Institut Technique de
l'Agriculture Biologique

How do we evaluate and give economical values to organic farming externalities?

Summary of the study

carried out by ITAB
(French National Organic Food and Farming Research Center)

with scientific support from INRA
(French National Institute for Agricultural Research)

at the request of the French Ministry of Agriculture, Agrifood, and Forestry

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avec la contribution financière du compte d'affectation spéciale « Développement agricole et rural »

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A study by ITAB, with the support of INRA

This study was carried out by Natacha Sautereau, Agricultural Economist at ITAB. INRA designated Marc Benoit, Agricultural Economist (and Joint Director of CIAB, INRA's Internal Organic Farming Committee) as the INRA adviser to support this mission and lead INRA's internal researchers. The research was carried out between January and July 2016. After analysing and updating the work in the fall, the results of the study were presented to the French Ministry of Agriculture in October, and then to the public in November.

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Picture legend

Savings = fewer negative externalities

Benefits = greater positive externalities

Zoom in

Methodology insert

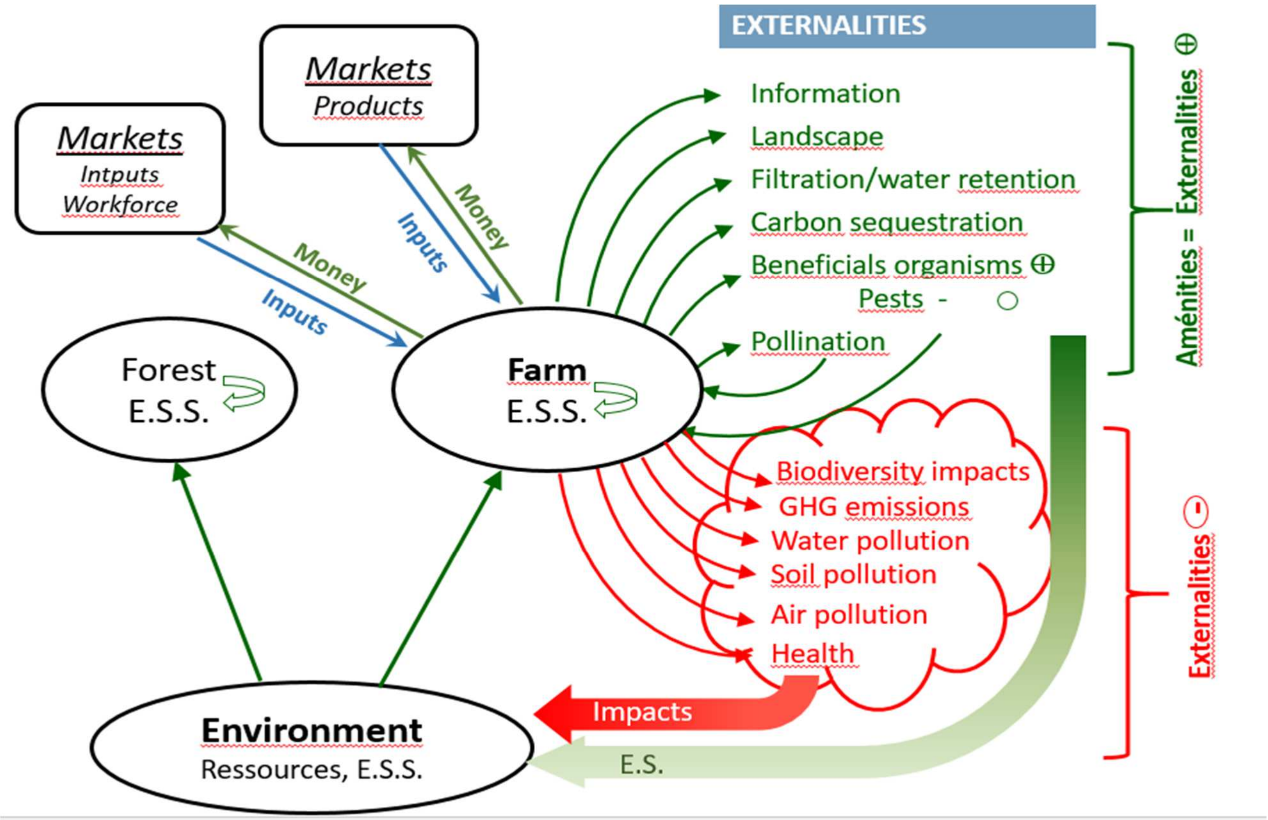
Introduction

In addition to producing food, farming also generates **negative externalities (social costs) or positive externalities (benefits or amenities) that financial markets do not take into account.** By reducing negative externalities or increasing positive externalities, farming can be a real asset for local communities, which in turn could justify financial support from the government. This is the goal of the agri-environment measures (AEMs), which encourage farmers to use methods that have positive effects on the environment. Compensation to farmers is determined based on the increased cost of employing 'best' practices rather than standard practices.

It is possible that a similar type of government aid could be given to organic farming, whereby farmers would receive compensation for the benefits organic farming provides to society. The Ministry of Agriculture decided that a summary of existing scientific knowledge was needed in order to objectively evaluate the externalities of organic farming, and to have numbers that would support such a process. This work was entrusted to ITAB, with the scientific support of INRA researchers. **The methodology used for this evaluation was to analyse the externalities generated by organic farming as compared to those generated by 'non-organic' farming, or 'conventional farming'.** The work consisted in identifying, qualifying, quantifying and measuring the cost of the externality differentials between organic farming and conventional farming.

Taking into account both the negative and positive externalities, and their environmental and social impacts (on health, for instance), these differentials were measured and analysed. For each category, the goal was to quantify these externalities where possible, then assign economic cost to their value, where references numbers were possible, and make sure the figures were robust enough and generic enough so that the results can be validated.

