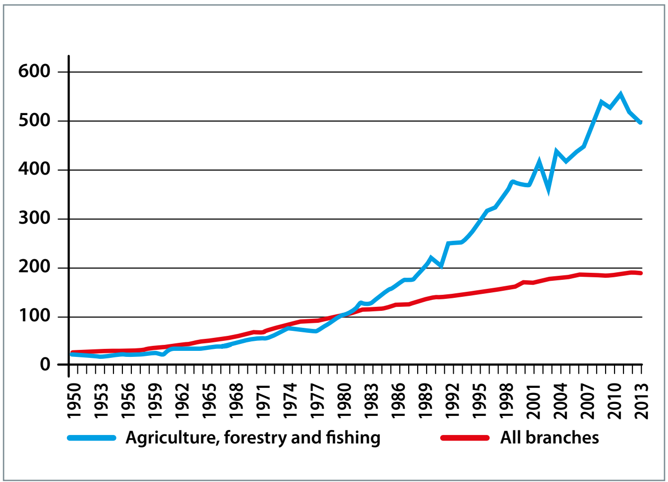
[107] Within the framework of article 17 of the Habitats Directive, the assessment carried out over the 2001-2006 period showed that over 50 % of agricultural habitats were in a very unfavourable conservation state.
[108] This is the case for meadow butterflies, messicole plants, the little bustard or corncrake, all species that have decreased by over 70% since the 1970's, in headcount or in occupation area.
[109] Source: POINTEREAU P., COULON F., DOXA A., JIGUET F., PARACCHINI M.L., 2010. Location of HVN farmland area in France and links between changes in High nature value farmland areas and changes in bird's population. JRC/Solagro, 2010 http://agrienv.jrc.ec.europa.eu/

Economy and employment

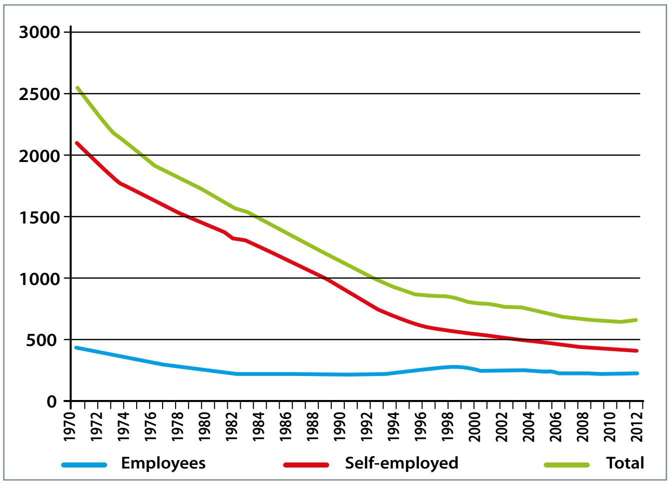
Some agricultural economy basics

Strong increase in productivity, strong decrease in jobs

Farming modernisation has led to a strong increase in productivity (that is to say the added value per amount of work), far above the rest of the economy. Taking the year 1980 as a reference point for example, productivity has been multiplied by 5 in agriculture, compared to 2 in the other sectors. This productivity has increased much faster than the added value generated by agriculture, the amount of work has thus decreased, in a spectacular way. From 2.5 million jobs in 1970, today we are down to 650.000.



- Compared evolution of productivity: agriculture and the rest of the economy, base 100 in 1980.



- Evolution of the number of jobs in agriculture since 1970, in thousands.

An original economic model

Agricultural production value amounts to 75 G€. Intermediate consumptions (fertilisers, seeds, energy, crop protection products, etc.) deducted, 30 G€ net added value remains. Let's further remove the consumption of fixed capital (linked to investments), leasing and rent, loan interests, taxes: 14 G€ remain to pay the 650.000 employees and farm managers, that is to say less than 1800 € a month.
This amount doubles with subventions: at 9 G€, subventions represent 11% of the value of agricultural productions but 40% of the salary of all agricultural labour force.

Production excluding subsidies (a)	**75.3**	**Production excluding subsidies**	**75.3**
Plant production	**44.2**	**Intermediate consumption (b)**	**45.7**
Cereals	11.2	Seeds and propagating material	2.7
Oil seeds and protein plants, beets and industrial plants	4.2	Energy and lubricants	3.6
Forages	5.6	Fertiliser and amendments	4.2
Vegetables and flowers	5.8	Pesticides	3.3
Potatoes	2.0	Veterinary costs	1.5
Fruits	3.0	Animal feedstuffs intra-produced	6.9
Wine	12.4	Animal feedstuffs out produced	8.3
Animal production	**26.4**	Building, material and equipment maintenance	3.6
Cattle and Calves, sheep and goats, equidae	8.1	External services	4.5
Pigs	0.8	Other goods and services	7.5
Poultry	3.0	**gross value added (c=a-b)**	**29.5**
Eggs	4.8	Fixed capital consumption (d)	11.0
Milk and others	9.7	Employee remuneration €	7.9
Services	**4.7**	Rental costs and interests (f)	3.3
		Taxes on production (g)	1.6
		Operating subsidies (h)	8.6
		Net income (c-d-e-f+g +h)	***14.2***

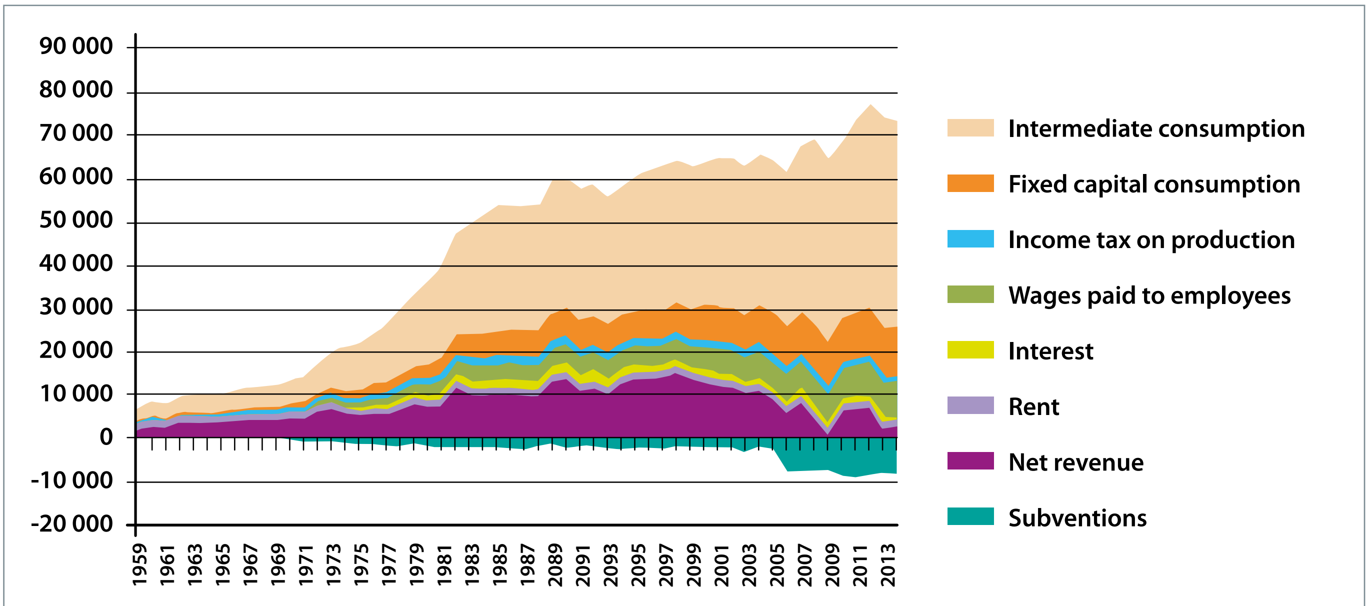
- Agricultural production and construction of agricultural income.

These subventions are payed within the CAP framework, the Common Agricultural Policy, set up following the 1957 Rome Treaty, with the initial goals of promoting the modernisation of agriculture and supporting agricultural income without raising the cost of food for the population. This policy worked on lots of levels as France became a big cereal and milk exporting country, whereas historically it was barely auto sufficient. However, in the process, 2 million jobs were lost over half a century.

The following table shows the evolution of the main accounting items on which agricultural income is based. A strong progression can be seen in intermediate consumption: agriculture is an economy that generates numerous upstream activities. Net income progresses more slowly than intermediate consumption.

The same applies downstream: the portion of household food expenses has continuously decreased over the decades, but agri-food and distribution profit from it far more than farmers do, and the added value isn't fairly shared.

Maintaining the agricultural labour force and improving its income implies combining an increase in production value, and so the sales prices, and a decrease in intermediate consumption. In the former, household purchasing power is impacted: if more is spent on food, there will be less to spend on other things. In the latter, both upstream and downstream agricultural activities might decrease. In all cases, these are societal choices: do we want a prosperous agriculture, are we ready to pay a fair price for the value of products and amenities provided by the agricultural sector?



- Evolution of French agricultural accounts since 1959, in current euros.

Graph: evolution of the French agricultural accounts since 1959. The graph is in millions of euros. The higher curve (sum of all items) expresses agricultural production value (the turnover). The «subvention» item brutally increases from 2005: in actual fact, up until this date subventions counted as a support to the prices of agricultural products and participated to the turnover. Since the 2003 CAP reform, the majority of subventions have become decoupled from production; from an accountancy point of view, they no longer appear in the turnover but as a «negative cost». Indirect public subventions (for example to agricultural organisations such as technical institutes or chambers of agriculture) are not counted here.

First explorations of the socio-economic issues

Agricultural employment: less intermediate consumption, more jobs

Is the Afterres2050 scenario a net creator or destructor of jobs? Which ones, and how many ? In a first attempt to answer, a socio-economic assessment was entrusted to Philippe Quirion, from CIRED[110], to evaluate the net job evolution. The timeframe was set until 2030: there would be too many undecidable hypotheses if the exercise had been carried out over a longer period.

First step: the calculation of direct agricultural jobs. They are linked to the production value, thus to the volumes of the various plant and animal productions, multiplied by their sales price. Intermediate consumption is deducted; it is lower in Afterres2050 as less fertilisers, less fuel and less agrochemicals are consumed. Investments are also deducted, to obtain the net added value. To get this far, hypotheses had to be made on sales prices: several sets of hypotheses were tested, up to a 25% increase on products from organic agriculture (the current situation is +40%), +10% for those from integrated productions, and + 5% for other productions.

Another major hypothesis is the evolution of productivity. Will it continue to increase by 0.75% per year ? Or should we believe it will stabilise? If we chose the first hypothesis, applying the calculation to the net added value, productivity would climb from 21.200 € per working person today to 24.600 € in 2030. Choosing the hypothesis where it would be halved, productivity would progress to 22.800 €. Under what conditions can we maintain the number of agricultural workers constant? In Afterres2050, with a productivity of +0,75% per year, prices must be progress by +25% for organic, +10% for integrated productions, and +1% for conventional productions. With the same conditions, the Trend scenario loses 50.000 jobs. In the Afterres2050 scenario, the agriculture turnover is slightly lower, whereas it increases in the Trend scenario: the price effect doesn't compensate the volume effect. But intermediate consumption and investments are lower, and so the net added value increases and is 10% higher than in the Trend scenario.

Of course, the more the relative cost of organic and integrated productions increase, the more the Afterres2050 scenario creates jobs. This is also the case if productivity doesn't increase as fast. If productivity increases half as fast (+0.375% per year), the Trend scenario manages to preserve the number of jobs, whereas Afterres2050 creates 72.000 extra.

The subventions are considered to remain constant in the calculations. As the number of jobs is calculated based on net added value, the Afterres2050 scenario maintains or creates more jobs than the Trend one. Also, subventions are to be shared over a larger number of jobs. This explains that the result per job should be slightly higher in the Trend scenario: if the subventions were proportional to the number of jobs, the result would be strictly identical.

	2010	2030 Afterres	2030 Trend
Production, G€	65	63	67
Intermediate consumption, G€	39	35	38
Gross added value, G€	26	27	28
Fixed capital consumption, G€	10	8	10
Net added value, G€	17	20	18
Subventions, G€	8.1	8.1	8.1
Taxes on production. G€	1.4	1.4	1.5
Net agricultural result, G€	23	26	25
Result per working person, in k€	30	36	37
Number of working persons (thousands)	789	799	736

• Main macro-economic indicators for agriculture according to the scenario.

Indirect and induced jobs

Of course, the reduction of intermediate consumption and of agricultural production has a negative effect on upstream jobs and on downstream agri-food. The increase of agricultural prices also has an impact on household purchasing power, but here the volume effect is predominant. Households buy slightly less but mainly they buy cheaper products: more cereals and less meat, and so the household food bills decrease.

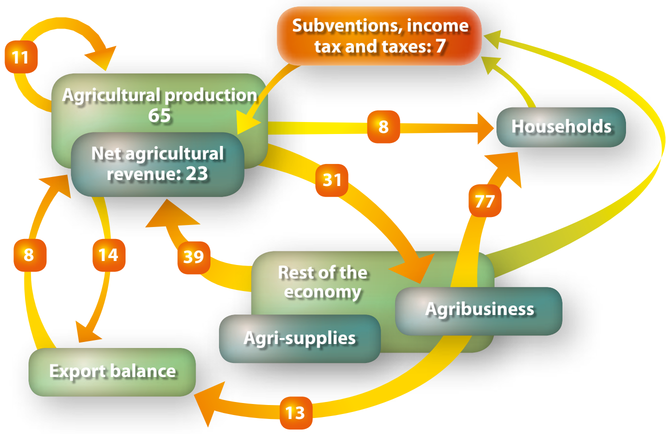
The analysis of Input-Output is the method used to measure this effect. The entire national economy is modelled by measuring the demand from each activity branch to all the others. The agriculture branch thus requests fertilisers from industrial chemistry, which in turn requests gas from the energy branch. The energy branch will in turn buy bioenergies from the agricultural branch. The IOT (Input Output Table) is a matrix established by INSEE, that allows to calculate the added value for each branch of the primary, secondary and tertiary sectors, and thus the number of jobs per branch, and to identify the relationships between branches. Exports and the final household demand (and administration demands, that are included in the final demand in the nation's accountancy), are at the base of the approach. Imports are counted either directly in order to satisfy the final demand, or added to the intermediate consumption of the branches.

[110] The Centre International de recherche sur l'environnement et le développement (International Research Center on the Environment and Development) is a joint research unit between various public research institutions, including the CNRS, AgroParisTech, and CIRAD.

A schematisation of the main monetary fluxes between the major economic sectors (millions of euros)

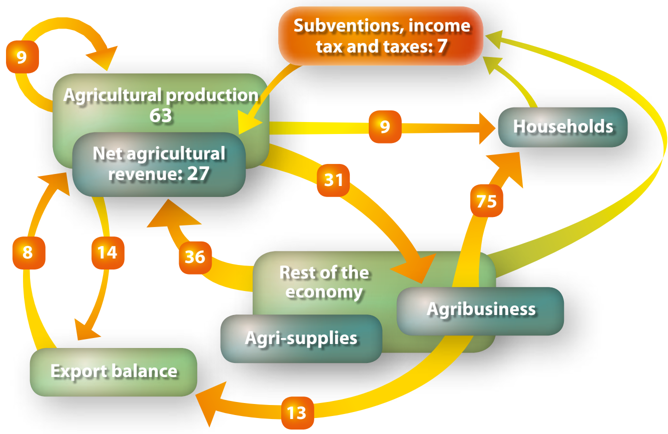
Reading the graphs: a representation of the main monetary fluxes, in G€, in 2010. The agricultural production, 65 G€, is sold to households, to the food industry, as exports or to itself (livestock feed). Agricultural income is also supplied by subventions minus taxes. Agriculture buys inputs from the rest the economy. Households buy 90% of their food from distribution. The food business is also an exporter.

2010



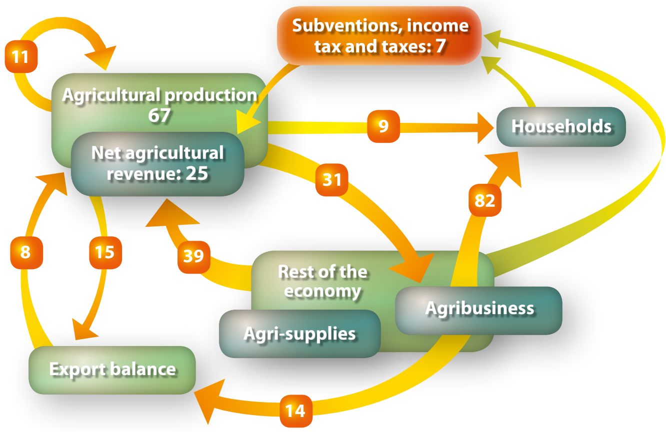
- Schematisation of the main monetary fluxes between the major economic sectors - 2010.

Afterres, 2030



- Schematisation of the main monetary fluxes between the major economic sectors – Afterres, 2030

Trend, 2030

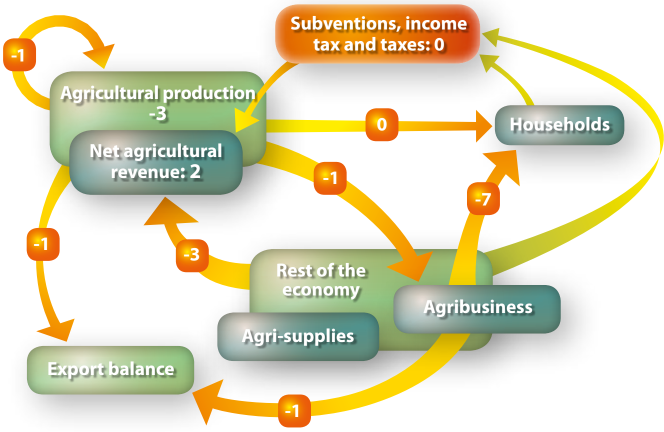


- Schematisation of the main monetary fluxes between the major economic sectors –Trend, 2030.

In the Afterres2050 scenario, the agricultural production decreases less than the intermediate consumption, hence an increasing agricultural income. The export balance remains unchanged, as does household spending. Globally, the volume effects compensate the price effects.

In the Trend scenario, agricultural income is a little lower as intermediate consumption has not decreased. Household spending increases, as do exports.

Difference Afterres, Trend 2030



- Schematisation of the main monetary fluxes between the major economic sectors –Difference Afterres– Trend, 2030.

Evolution of the number of jobs, in thousands	Afterres vs Trend	Afterres vs 2010
Agriculture	57	2
Agri-food	- 60	4
Other industries	16	17
Construction	17	21
Catering	26	48
Other services	69	41
Total	125	134

- Difference in number of jobs in 2030 between Afterres and the Trend scenario, and between Afterres and the current situation

The graph below shows the difference between the Afterres scenario and the Trend scenario. Agricultural income increases by 2 G€, exports decrease by 2 G€, and households save 7 G€. These 7 billion euros saved by households can be invested in several ways. First, they can be redistributed into the general economy, without at this stage being able to assign this buying power gain to any sector in particular. «Induced jobs» are thus created. All things being equal, these 7 G€ induce an overall increase of 125.000 jobs. Some sectors gain more than others. The agri-food sector creates the least jobs, 60.000 less than in the Trend scenario, even if the current number of jobs is preserved.

Integrating externalities

However, other choices can be made. Some compilation work carried out within Afterres2050 gives an estimate of the negative externalities related to agriculture[111]. The total varies between 14 and 55 billion euros a year, with deviations between estimates varying from 1 to 10 on some accounting items.

Of course, it would be interesting to consider the positive externalities. But the subject treated is to reduce the former without reducing the latter. As Afterres2050 leads to a division by 2 or 3 of all measurable impacts, we can assume that to an order of magnitude, the cost of externalities is also divided by 2 to 3, that is to say at least 7 G€ per year for the lowest estimate (half of 17 G€), and up to 37 for the highest estimate (two thirds of 55 G€)…

Let us settle for the lowest number: it corresponds exactly to the household buying power gain, and it would be legitimate for it to return entirely to farmers.

		Low value	High value
Air pollution		**460**	**3 240**
	Nitrates	26	1 930
	Pesticides	270	420
	Phosphates	72	290
	Control / counsel	26	72
	Eutrophication	14	250
	Others	50	270
Air pollution		**2 500**	**16 000**
	Ammoniac	1 840	13 800
	Nitrate oxides	670	2 230
Greenhouse gas		**3 710**	**3 710**
Soil pollution		**220**	**560**
Human health		**7 180**	**31 400**
	Pesticides	6 740	28 000
	Food	440	3 420
Biodiversity and landscapes		**280**	**520**
TOTAL		14 300	55 400

- Value of the negative externalities of agriculture (In M€).

[111] Bâ M., Gresset-Bourgeois M. and Quirion P. (2015), Combien coûte la pollution agricole en France ? Une synthèse des études existantes (What is the cost of agricultural pollution in France? A synthesis of existing studies). CIRED

Afterres2050

Conclusions and perspectives

Synthesis of the main results

Key indicators

Afterres2050 describes how it is possible to maintain primary plant production at a level that is close to today's, while dividing by 3 all inputs and impacts: greenhouse gas (a factor of 2.5 in the current version) and ammoniac emissions; mineral nitrogen, energy and crop protection products consumption.

Water consumption alone remains at a level close to today's (-15%), irrigated areas increase (+30%) with however a major difference as summer irrigation drops by 80%, replaced by spring irrigation.

Scenario		Current	Trend	Afterres v. Oct. 2015	BHF	PAR
Year		2010	2050	2050	2050	2050
Primary production (+)	PJ	4 202	4 200	4 300	4 000	4 300
Export balance (+)	PJ	367	248	308	115	472
Non-food productions (+)	PJ	41	192	787	665	762
Greenhouse gas (-)	$MteqCO_2$	117	89	51	50	56
Carbon footprint (excluding materials and energy) (-)	$MteqCO_2$	109	96	46	48	52
Consumption of mineral nitrogen (-)	Mt	2.3	1.9	0.9	0.3	1.4
Ammoniac emissions (-)	kt	758	388	229	201	219
Agrochemical indicator (-)	M NOUD doses	88	57	23	4	44
Irrigation (-)	B m^3	2.8	3.7	2.4	2.2	2.9
Agroecological infrastructures (+)	kha	536	326	1 140	951	1 085

- Table: main key indicators (the (+) and (-) notations indicate the desired evolution direction for each indicator).