The goal of this study was to serve as an overview of current scientific knowledge, based on published works and not on expert opinion. The analysis of the source material aims to give a summary of established knowledge and to identify the points where gaps need to be filled or which are controversial. A major part of this work is a critique of the data, methods and calculation assumptions used to quantify and economically evaluate externalities.



Representation of the positive and negative externalities that might be generated by farming *ESS: ecosystem services*
ES: environmental services (linked to the practices)

Conceptual framework

• Externalities: understanding the non-commercial costs and benefits incurred by production and consumption

Externalities occur when the production activities of one actor have a non-commercial influence (whether positive or negative) on the well-being of another, without this actor receiving or providing any compensation for this effect. The consumer cannot explicitly see or measure externalities. **Negative externalities** (see figure) may penalise certain types of economic actors or the well-being of the general public and negatively affect taxpayers (cost of pollution, health risks, etc.). As a result, there have been a number of studies aiming to estimate negative externalities in order to understand what the total 'cost' would be if these 'social costs' were included. As for **positive externalities** (see figure), we must ascribe value to them in order to recognise them. The level of the externality depends on what is considered the 'normal state' – of an environment for instance – below which we consider there to be degradation to the detriment of society, and above which we consider there to be societal benefits. While science can help us understand what the desirable state is in terms of sustainability, accepted norms are always determined as a social construction. For farming, externalities are evaluated in reference to these social norms and to the states created by the practice of 'conventional' farming. They are thus relative and evolve mechanically. **We consider that an increase in positive externalities as well as a decrease in negative externalities constitutes a benefit for the local community.**

• Multifunctional farming, ecosystem services (ESS) and environmental services (ES)

For farming, this question of externalities (be they negative or positive) is taken into account through national and EU regulations, and by the common agricultural policy (CAP), via a mechanism of access to general farming aid (single farm payment – SFP) in order to reduce premiums, and supporting measures to help increase aid. **The concept of multifunctional farming** has helped raise awareness of farming's positive externalities in the CAP, with the creation of agri-environment measures (AEMs). AEMs form part of the 'second pillar' dedicated to rural development, established by the 1999 reform.

On the environmental side, the *Millennium Ecosystem Assessment* (MEA, 2005) introduced the idea of **ecosystem services** (ESS), services that humans gain from biodiversity (species, ecosystems, etc.). The MEA proposed a classification of these services (provisioning, regulating, etc.), and a distinction between services that benefit farming (pest control, pollination, etc.) and services that benefit the rest of society (water purification, climate and landscape maintenance, etc.).