In a nutshell, Afterres in 2050 is…

A healthier and better-balanced plate
A «demitarian» diet, closer to the «Mediterranean» diet – decreased overconsumption, losses and waste – fish consumption compatible with world stock preservation – stable oyster and shellfish consumption.

A net gain in employment
Less jobs lost than in the Trend scenario – increased household buying power.

Limited artificialisation of agricultural lands
Halved artificialisation of agricultural lands – forest area increased by 0.5 Mha – stable number of natural permanent grasslands.

Generalised agroecology
Generalised permanent cover, simplified culture practices and non-ploughing – generalised semi-natural habitats – increased soil carbon content and soil biological activity – generalised integrated production and organic agriculture – strongly developed agroforestry and associated crops.

A profound transformation of animal farming
Generalised quality indicators – decreased meat and milk consumption and production – stable numbers of mixed bovine breeds, strongly decreased specialised herds, in particular lactating – increased numbers of sheep herds.

Performant agricultural production
Plant production level equivalent to today's – production diversification, increased market gardening and arboriculture.
Division by 2 to 3:

- Of greenhouse gas emissions and ammoniac
- Of energy, mineral nitrogen, crop protection product and summer water consumptions.

…All without any ruptures, solely through the generalisation of better practices and known techniques.

Better balanced exchanges with the rest of the world
Increased food cereal exports towards the Mediterranean/ Middle East region by 60% – halved forage cereal exports towards Europe – elimination of soya imports and of the deficit of the forest-wood sector.

A major contribution of bioenergies to the French national energy balance
Increased forest harvesting within a sustainable silviculture framework, combined production of material (construction) and energy wood – strong development of agricultural anaerobic digestion, conceived as an agroecological and energy transition tool – multiplication by 3 of sustainably produced bioenergies (including non-agricultural biomasses).

So?

Her, is Aurélie Robin. ***Him***, is Guillaume Roquecourt. They took part in the prospective exercise, their farms served as test cases, and we imagined how their stories continued in the «Focus» sections of this document. They have just finished reading this brochure[112]. ***Us***, is Philippe, Madeleine, Christian, Sylvain, as well as Elen, Claire, Nicolas and Gaël. They are the lynchpins of the Afterres2050 project. Many others contributed: Marc, Denis, Monique, Alain, Cécile, Arthur, Philippe, and the several thousand people who kindly agreed to lend us an ear.

Us: slightly worried … So?

Him: Well… it's enough to give you a headache! Lots of numbers, lots of concepts to understand.

Her: Yes, you really have to dive down into it! Thanks for the warning at the beginning: it prevents immediate drowning!

Us: … And did you recognize yourselves?

Her: Absolutely! We can't wait to get to 2035!

Him: It's simplified of course, but overall that is what it's like. We already more or less put into practice in the field all that you have written in Afterres2050. We often even go further than you!

Us: That is precisely the principle. No betting on technology nor society.

Her: No jargon betting either, that's almost successful! The language is technical, a little scholarly: it isn't for the general public, you have to be quite well-informed.

Us: Yes, it's written for a well-informed general public! The idea is to address all backgrounds and to offer a common thinking tool to all publics who might wish to discuss these questions.

Him: Good luck then! Have you ever presented your work to animal farmers?

Us: Yes, to the general assembly of dairy farmers in the Mayenne for example! Also to the Young Farmers of the Bourgogne region. And to the French Agriculture Ministry, in answer to an invitation from its general Secretary. To organic producers, to consumer associations, to citizen publics. Or to INRA research groups. We have always been made very welcome, with a high listening quality. It's a little more complicated when you move up into national syndicate structures, where there are postural questions and political lines to be held.

Her: Because in the field there is real questioning and a real wish to evolve. Lots of suffering also and tensions and stalling, a fractured dialog, and certainly, deep down, a mutual incomprehension between the agricultural world and society.

Him: All the more so that the agricultural world and society are divided, fragmented even! And that we have the feeling that we no longer know where we are heading at all. That was partly my aim: to see where Afterres2050 would take us. Realistic? Plausible? That's what we were told.

Us: … and?

Her: Technically it's strong and well-reasoned. Probably others could do otherwise or better: they would just need to do it! You don't have much competition for the moment in this field. All other works are partial, still reasoned sector by sector, often without many figures. And lots of agricultural prospective scenarios are very optimistic and out of touch with reality, when you are aware of the violence of the crisis.

Him: For me the question is no longer to know if «it's preferable» nor even if «it's possible». Now we have the elements of debate. What counts is the «how». You didn't address political questions at all, and the economy aspect remains rather exploratory.

Her: And what about agri-food? And agri-supply industries? And mass distribution!

Him: And Europe!

Us: Yes, we know. We still have work to do.

Her: During your winter universities, you invited a Belgian academic to speak about the lockdown of socio-technical systems…

Us: Yes, Philippe Barret, he is an agronomist at Louvain.

Her: … if I remember correctly, he considers that the emergence of a new system requires several conditions .

Us: One: establish a consensus on the limits of the current system. Two: validate the proposed alternatives…

Him: … Three: protect and support the early adopters!

Her: I was about to say that! And four: put forward something that is attractive to farmers.

Him: That is the keystone! You can't change agriculture without the farmers.

Her: And the forest? What you write is interesting, but you can tell that it could take up a whole chapter!

Us: Ok. What else have we forgotten?

Her: Do you want a wish list?

Him: Will there be a follow-up?

Us: What do you think?

[112] These are fictitious characters! But any resemblance with existing persons is not purely coincidental.

The making of Afterres2050

The approach

A scenario for public debate

The idea of the project

The Afterres2050 scenario is a prospective exercise on the French food system –from the field to the plate- conducted by the "non-profit" enterprise SOLAGRO.

Afterres2050 was conceived to answer a set of questions from society to agriculture: is it possible to feed mankind, fight against climate change, improve farmer income, restore ecosystems, provide new products and services, take animal welfare into account, ensure product quality, improve consumer health and provide flavour, terroirs and landscapes all at the same time? The list of often contradictory injunctions addressed to the agricultural world is a long one.

A participative approach

The challenge of trying to provide a coherent reply to all these questions was taken up during an internal seminar of the Solagro association in November 2010. The first public presentation of the scenario was held in Mai 2011. Two winter universities brought together 150 people (farmers, researchers, experts and citizens) in 2012 and 2013 to discuss, refine and complete the different elements of the work. A first publication as a brochure was released in 2014.

We then worked on a regional scale for 2 years with:

- The actors of four French regions: farmers, foresters, researchers, teachers, elected representatives and territorial community officials, entrepreneurs, journalists, nutritionists, etc. Sixty people were mobilised in each region for the various work meetings.
- A multidisciplinary scientific counsel.

A second version of the scenario, updated and enriched, was presented on October 15th-16th 2015 at Nanterre. It was published as this brochure.

Numerous presentations were given and debated throughout France with very diverse publics, whose thoughts continue to enrich and stimulate our own.

The support of a scientific counsel

A scientific counsel composed of 18 researchers in agronomy, forestry, fishing, economy, sociology, industrial processes, energy and climate supported the regionalisation work. Its mission was to help consolidate the scientific foundations of the scenario, to take a step back from the technical modelling or work conduction of the concertation, to provide enlightening critiques and to open up new perspectives. The scientific counsel provided a space for knowledge and thought exchanges, and contributed to the validation of methodology choices, to the orientation of our reflexions and to the definition of priority axes, and to enlightening the limits of the exercise and its validity domain in the view of the current state of knowledge. It also allowed to communicate with the scientific community about the approach and to let new research subjects emerge.

An «assessment» approach allowing to open the debate: the MoSUT tool (Modèle Systémique d'Utilisation des Terres: Systemic Model of Land Uses)

The scenario was built with the help of the MoSUT (Modèle systémique d'utilisation des terres: Systemic Model of Land Uses) modelling tool conceived by SOLAGRO and used within the framework of various exercises: in particular for the Trajectory 2030-2050 ADEME works aimed to provide input to the French national debate on energy transition (DNTE) that led to the eponymous law in August 2015.

As for Afterres2050, it is coupled with the négaWatt scenario, the first French energy transition scenario, completed in its first version in 2003 by the négaWatt association and showing a possible path to reach the «factor 4» goal, that is to say dividing by 4 greenhouse gas emissions.

Both the Trajectory 2030-2050 ADEME exercise and the coupled négaWatt and Afterres2050 scenario exercise, are the only prospective works to describe how France can reach this factor 4 by 2050, all greenhouse gases combined, without solely considering fossil origin CO_2.

Let us also underline that there is of yet no long-term prospective scenario for the whole of the French food system, presenting both an assessment approach and a multicriterial evaluation. The assessment approach consists in modelling, calculating and ensuring the coherence of physical data. It is based on notions of areas, of produced, consumed and lost quantities, at all stages of the system, from primary plant production to the final food or non-food uses. The multicriterial evaluation is based on a significant set of indicators: for example, the value (in Joules) of the export balance, the reduction rate of greenhouse gas emissions, the crop protection product consumption index, the semi natural habitats, the natural grassland area, the amount of carbon input to the soil, the result of the nitrate balance, etc.

Physical, ascending, normative and recursive

A physical model

The Afterres2050 scenario can thus be qualified as physical. The model describes the supply balance of several tens of agricultural or food products, that is to say the fluxes of matter from primary agricultural production to the final food or non-food uses, through animal farms, transformations, industrial uses, imports and exports. It doesn't depend on any type of socio-economic factor, as that would necessarily imply resorting to long-term price level hypotheses, and essentially on price differences, that are impossible to model.

An ascending method

Built on the aggregation of technically controlled data, it is also ascending or 'bottom-up». For example, the dairy cattle herd is described by a set of characteristics such as feed rations, milk and meat production, grazing time, enteric fermentations and animal waste management practices. 6 types of dairy farms are described with a panel ranging from the solely grazing cow producing 4.000 litres of milk to none grazing cow fed on with concentrates and producing 10.000 litres. The first step consists in disaggregating the «French farm»: the entire dairy herd is distributed between these main types of farming in order to obtain a simplified representation of the dairy herd on a national level. Creating scenarios then consists in varying this proportion to obtain contrasted scenarios: for example, a scenario including more grazing (grass diet) versus a more intensification-oriented scenario (diet with concentrates).

A normative approach

The scenario is also normative, that is to say that certain indicators are subject to a target objective. The exercise doesn't consist here in exploring all possible futures, but in identifying at least one path leading to a desirable future, that is to say a scenario where the indicators correspond more or less to the objectives initially fixed by the scenario conceivers. This is called a «backcasting» exercise, or sometimes a retro-prospective exercise: a future objective is defined and then one backtracks to the present, allowing to determine trajectories and evolution speeds.

An iterative approach

As a consequence, the scenario is recursive, as the solution found in fine isn't the first solution found, and successive modifications correct the first trials before reaching the final result. One of the questions initially raised consisted in identifying under what conditions agriculture could divide its GHG emissions by 4, conforming to national objectives. These conditions were rapidly judged unacceptable as they implied, within the state of practices and techniques that could be mobilised on a large scale by 2050, to abandon an vast agricultural area to the afforestation of several million hectares of natural grasslands. The «factor 2» objective was judged feasible with no technical nor society betting, that is to say solely by the massification of existing solutions and by reinforcing current trends. The following works allowed to go beyond this factor 2: the directive now became to aim at least for the factor 2 and to go as far as possible and desirable towards factor 4. This implies that the other sectors, such as construction, transportation and industry, go further than factor 4: this is indeed the case of the négaWatt scenario that aims for a factor above 8 for CO_2 energy.

Combining scales

A national dimension as part of a worldwide vision

The Afterres2050 scenario was initially conceived on the scale of metropolitan France. The «system limits» were managed by integrating the constraint of providing a relatively stable export balance: keeping the milk export in its various forms stable; increasing by 60% the human food cereal export towards regions that will necessarily be in deficit by 2050, that is to say all of the Mediterranean basin and of the Middle East, based on the AGRIMONDE prospective (G1 version); and reducing forage cereal export towards Europe, as the European herd decreases.

Regionalisation

The second phase of the project -after the initial phase that consisted in imagining a national level scenario - consisted in working at other geographical levels, in particular on the scale of the 2015 administrative regions. Other choices could have been made, closer to agricultural geography for example, but the partnership with the Regional Council political entities provided the benefit of working collaboratively in a very open concertation space. These works were carried out in partnership with the Picardie, Ile-de-France, Centre Val de Loire and Rhône-Alpes regions, thanks to the mobilisation of numerous actors of the various activity sectors involved.

Second scale change: the local level

A third working scale was added: «type case farms», in order to test the coherence of new systems on the scale of basic production units. They are not farms strictly speaking, as the form itself that agricultural businesses will take by 2050 remains an unknown. This scale allows to check the feasibility of new agrosystems (crop systems and animal farming systems), and to better integrate the effects of climate change. Each of the three scales -local, regional and national- supply one another.

For example, in large scale crop regions, massively changing to organic agriculture systems (close to 50% of crop plants) radically changes the nitrogen question, compared to situations where organic agriculture remains marginal: these agrosystems must be autonomous in nitrogen, implying a sufficient area of legumes, the only primary source of nitrogen in organic agriculture. One of the limiting factors is the outlet for these legumes. Prioritising ruminant farming in mountainous regions, in natural grasslands and in a global herd reduction context rules out creating a cattle herd capable of getting through the legume production of large-scale crop regions, all the more so as -let's not forget- all animal farming is a net nitrogen exporter. Various types of outlets were thus imagined: human food, animal feed export, green fertilisers, including the anaerobic digestion variant in order to reconstitute nitrogen cycles similar to those found in polyculture-animal farming systems. Amongst other teachings, the exercise demonstrated the limits of polyculture-animal farming systems: it cannot be generalised to the entire national territory, agrosystems should be build that are both autonomous in nitrogen and without animal farming.

The modelling work: decomposing and recomposing

On the regional scale, the agricultural land was decomposed into various typical crop systems, representative of regional practices, and described by a rotation. Creating scenarios consisted here both in imagining other typical systems and in bringing the proportion of each of these systems to evolve. In large scale crop regions, the current rotations are strongly dominated by cereals, and so any lengthening or diversification of rotations necessarily implies less land planted with cereals, mainly replaced by grain or grass legumes. Inversely in animal farming regions, forage crops would give way to large scale crops, both cereals and protein crops.

We now have a whole set of basic «bricks» (type case farms for large scale crops, dairy cattle, meat cattle, granivorous herds) that allows both to describe the current situation and to consider future situations, by assembling them on first the regional level then the national level.

Questioning demand, articulating it with supply

The scenario combines geographical scales, it also tries to articulate supply and demand. Demand evolution is not set as a starting postulate, but as a social construction that should be questioned. The works are based in particular upon the first results of the BioNutriNet program, that bring to light the value of demitarian[113] type diets in terms of public health (decreased obesity and overweightness in particular). They are characterised, in comparison with the current diet, by an increased use of plant proteins, less refined cereals, fruit, vegetables, pulses and nuts, and a lower consumption of meat products, cheese, simple carbohydrates, refined or transformed products. The strong connection between field and plate, in terms of flux modelling, is scarcely documented and constitutes one of the contributions of Afterres2050.

Principles and values

The Afterres2050 approach and scenario are based on several principles:

- Mobilising controlled practices and techniques;
- Favouring «no regret» or «multi-dividend» paths as much as possible
- Developing a holistic approach.

Mobilising controlled practices and techniques

The Afterres2050 scenario isn't based on any technological or societal bet and doesn't presume any lifestyle or organisation revolutions. It is neither a return to the past nor a bet on hypothetical revolutionary scientific or technical breakthroughs. All the practices and techniques mobilised in our scenario already exist and are successfully practiced by early adopter farmers, they are based on knowledge provided by science and on innovations concretely implemented. Creating scenarios consisted in generalising the existing best practices and techniques as much as possible.

Favouring no regret or multi-dividend paths

The selected systems and practices were chosen so as to not exhaust the soils; they minimise air and water pollution and nitrate and pesticide soil pollution, fight the worrying reduction of our pollinating insect populations, reduce our dependency on food protein and wood imports and input imports in order to preserve the resources from other world territories.
Wherever possible, solutions offering «multi-dividends», that is to say with additional positive side effects on other levels, were systematically favoured.

Developing a holistic approach

The Afterres2050 approach aims to defragment problems:

- Themes: agricultural production, food, consumption, the environment…
- Space and time scales: the farm, the region, France, the world, yesterday, today, short term and long term;
- Disciplines: agronomy, socio-economy, ecology.

These problems are not considered as independent objects to analyse but are integrated within a global and complex system. Not all of these fields were explored, because of the extent of the task, but none was ignored.

The choice of «multi-dividend» solutions doesn't allow to solve all the dilemmas identified using the systemic approach. The global and multicriteria evaluation is an analysis means.

[113] The demitarian diet (a neologism that appeared around ten years ago) is based on a 60/40 balance between animal and plant proteins, which means approximatively halving the consumption of animal origin products, placing it at an equal distance between the current average diet of rich countries and a vegetarian diet.

Three variants + a trend…

Two variants of the Afterres2050 scenario were conceived: the «BHF» (Biodiversity, Health, Food) scenario and the «PaR» (Production and Resilience) scenario. A so-called «Trend» scenario, a projection of the current system with its tendencies and especially with climatic constraints, was also produced: it allows more relevant comparisons than the current situation does. BHF puts an accent on the nutritional quality of food, the sanitary and environmental aspects and is «all organic». PaR is more concerned with food security; it aims to be more productive and puts the accent on exports. The three variants remain relatively close however, the aim remaining to test various paths to reach similar objectives. Let us point out for example, that dairy grazing is above 60% in all 3 variants, organic and integrated systems represent 50% of crop plans in PaR and BHF uses 20% of crop residues and intercrops for anaerobic digestion. The Afterres2050 scenario integrates an increase of 1.5 Mha of artificialized areas, judged incompressible, that is to say 0.8 Mha less than in the Trend scenario.

Forest area increases slightly by 0.6 Mha (instead of decreasing by 0.6 Mha), and natural grasslands lose 1 Mha, instead of 1.5 Mha, showing a noticeable inflexion of the ongoing evolution, without however cancelling it.

The scenario assumes that fish availability drops sharply because of the threats on world stocks, representing a strong constraint on food balance.

The Afterres2050 scenario generalises permanent cover, simplified cultivation techniques, long rotations and semi-natural habitats. It foresees a strong development of anaerobic digestion, of agroforestry, of integrated crops, and of all forms of associations and of diversity in general.

	Current	Trend	Afterres	BHF	PAR
	2010	2050	2050	2050	2050
Food					
Plant proteins	38%	44%	61%	61%	48%
Over consumption + losses	33%	31%	20%	20%	18%
Agriculture					
Organic	2%	15%	45%	90%	15%
Integrated	1%	10%	45%	7%	35%
Reasoned	97%	75%	10%	3%	50%
Animal farming					
Milk production per cow	6400	7800	6100	5900	6400
Grazing time	40%	36%	66%	68%	62%
Caged laying hens	69%	50%	5%	2%	15%
Pigs	Conventional 91%	Conventional 74%	Organic indoors 41%	Organic indoors 64%	Improved 58%
Materials and energy					
Straw use rate as material		1%	15%	10%	15%
Straw use rate for anaerobic digestion		4%	30%	20%	30%
Intercrop use rate for anaerobic digestion		7%	33%	20%	33%

- Representative hypothesis of the studied scenarios.

Within the accounting intricacies of the bioeconomy

Statistics on food, agriculture or the forest obey accountancy rules that must be well understood before undertaking such an exercise. And as we well intend to create emulation and vocations, it is useful to dive down into the intricacies of this accountancy.

Counting units

We use common units such as the ton, as well as scientific units of the International System such as the Joule.
It's easy to find energy conversion tables between TeraWatt hours (TWh) and Petajoules (PJ), but first it is necessary to know what we are talking about. The energy values used in Afterres2050 are all expressed in primary energy, and in higher heating value (HHV), unless otherwise indicated. All biomass fluxes can be expressed in energy value, starting with food. Food energy value, for nutritionists, is equivalent to the HHV value of energy specialists.

Counting our food

Bought food, eaten food

Each French inhabitant consumes close to 2.5 kg of food and drinks each day. The detail is provided by food habit surveys, in particular the vast INCA2 study (Individual National Food Consumption study), study that is probably the most representative on the subject. We have knowledge of household food budgets through the surveys carried out by INSEE (French institute of statistics and economic studies) but they don't provide the weight of food consumed.
The FAO produces detailed supply balances from 1961, based on data provided by the states[114]. They detail the quantity of foodstuffs consumed as human food and per food type[115]. The FAO supply balance statistics aggregate certain items: for example, the «wheat and wheat products» section includes flour, pasta, bread and glucose syrup, bringing the total to around fifteen food items that are directly or indirectly consumed by households. These ingredients are counted as «wheat equivalent», integrating matter yields so as to convert transformed products into basic agricultural products.
This way of counting differs greatly from the nutritionists' approach, who count consumed food. For example, the INCA2

Unless otherwise indicated, data on human nutrition are presented here in the format of FAO's supply balances, that is, agricultural commodities in production equivalent, excluding water and non-alcoholic beverages.

	Food eaten (INCA2)	Food bought (FAO)	FAO / INCA2
	g/day for an adult	g/day per person[116]	
Cereals (including pastries, rice, biscuits, cakes, pizzas, quiches, sandwiches)	281	344	1.2
Potatoes	58	150	2.6
Sugar	21	103	5.0
Pulses	10	28	2.9
Oils	15	66	4.4
Vegetables	139	284	2.0
Fruit	160	302	1.9
Alcoholised beverages	155	239	1.5
Meats (including cured meats and mixed dishes)	188	297	1.6
Milk (including, butter, cream and desserts)	246	685	2.8
Eggs	15	34	2.2
Fish and seafood	31	95	3.1
TOTAL	1 319	2 627	1.99
Others (coffee, tea, soups, stock…)	367		
Non-alcoholised beverages	1 058		
General total	2 463		

- Comparison between INCA and FAO values.