The evaluation of ecosystem services has become a very rich field of study. However, the economic evaluation of these services is still cause for debate. While there is real interest in raising awareness of the importance of these services, the logic used is sometimes questionable. Moreover, it is difficult to make comparisons because the value gained from biodiversity and ecosystem services is multifaceted, and they include many different systems of measurement and personal preferences.

While the idea of ecosystem services gained traction, it often went hand-in-hand with a confusion between *ecosystem* services, which society gains from 'nature', and **environmental services** (ES), which are gained from human actors – whose actions can help maintain or increase ecosystem services. Environmental services are the positive externalities that farming exerts on the environment, in other words the benefit generated for society by the practices that farmers employ which affect the ecosystem.

A dialogue has started concerning **Payments for Environmental Services** (PES), but there is not yet a legal definition for PESs in French law (AEMs are one type of PES). PESs can take various forms and influence different kinds of actors, such as countries, local governments, private property owners or organisations. If there is to be a sort of **remuneration for positive externalities**, it will be within this conceptual framework of PESs, moving from an environmental focus to a view on health and society as well (particularly public health, but also animal welfare).

• Negative and positive externalities in farming

Farming externalities can affect the environment (local or global), human health and various aspects of society (see figure).

For **negative externalities**, we have analysed the difference between the impact of organic farming and conventional farming on different environmental aspects (**pollution, biodiversity loss, soil erosion, run-off and flooding, greenhouse gas emissions, consumption of non-renewable resources**), as well as on **health** (**impacts** from farm inputs, as well as health security). In addition to all these negative externalities that organic farming might reduce, we have also included the cross-functional externality of regulatory costs. Organic farming is subject to explicit regulation aimed at reducing costs of management and pesticide control.

For **positive externalities**, we have also analysed both environmental and social aspects. Determining the differential in positive externalities between organic and conventional farming required examining the level of ecosystem services provided by agroecosystems in both. Certain ecosystem services, such as organic matter mineralisation (nitrogen supply), are services that directly benefit farmers, but which only indirectly benefit society at large. A healthy mineralisation allows farmers to use fewer mineral fertilisers, which in turn means less pollution.

Similarly, **better pest control and pollination** directly benefit the farmers who choose organic farming, but also have indirect benefits for other farmers and on society at large. By reducing the amount of agrochemicals used, agro-ecological methods have a positive impact on people and on the environment.

Finally, we will examine **carbon sequestration** as a service from the point of view of carbon levels and additional carbon offsets, and how it helps in the fight against climate change.

As for human health, we have examined the positive externalities which have **nutritional benefits**. The intrinsic qualities of a product (e.g. how it tastes) are merely advantages for consumers. Only the benefits that a product has on consumers' health were considered as an externality (e.g. reduced medical spending for the community). For externalities affecting animals, we have considered their **welfare**, meaning the ethical issues at play throughout their lives.

For social benefits, we have considered **job creation**, which is not an externality as defined by economists, because there a job market exists. However, we consider there to be market failure in this instance because unemployment has a cost for society.

Finally, we have examined **information as a cross-functional externality**. Knowledge that is produced by organic farming practices can be useful outside of the organic farming sector and help other systems to evolve towards agro-ecology.

A solid analysis of externality differentials requires a detailed evaluation of the externalities generated by conventional farming. We have done this in four steps (Box A).

A – Externality differentials between organic and conventional farming

1- Identify and quantify conventional farming externalities
2- Identify the characteristics of organic framing that could have positive or negative effects compared to conventional farming
3- Quantify the externality differentials that are attributable to organic farming
4- Evaluate their economic value

Method

• Characteristics of organic farming systems

The **requirements** of organic farming forbid the use of pesticides, synthetic mineral fertilisers and GMOs. They also limit farmers' use of allopathic veterinary treatments and feed additives. These restrictions, which are regulated and validated by third parties, differentiate organic farming from other practices that promote more agroecological farming without forbidding the use of synthetic inputs. More broadly, organic farming operates on a series of 'principles' (increased autonomy of the farm, 'closing' the nutrient cycle, diversification of crops and units, fair trade, etc.) which are not all the result of concrete, controlled technical rules, but which inform practices.