[114] EIn France it is provided by AGRESTE – the French agricultural Ministry's Statistics and Prospective Service
[115] The FAO uses a specific nomenclature, the FAO Stat Commodity List (FCL), with several aggregation levels, detailing all the food items, raw or transformed agricultural products (sugar, oil…), and allowing to estimate exchanges between countries.
[116] These are values provided by the FAO, in tons, and divided by the number of inhabitants in metropolitan France, that is to say 63,5 million inhabitants, on average, for years 2008-2011.

survey counts the contents of a cup of coffee drunk, a bowl of cooked rice, peeled and cook vegetables and deboned and cooked prime rib, whereas the FAO counts coffee grains, husked rice, vegetables in their raw state, beef carcasses. The two counting methods aren't comparable and there are no conversion tables between these different accounting methods. French or international agricultural statistics are thus absolutely not comparable to the plates described by the surveys on eating habits.
We can attempt a comparison between INCA and FAO data, excluding drinking water and non-alcoholised beverages, that weighs the same as drinking water (coffee, tea…). There is a factor of 1.2 to 5 between FAO consumption and INCA food regarding the main accounting items.
The differential results from lots of differences: losses and waste of course, and matter yields, but also the fact that, for example, frying oil is consumed by households, but not eaten; that sugar is hidden in numerous foods; etc.

Main information sources on eating habits and food quality

ANSES, the French National Agency of food sanitary security, of the environment and of work, is a public administrative institution created in 2010 by the ministries in charge of Health, Agriculture, Environment, Work and Consumption. ANSES is in charge of several major means concerning food and health, in particular:

- The **INCA** surveys (Individual National Food Consumption study): the INCA surveys piloted by ANSES provide a complete picture of the French metropolitan population's eating habits from a representative sample of 3 to 4.000 people. After INCA1 (1999) and INCA2 (2006-2007), INCA3 launched in 2014 will soon be published.
- The **RNI** (Recommended Nutrient Intakes) are values defined for each nutrient (proteins, trace elements such as iron, minerals such as calcium, vitamin C, fatty acids…) as being the intake that allows to cover the physiological needs of the population (and not of an individual): they correspond in general to 130% of the average nutritional needs of an individual, so as to minimise the risk of deficiency. The RNI characterise the nutritional situation of a population, whereas the average nutritional needs measure the situation of an individual. The RNI are not a norm but a reference that also provides higher and lower limit values. That last update of RNIs dates back to 2010, a future edition will take the INCA3 results into account.
- **CIQUAL** (Centre d'information sur la qualité des aliments): the Information Centre on Food Quality depends on ANSES. It establishes a food nutritional composition table.
- Producing advice notes based on a collective expertise report to establish and update the PNNS benchmarks and references.

The **PNNS** (Plan national nutrition santé): National Nutrition and Health Plan is established by the French Public Health High Council. The plan aims to improve the population's state of health by acting on one of its major factors: nutrition. Nutrition should be understood here as a balance between food intakes and the energy used up by physical activity; eat-move is the tagline of the current plan. The next plan, PNNS 4 is expected in 2017.

INPES (Institut national de prévention et d'éducation pour la santé): French National Institute for Health Prevention and Education, that merged with the Health Monitoring Institute (Institut de veille sanitaire: InVS) and EPRUS (Etablissement de préparation et de réponse aux urgences sanitaires: Establishment for the Preparation and Response to Sanitary Emergencies) to become the French Public Health.

NUTRINET-santé: a survey coordinated by the Nutritional Epidemiology Research Team (ERE – INSERM/INRA/ CNAM / Université Paris 13) with the support of numerous partners. Its aim is to identify risk or protection factors linked to nutrition, regarding illnesses that have become major public health concerns today, so as to establish nutritional recommendations to prevent these illnesses and to improve the population's health. Nutrinet mobilises a cohort of 500.000 voluntary «nutrinautes».

ESTEBAN (Étude de santé sur l'environnement, la biosurveillance, l'activité physique et la nutrition): the Health, Environment, Bio-surveillance, physical Activity and Nutrition Study, is a survey piloted by InVS (Institut national de veille sanitaire: Health Monitoring Institute, public institution reporting to the health ministry) and INPES (Institut national de prévention et d'éducation pour la santé: French National Institute for Health Prevention and Education, public administrative institution created in 2002), drawing a precise picture of the population's food consumption, physical activity, of the prevalence of chronical pathologies and risk factors and of the exposure to numerous substances in the environment. The plan is to renew it every 7 years.

The **DREES** (Direction de la recherche, des études, de l'évaluation et des statistiques), the Direction of Research, Studies, Evaluations and Statistics of the French Health Ministry, regularly establishes an evaluation report on the French population's state of health, including chapters concerning eating habits.

From the field to the plate: supply balances

The FAO statistic databases

Our modelling of the Afterres2050 scenario starts with the reference year «2010», which is in reality an average over the last 5 years, for which we have the complete production, transformation, commercialisation and consumption statistics.
These statistics are issued by the FAO, that provides data per country from 1961. The FAO uses data provided by each country: agricultural and agrifood statistics from the Ministry of Agriculture and customs' statistics for exterior trade. Two accountancies and thus two different nomenclatures exist.

Basic «Trade» section N°	Name
15	Wheat
16	Wheat flour
17	Wheat bran
18	Pasta
19	Wheat germs
20	Bread
21	Bulgur
22	Pastries
23	Wheat starch
24	Wheat gluten
41	Breakfast cereal
110	Waffles
114	Bakery doughs
115	Malt foods, flour preparations, semolina or extracts

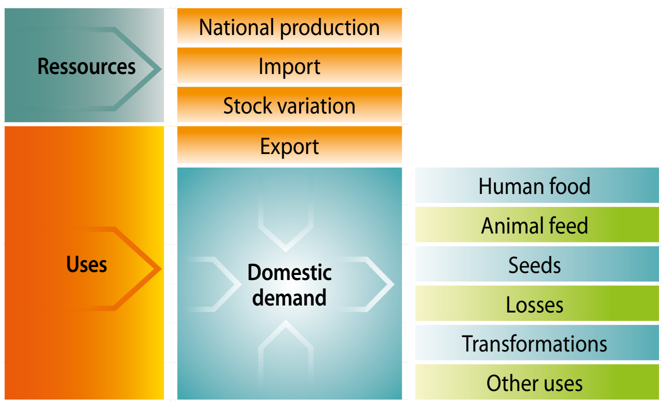
- Correspondence between FAO nomenclatures, wheat example - detailed composition of item 2511 of the product balance database.

The FAO «Trade» database uses a nomenclature detailing around 600 agricultural and fishing products. For example, there are 14 wheat products, and 33 milk products. The data provided in weight (in tons) is expressed for the products «as is», that is to say that 1 kg of exported cheese (section 901 of the Trade nomenclature) is counted as 1 kg of product.

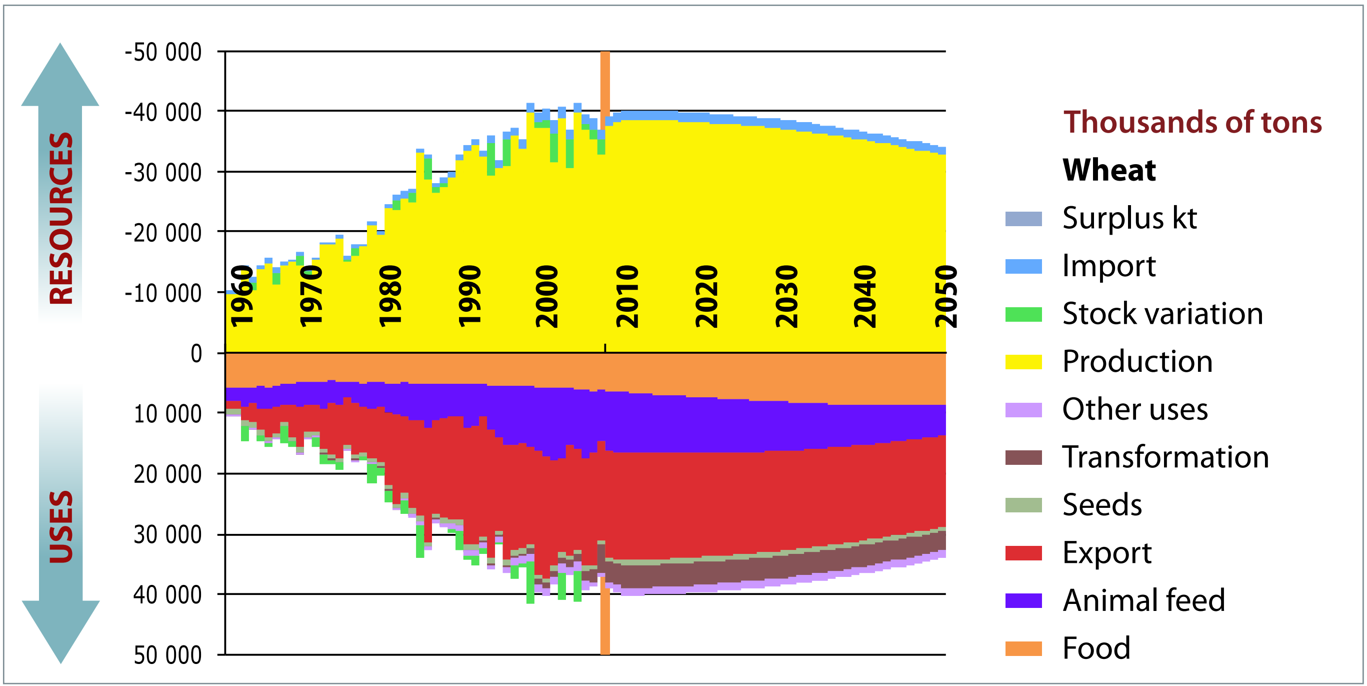
The «food and product balance» database obeys the logics of accountancy; it is a balanced resource – uses table. Here primary production (for example cow's milk) is considered, as well as consumed, transformed or exported quantities. And so, to be able to compare exporting 1 kg of cheese and producing the 7,7 litres of cow's milk required to make it (section 882 of the Trade nomenclature), the primary equivalent is considered: that is to say that 1 kg of cheese made from cow's milk will be counted as 7,7 litres primary equivalent milk.
The «Balance» FAO database thus uses a specific nomenclature in which products are not considered with their «as is» weight, but with their «primary equivalent». For example, all the wheat products fall under section 2511 of the Balance nomenclature, that provides the quantity of wheat that corresponds to all the final products. Likewise, section 2848 of the Balance nomenclature adds all the products made with milk, in equivalent litres of milk. The balance tables use aggregated sections, such as «Cereals» for example, that add all the products in primary equivalent made with cereals, save a few exceptions (for example beer, that is made with barley, isn't counted here, but in section 2924, «Alcoholised beverages». The data of the «Trade» base isn't directly comparable to that of the «Product Results and Balance» base. Thus, «milk» exports in the «Trade» base represent nearly 3 million tons of dairy products (milk, cheese, powdered milk…), whereas in the «Balance» accountancy they totalise 9,3 million tons of primary equivalent.

Use – resource balance

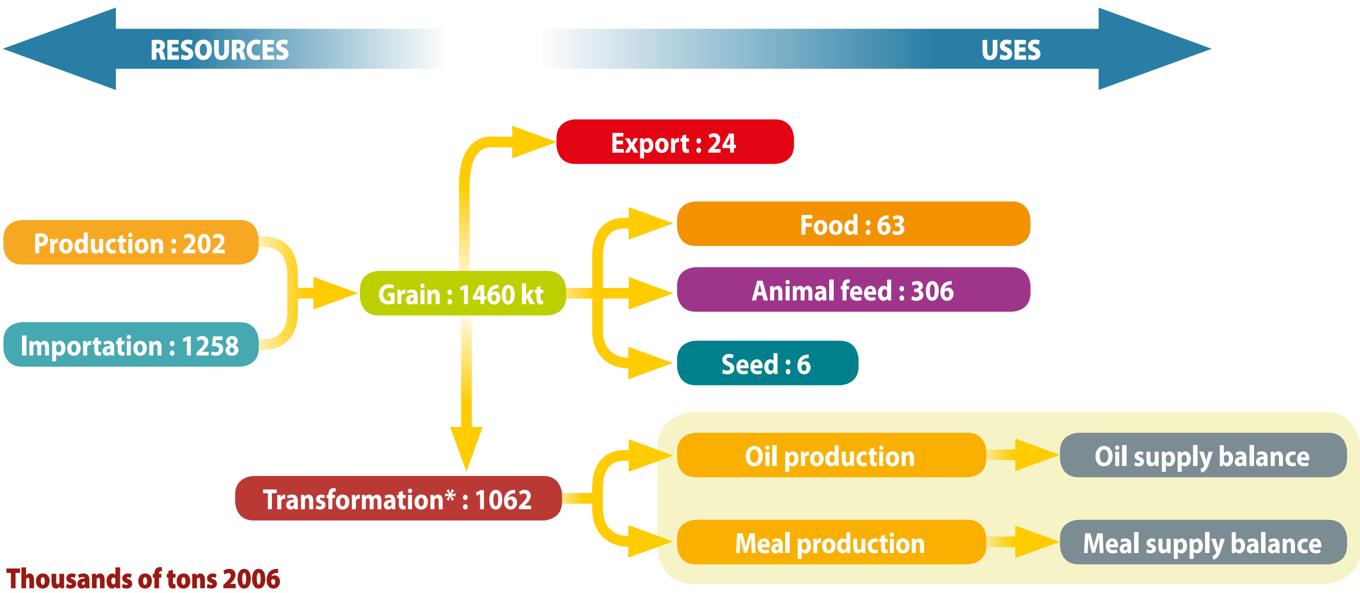
A supply balance is a «use /resource» table, describing the input/output fluxes for agricultural and agribusiness production.
The resources consist in the previously calculated domestic production and in imports. The uses consist in exports and in domestic consumption, that itself can be broken down into human food, animal feed, seeds, transformations and other uses. Uses and resources are equal, more or less stock variations.



- The use – resource table construction principle.



- Wheat supply balance evolution example, in thousands of tons. Resources are represented in the top part of the chart, uses in the bottom part: both terms are strictly symmetrical. Wheat resources are mainly made up of the national production, imports are marginal. As for uses, exports, that have considerably increased since 1960, stabilise and hardly evolve until 2050. Domestic demand changes significantly: animal feed decreases whereas human food increases.



- Supply balance example (soya bean).

The supply balance for certain agricultural goods can only be correctly described when integrating several balances: this is the case for example for oilseed that produces both oil and meal, each with its own supply balance. We have also sought coherence in the wine grape, wine and alcohol balances, that are articulated together.

* Treatments: transformation into starch, ethanol, or other non-food products.

		A1. Food disponibility	A2. Animal feed	A3. Treatment	A4. Other uses	A5. Seeds	A6. Losses	B1. Domestic disponibility	B2. Exports	C1. Imports	C2. Stock variation	C3. Production
2905	Cereals-Excluding Beer	7 765	21 337	2 945	2 998	1 155	558	36 758	33 016	3 619	403	65 752
2907	Starchy roots	3 480	375	400	186	352	1 270	6 063	2 590	1 566	13	7 074
2908	Sugar crops			27 456	6 277			33 733	1	2		33 732
2909	Sugar & sweeteners	2 386	58	0	1 517			3 962	2 683	1 186	-103	5 562
2911	Dried pulses	116	465			39	3	624	556	107	0	1 073
2912	Nuts	244					1	245	62	258	0	49
2913	Oilseed crops	175	732	5 438	98	23	56	6 522	2 169	1 715	67	6 908
2914	Vegetable oils	1 323		0	1 859			3 118	1 132	2 042	-156	2 364
2918	Pulses	6 412	108	0			1 013	7 532	1 861	3 748	18	5 627
2919	Fruit – Excluding wine	7 150		6 857			492	14 490	2 139	7 584	-11	9 056
2922	Stimulants	620		0				620	375	995		
2923	Spices	20						20	12	32	0	
2924	Alcoholised beverages	5 286		1 060	674		49	7 069	2 793	1 625	150	8 087
2943	Meat	5 590		74	31			5 695	1 617	1 577	0	5 735
2945	Offal	429			0			429	154	97	0	485
2946	Animal fats	1 019	6	41	51			1 111	641	419	2	1 330
2948	Milk - Excluding butter	15 673	2 181	0	579		31	18 465	9 341	3 269	8	24 529
2949	Eggs	855			12	73	8	942	111	159	0	893
2960	Fish & Seafood	2 154	11		1			2 166	607	2 073	19	681
2961	Aquatic products, others	12			43			55	7	33	0	29

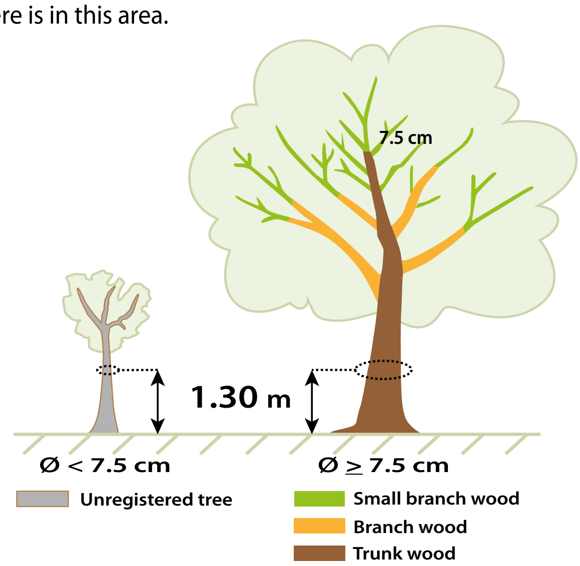
- Detail of the main agricultural goods supply balance, average 2008-2012.

All fluxes can be expressed via a uses-resources balance: for example, energy, nitrogen, protein, greenhouse gas fluxes, etc.

The forest and wood

Forest accountancy units

Forestry statistics are full of traps and different units are used that need to be made explicit considering the great confusion there is in this area.



- Aerial forest biomass compartments.

Trunk wood: wood is usually counted in statistics as «trunk wood». Trunk Wood is the trunk volume up to a 7 cm diameter cut, of all «recruitable» trees, that is to say with a diameter wider than 7.5 cm at 1.30 m from the ground. Trunk wood is regularly evaluated by the IGN (National Geographic Institute) in its inventories, based on the characteristics of the trees present: the diameter of the tree is measured at a certain height from the ground, and cubic tables per species are used, allowing to estimate the volume of TW.

Branch wood: branch wood is the volume of branches up to a 7 cm cut.

Total wood: total wood is the addition of trunk wood and branch wood.

Small branch wood (SBW): small branch wood includes all the ends of trunks and branches with a diameter smaller than 7 cm.

Total aerial wood: to obtain the total aerial wood, that is to say the aerial ligno-cellulosic biomass, excluding leaves and roots, coefficients called «branch expansion factors (BEF)» that allow to calculate the crown volume, also in m^3, based on the trunk volume) are considered. The BEF is on average of 1.61 for the French hardwood forest and of 1.335 for the softwood forest, that is to say an average of around 1.5. The BEF is estimated for each species, based on research programs[117].

Total tree wood: it also includes the roots. As was the case for the crown, a root expansion factor is used to estimate their volume based on the trunk wood volume. It is of around 1.3.

Total forest biomass and carbon: the forest biomass includes not only aerial and root wood, but also the shrub and grass layer and the litter.

Main concepts

Annual organic production: organic production is the mass of matter fixed through photosynthesis within a year. Gross production and net production, mortality deducted, are differentiated.

Annual harvesting: the harvest is the quantity of wood obtained, all purposes combined, classified between timber, industry wood and energy wood. These volumes are estimated, either with the EAB (French annual branch survey), or with other methods for non- EAB circuits. Their sum provides the net harvest. Gross harvest includes mass loss, in the order of 10% of the harvest.

Harvest rate: this is the harvest over organic annual production. It's an indicator of the sustainability of forestry: on the scale of a mountain, the long-term harvest rate should remain below the annual organic production so as to not decapitalise it.

Disponibility: the disponibility, also called harvest potential, takes the cumulated net annual organic production between two harvest dates into account. In agriculture, the disponibility of annual crops is of 100% of organic production, but in forestry the cycle isn't annual so reasoning must be over a longer time period. Disponibility is an objective-dependant notion of forestry: it differs if the objective is to produce timber over a long period (100 years for oak stands) or industry wood over shorter cycles (20 years for poplar groves, 7 years for coppices or even 3 to 5 years for SRCs, short rotation coppices). The term gross disponibility is used to estimate the physical harvest, net disponibility is the term used when various factors should be taken into account: environmental, technico-economical, and societal criteria (protection forests).

The main sources of French forest statistics

French forest statistics are established by the IGN [118], (National Geographic Institute) that regularly carries out a national inventory. Calculation methods were deeply modified in 2011, leading to a reconsideration of lots of statistical data[119].

The most recent and complete works are presented in the «Disponibilités forestières pour l'énergie et les matériaux à l'horizon 2035» study («Forest disponibility for energy and materials within the 2035 timeframe»), carried out by the IGN and the FCBA (French Technical Institute of Wood) for ADEME (Environment and Energy Agency).

This study evaluates net disponibility within the 2035 timeframe, considering environmental [120] and techno-economic criteria. It in particular simulates two forestry scenarios, a conservative or trend scenario, and a progressive dynamic scenario.

This study is a follow-up to a series of works initiated in 2005, the first to have set the question of the overall disponibility in resources other than timber or industry wood [121]. It also updates several previous studies: in particular works carried out by the IGN and IRSTEA [122], (National Institute for Research in Science and Technology for Environment and Agriculture) or those

[118] Results of the CARBOFOR program, Séquestration de carbone dans les grands écosystèmes forestiers en France. Quantification, spatialisation, vulnérabilité et impacts de différents scénarios climatiques et sylvicoles. *(Carbon sequestration in great forest ecosystems in France. Quantification, spatialization, vulnerability and impacts of various climate and forestry scenarios)* Final report, 2004. Coordinated by D. Loustau, INRA. Also see the ANR EMERGE Program for small branch wood.