Organic farming is thus characterised by the following **specific practices or practices which are more common than in conventional farming**: among these practices, organic farmers employ **longer and more diversified crop rotation** (using pastures, alternating winter and spring crops) to control weeds, diseases and pests; **plant more legumes** to increase nitrogen in the soil; use more **ecological infrastructure** (such as hedgerows) to foster beneficial organisms and work with a **larger number of native species** (plant varieties and animal breeds). In terms of livestock production, free-range systems, connection to the soil and a **goal of food autonomy** (minimising the purchase of feed and thus how many nutrients are brought into the system) are practices that hold an important place in grazed pastures for herbivores, and limit the risk of animal waste exceeding the farm's spreading capacities. Because organic products cost more (to compensate for lower productivity and increased effort) and organic farms have a closer link with their consumers, their practices more often involve shorter processing periods and a shorter marketing chain.

Organic farming also has an impact on how systems operate, how the means of production are used and thus the **characteristics of farms themselves**, especially on land ownership and the workforce. This in turn has socio-economic repercussions for the local community (land use, jobs, etc.).

• Quantifying externalities attributable to organic farming compared with conventional farming

Comparisons between organic and conventional farming are faced with one major methodological difficulty, which is **the diversity of systems within organic farming and within conventional farming**. The 'model' of the mixed crop-livestock organic farm and the practices this brings to mind (pastures, using legumes in crop rotations, organic fertilisers, etc.) is not systematically implemented. What is more, these practices are becoming less of a focus as organic farming expands and farms are becoming more specialised and do not necessarily have livestock. At the same time, conventional farms are starting to develop systems that use fewer synthetic and less polluting inputs ('low input' or 'integrated' farming, precision farming, etc.). Some of the distinctions between organic and conventional farming can become blurred, depending on the model of comparison used. It is thus important to regularly update these evaluations (see recommendations below). Moreover, any comparison must account for this potential confusion and control for selection bias (Box B).

B – Statistical comparisons between organic and conventional farming

'Intuitive' methods, which consist in comparing the economic characteristics or the farming practices of 'organic or non-organic' farms, do not allow us to accurately evaluate the effects directly attributable to organic farming, because you cannot necessarily assume that all other factors are equal. 'Matching' methods help reduce so-called selection biases, by comparing the characteristics or practices of matching pairs of farms (which match according to a pre-determined set of characteristics), where one is organic and one is not.

• Economic evaluation methods

Determining the economic costs turns out to be even trickier than quantifying the effects.

For the **negative externalities**, this study largely used a literature review published in 2016 (referred to as "B&G"[1] below), which examined the societal costs of using pesticides in the United States, in terms of the environment and human health.

For the **positives environmental externalities**, a vast study on the economic approach towards ecosystem services[2] published in 2009 helped to provide both a methodological reflection and the basis for economic evaluations of biodiversity and ecosystems.

The economic evaluation of services should ideally use **methods based on costs or on the market**, using precise calculations of, depending on the case, the costs avoided (e.g. water purification stations), restoration costs (of a degraded ecosystem), or indirect costs resulting from adverse effects (e.g. cost of treating an illness).

[1] Bourguet D., Guillemaud T., 2016. The hidden and external costs of pesticide use. Sustainable Agriculture Reviews, 19. Springer, 120 p.

[2] Chevassus-au-Louis B. et al., 2009. Approche économique de la biodiversité et des services liés aux écosystèmes – Contribution à la décision publique. La documentation française, 378 p.

For some non-market goods and services – or goods and services for which there is market failure – there are **reference values**, used in the evaluation of public policies or for insurance purposes (for example, the value of a statistical life). For 'merit' and 'demerit' goods (the consumption of which the government regulates, by either encouraging or discouraging consumption), a reference value based on political consensus serves as a reference in the evaluation of public investments (the price of carbon, for example).

For non-market goods and services which stem from individual preferences, such as environmental amenities for instance, economists propose **indirect methods**, aiming to identify the (monetary) value attributable to the externality by using observed or stated preferences. We have not taken these into account in this study, because these methods are necessarily biased (especially in terms of representation on panels, the subjectivity of the options presented in the surveys, etc.).

• Evaluating the economic costs in terms of one hectare of major French crop

The literature used for this study provides evaluations based on very different scales (one plot of land, one country, etc.), even for the same externality. In order to compare this disparate data, we needed to convert the estimates to a common unit. We chose to evaluate the economic costs of externalities in terms of one hectare of major French crop, because of i) the large number of acres they cover in France, ii) the portion of total volume of pesticides that they consume (68% according to the Farm Accountancy Data Network – FADN – in 2006) and iii) the importance of pesticides in the evaluation of externalities. However, we did not measure some of the externalities related to livestock (antibiotic resistance, for instance) in terms of one hectare of major French crop.

In the case of negative externalities tied to synthetic pesticide use, when there was data from the United States for instance, we transposed it in order to evaluate the external cost of pesticides on the major French crops. The global costs of negative externalities tied to pesticides in the United States was thus spread out among the major American crops, based on the portion of cropland and their TFIs[3], by applying the average French TFI for each crop (under the assumption that TFIs are more or less equivalent between countries). The same method was used when confronted with numbers from the rest of Europe as well. When we were working with values tied to positive externalities, we obviously did not use the concept of TFI.

[3] *Treatment Frequency Index (an indicator that calculates the number of treatments applied during a campaign, taking into account the applied dose)*

The use of inputs that organic farming forbids or limits

✱ Pesticide use

In France, despite the 2009 adoption of the Ecophyto plan, which reduces the use of agrochemicals, total pesticide use in conventional farming (measured in number of doses – per 1 hectare – sold) has not dropped. In fact, it has increased.

Organic farming uses almost no pesticides on fields of major crops (the exception is copper-based treatments used for potatoes). On perennial crops and market-garden crops, organic farming mostly uses mineral fungicide treatments (these are prepared primarily using copper, as well as sulphur) and pulverised plant extracts. Whether or not the latter is effective is a matter of some debate, but they are accepted as harmless (classified as 'lower concern substances'). The few chemicals allowed in organic farming which have been questioned for their (eco-) toxicity have gradually been retired: rotenone (an insecticide that was classified as toxic for those who apply it) has been banned since 2011 and PBO (a synergist, mostly toxic for aquatic organisms) will be banned in France starting in 2017. The main problem left is copper. Widely used in organic farming, copper accumulates in the soil where it can potentially be toxic for microflora and fauna.

✱ Nitrogen fertilisers

France consumes more nitrogen fertilisers than any country in Europe and has one of the highest rates per hectare. Nitrogen leaks, due to ammonia volatilisation and/or nitrate leaching, are estimated to account for half of added nitrogen, and contribute to air and water pollution.

Without having recourse to these synthetic mineral fertilisers, organic farming must rely more on the introduction of legumes (symbiotic nitrogen fixation) or other plants used to serve crop systems (main crops, intermediate crops or intercrops) as well as organic matter. With organic fertilisation, the plant available nitrogen is freed through the mineralisation of organic matter (OM), which depends on the climate. Nitrogen release in this instance is slower, but it also makes it more difficult to plan the timing for the needs of the crops. Organic farming is thus not exempt from nitrogen leaks. It is actually proven that nitrogen leaks occur in organic farming, especially after turning under certain cover crops (particularly alfalfa) or market-garden crops (which are highly fertilised). Because its yield targets are lower than in conventional farming, organic farming uses a smaller amount of fertilisers. The literature indicates that organic farming reduces nitrogen leaching anywhere from 35 to 65%. We used 40% as the reduction compared with conventional farming. This assumption is consistent with the results of comparisons of nitrogen balances between organic and conventional farming crop rotations carried out in the Paris Region. It does not apply to market-garden systems.

✱ Allopathic treatments in livestock farming

France is slightly below average among European countries in terms of antibiotics sold, measured in mg of antibiotic per kg of live weight, for all species combined. The use of antibiotics on animals contributes to the development of antibiotic resistance, which is a major issue for human health.

Organic farming favours ‘natural medicine’ (mainly herbal medicine) and prevention. The requirements of organic farming limit the use of synthetic allopathic treatments (limited, for example, to 3 per animal per year for ruminants, not including anthelmintics). In general, organic farmers use fewer antibiotics, pesticides and vaccines than conventional farmers. Due to the lack of general data on medicine consumption, we relied on two French studies (CasDar projects): one, carried out on 144 cattle farms, half of which were organic farms, observed 3.5 times fewer treatments in organic farming than conventional farming; the other, on 85 organic table poultry farms, showed that 94% of the batches of chickens were not given antibiotics.