[118] The IGN *(National Geographic Institue)*, absorbed the French National Forest Institute.

[119] See the Rapport de la mission d'expertise sur les méthodes de l'IFN *(Report on the expertise mission on IFM methods)*, Charles Dereix, Jean-Jacques Lafitte, Jean-Pierre Puig, July 2011.

[120] Limitation of small branch wood harvesting, that is rich in nutriments, on more fragile soils.

[121] SOLAGRO participated to the first works: see Colin A., Thivolle-Cazat A., Coulon F., Barnérias C., Couturier C. 2009 Biomasse forestière, populicole et bocagère disponible pour l'énergie à l'horizon 2020 (Forest, poplar and bocage biomass available for energy within the 2020 timeframe).

[122] IRSTEA : Ginisty C., Vallet P., Chevalier H., Colin A. 2011. Disponibilité en biomasse ligneuse en forêt, dans les peupleraies et dans les haies pour les différents usages du bois (Woody biomass disponibility in forests, poplar groves and in hedgerows for the various uses of wood).

carried out with CITEPA (French Study Center on Air Pollution) for the Ministry of Ecology on forest carbon storage, with new forestry scenarios [123].

The methodology applied depends on the publication date of the various IGN works, meaning that all data is thus not comparable.

Finding one's way in the maquis of national statistics

The harvests estimated by the IGN (are of 41 Mm3 of trunk wood, 48 Mm^3 of total wood, and 53 Mm^3 total tree wood, including 5 Mm^3 of small branch wood. To which about 10% of exploitation losses can be added, giving an estimate of 58 Mm^3. When reasoning in physical fluxes, similar fluxes are compared. Harvest rate per compartment, including losses, varies between 50% for TW to 43% for total aerial wood. The IGN-FCBA study indicates a harvest rate of 55%, but what is considered here is the proportion between harvested total wood (48 Mm^3) and the organic production of trunk wood.

Mm^3/year	Organic production	Harvesting (losses excluded)	Harvest rate (including 10% loss)
Trunk wood	88-91	41	50%
Total wood	119-125	48	43%
Total aerial wood	132-137	53	43%

- Organic production and harvesting in forests, according to compartments.

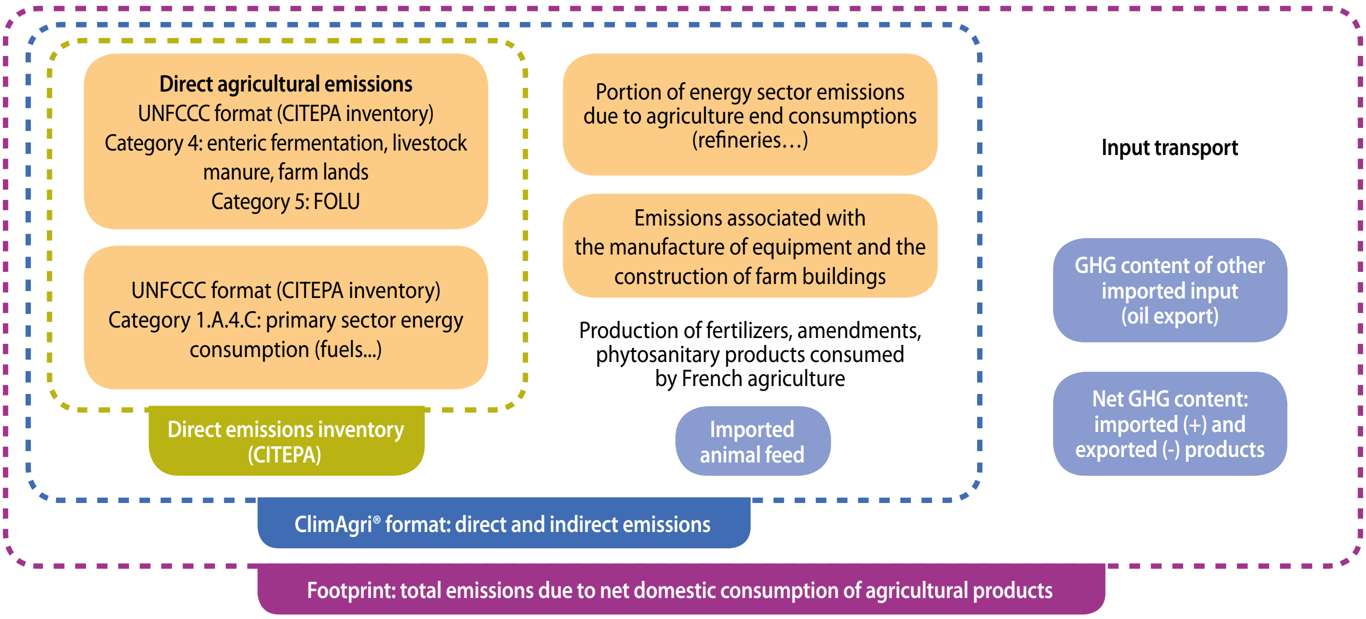
Carbon and greenhouse gas accountancy

Greenhouse gas emissions

Greenhouse gas emissions are estimated in the CLIM'AGRI® format. This tool, conceived by SOLAGRO for ADEME, allows to estimate agriculture and forest greenhouse gas emissions on a territory. The emissions inventoried in CLIM'AGRI® consider the direct and indirect agriculture and forest emissions.

The direct emissions are methane and nitrous oxide generated by biological and natural phenomena such as enteric fermentation or the nitrification process in soils. Added to these are carbon dioxide gas emissions from tractors or greenhouse and animal farming building heating. The indirect emissions, that is to say not emitted by agriculture strictly speaking, are due to input production (fertilisers, imported animal feed, etc.) and to emissions linked to agricultural building and machine construction (grey energy).

The CITEPA regularly draws up the inventory of GHG emissions, according to the format of the UNFCCC, the United Nations Framework Convention on Climate Change, used to establish international comparisons and to check if countries are staying true to their commitments to fight climate change. Agriculture is counted in category 4, here only agricultural emissions strictly speaking are considered. Carbon dioxide gas emissions due to the use of fossil



- The different GHG accountancy perimeters.

[123] Colin A. 2014 Emissions et absorptions de gaz à effet de serre liées au secteur forestier. (Greenhouse gas emissions and absorptions related to the forest sector)

energies in agriculture are counted in another category (1.A.4.C). Concerning fertiliser production, only emissions due to their production on national territory are considered, whereas CLIM'AGRI® also considers the emissions linked to the production of imported fertilisers.
Apart from these perimeter differences, the accountancy according to the CLIM'AGRI® and UNFCCC formats obeys a similar logic: count the tons of fertilisers, litres of fuel, the number of cows, and apply emission factors. These factors are discussed and validated by groups of experts and regularly updated.

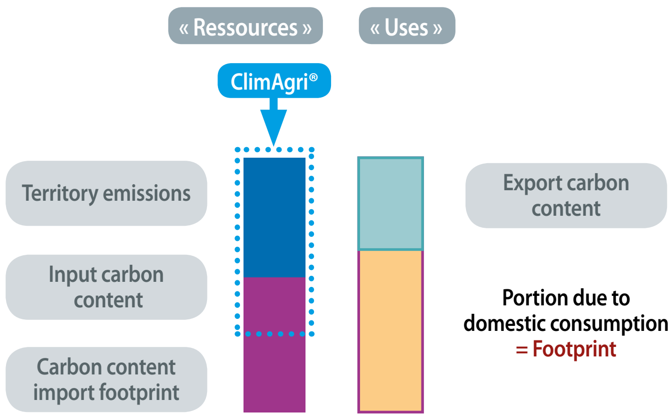
Counting carbon

The absorption of carbon dioxide by the soils and the biomass is added to greenhouse gas emissions: it is counted as a carbon sink or as a source according to whether the stock increases or decreases. This sink or source effect depends on the variations of land use and on the evolution of forest biomass: it is category 5, or LULUCF [124]. This accounting item is considered in both the UNFCCC and the CLIM'AGRI® format.
Carbon storage is thus counted as carbon storage due to the conversion of grasslands to forest, carbon storage of forest remaining forest, and carbon destocking of forest converted to meadow.
Let us point out that the methodology used by the CITEPA doesn't count the carbon storage of grasslands remaining grasslands, unlike CLIM'AGRI®.
Carbon storage should also be considered in biosourced products, in particular in sustainable construction materials. In order to do so, the stock variations of these biosourced products needs to be known, however there is a high uncertainty on their lifespan.
The CO_2 avoided emissions related to the substitution of fossil energies by bioenergies are not considered here. The exercise indeed ends at the farm limits: bioenergies are admitted as being carbon neutral on a short cycle, in the order of a year, as the carbon stock in bioenergies neither increases nor decreases. The benefit of energy substitution is counted in the négaWatt scenario.

Carbon footprint and territorial emissions

The aim of reducing greenhouse gas emissions isn't so much to decrease our emissions, strictly speaking, as to lower our footprint, that is to say our greenhouse gas emissions related to our lifestyle. The difference comes from considering imports and exports.
The carbon balance indeed obeys the same accountancy rules as all other resource/use balances. Our footprint, that is to say the emissions related to our consumption, equals the emissions of our production and our imports (resources), exports deducted. Reasoning in footprints allows to avoid comparison biases: we could indeed reduce GHG emissions by reducing exports, in which case the latter must be compensated by a production increase elsewhere, all things being equal, which would then be a simple transfer and not a real decrease.

The CLIM'AGRI® format takes into account the carbon content of agricultural input. To work out what our agricultural product consumption footprint is, the carbon content of our imported food products (fruit, vegetables, tropical products) must be added and that of exports (milk, cereals) deducted.
We used the agricultural product emission factors provided by databases such as Agribalyse (mainly for French productions) and EcoInvent (for imports) for this calculation. These emission factors, especially for imports, can vary greatly according to publications. The carbon footprint calculated using these emission factors was compared to the emissions calculated according to CLIM'AGRI®, making sure that the calculation perimeters were comparable. The difference between the two methods turned out to be very low, a few percent. We can thus estimate that these emission factors can be used to evaluate the carbon content of exports and imports, and thus calculate the footprint.



- GHG footprint calculation principles.

[124] Land use, land-use change, and forestry.

Systems and agricultural practices: definitions and illustrations

Systems and agricultural practices

The **agricultural system** qualifies a farm's choice of agricultural production organisation: nature, number and articulation of plant productions (crop plan) over space and time (crop rotation) in relation with socio-economic autonomy strategies for animal feed, production commercialisation, jobs and investments. Other considerations complete the notion of agricultural system, such as taking into account natural spaces, landscape and territory. There are numerous forms of agriculture: from conventional to permaculture, through organic, conservation or integrated agriculture, it isn't easy to separate what belongs precisely to one system or another. Even forms of agriculture that share a same strict specification present important variation from one farm to another.

Some agricultural systems describe agronomical practices, others are of a socio-economic nature. The cross between an agronomical system and a socio-economic one describes a socio-technical system. Organic agriculture for example is often associated with the notion of peasant agriculture, but the two concepts are far from being perfect carbon copies.
No agricultural system was initially conceived to answer all of today's challenges, none presents all the qualities, and all will have to evolve.
The **practices** are relative to the technical orientations adopted in terms of tillage, input levels and returning organic matter to the soil.