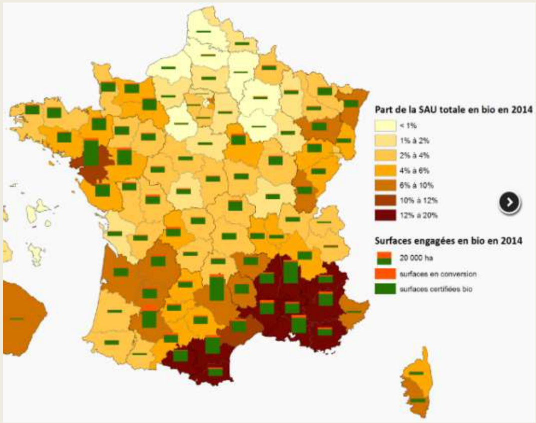
✱ Feed additives

Fifty-some feed additives are allowed in organic farming, as opposed to 300 in conventional farming. Those allowed in conventional farming include food colourings with proven adverse effects (asthma or allergies in sensitive individuals) and molecules that certain consumers cannot tolerate, such as glutamate (a flavour enhancer). Two controversial additives are still allowed in organic farming: nitrite in cured meats and sulphites in wines (within regulated levels).

C – A typical organic farm in France

The typical organic farm in France has a lower proportion of grain production than the typical French farm, and has less grassland, fodder, arboriculture, market gardening and viticulture, as well as fewer aromatic and medicinal plants.

Production	Portion of total AA using organic farming 2010	2015	Typical French Farm in 2015*	Typical Organic Farm in 2015**
Major crops	1.5%	2.5%	45%	21%
Forage crops	4.5%	7.2%	47%	65%
Grasslands	3.7%	5.4%		
Vegetables	3.3%	4.9%	0.8%	1.6%
Fruits	9.6%	11.5%	0.8%	2.6%
Grapevines	6.1%	9.1%	3.3%	6%
Aromatic and medicinal plants (AMPs)	13.1%	16.3%	0.1%	0.5%
Other	5.4%	4.7%	5%	3.3%
Total production	**3.1%**	**5.1%**	**100%**	**100%**



Sources: *Agreste; **AgenceBio/OC

Measuring the amount and economical values of organic farming externalities

1. Environmental externalities

The difference in negative and positives externalities between organic and conventional farming are examined here according to the segment of the environment affected (soil, water, air, biodiversity) or by the nature of the study (energy and greenhouse gases). They are not ranked in terms of importance. We systematically examined the literature that discusses negative externalities (the impact between organic and conventional farming), then the material that discusses positive externalities (the effects of organic versus conventional farming on environment services).

a. Biodiversity

While experts agree on many points concerning **biodiversity loss** (species loss and reduction, etc.), the various evaluations do not have a common unit of measure. Observations are usually focused on several taxonomic groups: plants, birds and certain arthropods. They have demonstrated a clear decrease in the populations of specialised birds in agricultural regions (from an index of 100 in 1989 to 55 in 2013). This has been caused by numerous factors and by direct and indirect effects: the toxicity of inputs, destruction of semi-natural habitats, lower food availability in fields, etc. Pesticides alone have multiple impacts, with direct effects that are both lethal and non-lethal (affecting behaviour, reproduction, etc.) and indirect effects, such as effects on the food chain. The example of honey bee colony decline illustrates the complexity of factors and their interactions: in this case, harmful interactions between an insecticide (neonicotinoids) and biological agents (varroa mites and nosema) have been demonstrated. In a decade, the bee mortality rate went from 5% to 30%. It is difficult to determine the weight of the effect pesticides have had and to attribute an exact percentage of the increased bee mortality that can be attributed to them, because the different effects – food stress, disease, chemicals – are intertwined. Moreover, there are other factors affecting bee colonies besides mortality, such as bees not returning to the hive (interference in homing and flights, even in small amounts).