What agricultures are we talking about?

Conventional farming: today's dominant agriculture model (90% of cultivated areas). It is characterised by its use of synthetic inputs (agrochemicals, fertilisers) and by technical and productive systems that are adapted to high production goals, with a triple intensification, specialisation and concentration movement.

Reasoned agriculture: practices a so-called «reasoned» pest control. Synthetic chemical products are still used on plots but it is no longer a systematic input. It is managed based on crop needs and according to agronomical tolerance limits. It shows a will to improve the dominating agriculture, via better observation of the environment and a rationalisation of agricultural practices without questioning the production goals.

Integrated production: integrated production is «a global approach of land use for agricultural production. Integrated production aims to reduce the use of inputs from outside of the farm (energy, chemicals, water), by making the best use of natural resources and taking advantage of natural regulation processes», like biodiversity. One of its advocates in France (Philippe Viaux[125]) presents it as the intermediate path between intensive agriculture and organic agriculture, that proposes to conciliate respecting the environment, quality and profitability.
The basics and the rules of integrated production were defined by the IOBC (International Organisation for Biological and Integrated Control [126]) in 1992. Integrated production finds its place in the continuity of the discoveries made at the beginning of the 20th century around integrated pest control (also called integrated protection) experimented in Californian orchards. In those days, chemical control (insecticides), creating pest resistance phenomena, was no longer capable of protecting the production. The logic then applied to pest control was extended to all the production factors (nutriments, fungicides, herbicides, water and tillage).
The Conservation agriculture and agroecology concepts are very close to integrated production; resting upon the same agronomical bases and reducing de facto the use of inputs. Although organic agriculture has similar foundations, it proposes the non-use of synthetic chemical products as a starting point.

Conservation agriculture: according to the FAO[127], *«conservation agriculture aims for sustainable and profitable agricultural systems and tends to improve farmers living conditions through the simultaneous implementation of three principles on the plot scale: minimal tillage; crop associations and rotations and permanent soil cover. CA presents a great potential for all types of farms and of agroecological environments. It is very interesting for small farms; those that have limited production means that don't allow to remove the strong time and manpower constraints represent a high-priority target. It's a way to conciliate agricultural production, improvement of living conditions and protection of the environment. CA is successfully implemented by various types of production systems and in diverse agroecological zones. It is perceived by users as a valid tool for lasting terroir management. The FAO is invested in CA promotion, more particularly so in developing nations.»*
This agriculture, that isn't subject to specifications nor to a label, regroups several thousand farmers to this day in France.

Agroecology: the agroecology term covers very diverse concepts. Miguel Altieri[128], researcher of Berkeley University, was one of the early adopters of this discipline and proposed

[125] Cf. Systèmes intégrés : une troisième voie en grandes culture (Integrated systems: a third path for large scale crops)– 2nd edition – Editions France Agricole
[126] www.iobc-wprs.org/
[127] http://www.fao.org/conservation-agriculture/en/
[128] Agroecology: The Scientific Basis Of Alternative Agriculture. CRC Press. 1987.

a definition for it as early as 1995. The CIRAD[129] defines it as a strictly agronomical system: *«attractive, profitable, environment friendly and sustainable cultivation systems … created to be popularized on a large scale, based on direct seeding on permanent plant cover (SPC). In these systems, the soil is never tilled and a living or dead cover is permanently left in place. Straw comes from crop residues, intercrops or secondary crops used as «biological pumps». These plants have powerful and deep root systems and can recycle nutriments from deep down towards the surface, where they can be used by main crops. They also rapidly produce a large biomass and can develop under harsh conditions such as during dry seasons, on compact soils, and under strong weed pressure».*
Pierre Rahbi[130] defines it including socio-economic elements: agroecology is an approach that is *«inspired by the laws of nature. It considers that agricultural practice shouldn't restrain itself to a technique, but instead consider the entire environment that it falls into with true ecology. It integrates multiple dimensions: water management, reforestation, fighting erosion, biodiversity, global warming, economic and social systems, the relationship between man and the environment... ».*

Organic agriculture: organic agriculture is a *«global concept that is based on the choice of values such as respecting the land and biological cycles, health, respecting the environment, animal well-being, social life»… «It is an agricultural production mode based on a set of complex techniques excluding the use of synthetic chemical products».*
FNAB (Fédération nationale d'agriculture biologique: French National Organic Agriculture Federation[131]).

Rotation: Succession order, on a same plot, of plants of different species or varieties and possibly of fallows, a succession that repeats regularly over time.

Crop plan: Space distribution of a farm's crops over the various plots during a given cycle.

Intercrops: Implanted between two main crops, cover crops or intercrops can be used in several ways: harvested (green) as silage or harvested as forage. Intercrops limit soil erosion – there is no bare soil– and nitrogen leaching. INTCs (Intermediate Nitrate Trap Crops) are variants, as are IEC (Inter-energy -crops), or catch crops.

Associated crops: Once very much used, particularly by animal farmers, associated crops – also called combined most often mix grasses and grain legumes (ex. wheat-peas) without them necessarily being sown and harvested at the same time. They are used to produce concentrates (that are energy and protein rich) for animals. But they can also be separated and used for human consumption.

Agroecological infrastructures: *«AEIs correspond to semi-natural habitats that receive neither chemical fertilisers, nor pesticides and that are managed extensively. They are certain permanent grasslands, mountain pastures, moors, hedgerows, isolated trees, wood fringes, grass strips along rivers or field borders as well as fallows, terraces and walls, ponds and ditches and other particularities. Essential for the environment, they contribute to the preservation of biodiversity, to the water cycle and its quality and to carbon storage. As habitats for pollinators and other species qualified as crop auxiliaries, AEIs are also of great interest to agriculture and allow to reduce pesticide use. Through the preservation and restauration of ecological continuities between natural environments, AEIs are a vital element to creating the green and blue belt (GBB)».* CGDD, *« Le point sur…»* (*«Taking stock on…»*) n°145, October 2012.

http://www.developpement-durable.gouv.fr/Les-infrastructures.html

[129] http://agroecologie.cirad.fr/
[130] http://www.fondationpierrerabhi.org/agroecologie-abcdaire.php
[1231] http://www.fnab.org/

Afterres2050

Additional tables

Additional tables

Losses and waste, in kg per person per year	Agricultural production	Post-harvest and storage operations	Processing and packaging	Distribution and retail	Consumption	TOTAL
Cereal	2	4	4	1	18	29
Roots and tubers	16	7	10	2	9	44
Oilseeds and protein crops	4	0	2	0	1	7
Fruits and vegetables	52	12	4	10	35	14
Meat	4	1	6	2	11	24
Milk	11	2	3	1	16	33
Sea products	4	0	2	1	2	10
Ensemble	93	26	31	18	93	260
Distributions	36%	29%			36%	100%

- Loss per product category and per stage. *(page : 10)*

Export balance by major product and country groups, FAO, 2011 values	North Africa, Near East	Africa Saharan	Americas	Asia, Oceania	Europe	TOTAL
Cereal	10 100	2 700	700	1 300	18 400	33 200
Dairy products	100	100	0	200	1 400	1 900
Alcohol	0	0	300	400	100	700
Sugar	100	0	-100	100	1 200	1 300
Vegetables	-500	0	0	-100	-900	-1 400
Stimulants	0	-200	-100	0	-400	-700
Animal fat (butter)	0	0	0	0	300	300
Fruit	0	-300	-200	0	-2 100	-2 600
Oil	0	0	-300	-300	300	-400
Oil plants	0	0	-700	-100	1 000	200
Potatoes	0	0	0	0	1 300	1 400
Leguminous plants	200	0	0	0	300	500
Offal	0	100	0	500	-300	300
Egs	0	0	0	0	0	0
Meal	100	0	-2 400	-200	-1 200	-3 800
Total, thousands of tons	10 000	2 300	-2 800	1 800	19 400	30 800
Energy value of the exporter balance	140	35	-30	24	260	420
Weight in total French exports	33%	7%	-7%	5%	62%	100%

- Exportation balance (exportations minus importations) by product category and region - thousands of tons per year. *(page : 14)*

CO_2 emissions per year Million tons / ha		New assignment					
		Forest	Prairie	Terres arables	Surfaces artificialisées	Autres	TOTAL
Former assignment	Forest	Meadow	+2	+3	+6	0	**-48**
	Meadow	Arable lands	/ [43]	+17	+5	-1	**+17**
	Arable lands	Artificial surfaces	-12	0	+1	-1	**-13**
	Artificial surfaces	Other	-2	0	0	-1	**-4**
	Other	0	+1	0	0	0	**+1**
	TOTAL	**-66**	**-11**	**+21**	**+13**	**-2**	**-47**

- CO_2 emissions per landscape type and when allocation changes occure (2013 values - Source CITEPA 2015). *(page : 21)*

		Thousands of hectares (2014)
Forest	Hardwood	9 280
	Resinous	3 210
	Mixed	2 580
Poplar		190
Wooded areas outside the forest	Groves outside poplar plantations	770
	Tree hedges and alignments	950
TOTAL		**17 030**

- Wooded areas in France (thousands of hectares in 2014 - source TERUTI). *(page : 41)*

Created in 1981, Solagro is a non-profit enterprise that has taken up the mission to open up new paths for agriculture, energy and the environment and to favour *«a sustainable, solidary and long-term management of natural resources»*[132].
In order to concretise this project, forbearer of the values of *«sustainable development»*, the association built up a team that today counts 30 permanent positions, including engineers in agronomy, energy, economy and ecology.

What does Solagro's action support?

- Engineering and assistance to project owners (public and private) for the conception and the implementation of their projects,
- The conception of decision aid tools destined to public authorities,

The capacity to initiate original prospective approaches, consolidated by the anchorage in field projects that allow to *«keep one's feet on the ground»*,
A great curiosity to *«go see elsewhere»* beyond boundaries, but also in archives and statistical databases that are so rich in teachings,

- An appetite for sharing knowledge through training and putting ideas up for debate,
- The richness of partnerships knotted with administrations, institutions, design offices, researchers, networks and agricultural organisations, in France and in numerous European countries.

And of course, the commitment of its network of members, essentially composed of citizens and a few legal entities. The volunteers consolidate actions, participate in reflexion commissions and ensure the coherence of the path followed.
Solagro is a member of several federations or exchange and mutualisation networks such as the CLER-Réseau for energy transition and the TEPOS network of positive energy territories … the Biogaz Club of the ATEE, the AFAHC- association française des arbres et des haies champêtres (French association of trees and field hedgerows), FNE Midi-Pyrénées.
These networks allow to collectively carry proposals towards a wider public, and local, national and European authorities, in the hope of guiding public policies.

[132] Article 1 of the association articles. Read our association articles here: http://www.solagro.org/site/258.html

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Graphic design, illustrations:
Eric Péro (spyro) - www.imageric.fr

Cover page:
Excerpts from the posters «Afterres2050 Landscapes Campaign»
produced by the INITIAL Paysagistes Agency,
at the request of the Landscapes of the After-Oil collective
and financed by the Seine-Normandy Water Agency

Decembre 2016

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