There are many factors besides a lack of pesticides that make the case that organic farming has a positive effect on biodiversity preservation (species and ecosystems): more grasslands and ecological infrastructure, diversified crop rotations which provide a variety of long-term shelters and food, etc. However, the large-scale European study “BioBio”, comparing organic and conventional farms, showed that, overall, species diversity is only slightly higher in organic farming, and the presence of rare or threatened species does not depend on the mode of production (organic or conventional) as much as the crop practices used and the diversity of natural and semi-natural habitats available.

Evaluating the **services received from biodiversity** in terms of organic regulation of pests and pollination meets with several obstacles. Most studies focus on quantifying the beneficial organisms (predatory and pollinating arthropods), without quantifying their actions or the benefits. Only a few studies propose monetary evaluations of these services, but they are carried out on the extreme end of the scale (one parcel or the entire world). No studies – or very few – specifically call out organic farming and there are likewise no references to help calculate how much organic farming contributes to these services. Semi-natural habitats, which are imperative for the organisms that provide these services, are not taken into account in the studies of one parcel or in the determination of crop land in worldwide estimates. Different types of production are not affected by these services to the same extent, even those among the major crops: the pollination of grains for instance does not rely on pollinators – it is fruits and vegetables that are more dependent on them.

For vertebrate loss, we relied on the B&G study. For birds, this study was based on one case (in the United States in the 90s) of acute poisoning by a pesticide made of coated grains, which tasted good to birds and led to the death of 17-91 million birds. These numbers are related to one area of the United States (the corn belt), one pesticide (carbofuran), one form (granular) and one crop (corn), but carbofuran grains were used on many other crops at the time. To take into account all pesticides, and the entire United States, B&G assumed 100 million birds killed by pesticides each year, with an individual value of €35 (€30 for recreational value and €5 for pest regulation), or a total cost of €6 billion. Given that this instance was certainly the most significant effect pesticides have had on birds, and that the impact is doubtlessly less severe today, we have proposed to divide the number of dead birds in half. For fish, B&G reports annual mortality of 2-14 million fish a year, and estimates their individual value from €0.40 to €10, or a total cost of €122 million. Transposing the B&G data to France gives a value of €43-78/ha/yr. We have not found equivalent estimates for plants, invertebrates or mammals.

For pollination services, there are several monetary evaluations calculated on the global scale (based on the dependence different crop species have on zoogamy, and the amount they generate). These are thus estimates of how much pollination contributes to wealth created, and not what its loss would cost. In 2005, contributions from pollination were estimated at €153 billion, but estimates in subsequent studies continued to go up. Converted to the major French crops, these amounts range from €3.5-48/ha/yr. This is a theoretical calculation, however, because the major French crops do not depend on pollination. For species that are directly dependent on pollination, such as fruit trees, it is possible to provide an estimate for pollination services based on the price of beehive rentals, which is a practice that exists (and costs around €300/ha in France).

In order to determine economic figures for pest management, just one reference was identified in New Zealand. This was a comparison between organic and conventional farming on the scale of one parcel. It considered that in conventional farming, the service provided was negligible, and for organic farming, the estimated positive externality was between €45-163/ha/yr, based on the avoided cost of conventional treatments. Based on this methodology, in France, the average cost of insecticidal treatments for major crops would be somewhere between €10-21/ha (TFI of 0.6 and €35/TFI). These estimates based on parcels of land do not account for the complexities of farmland, however, and this is crucial to pest management.
Since both services are mostly provided by invertebrates, the loss of which species was not evaluated in that of biodiversity loss, there is no risk of these calculations being counted twice.

b. Water

On the qualitative side, INRA’s 2013 report established that organic farming consumes less irrigation water because its yield targets are lower. Organic farming also tends to have a lower portion of grain maize (1.8% of AA compared with 6.9% in conventional farming), which is a summer crop and thus requires more water. This relatively lower consumption of water resources is thus a benefit of organic farming, but one for which we cannot estimate the economic costs.

On the quantitative side, France has experience a generalised contamination of its bodies of water due to **pesticides** or their metabolites and degradation products, which have been detected in 90% of measurement sites, as well as nitrogen, which is present in the form of **nitrate** in doses of at least 10 mg/l in 83% of testing sites on water surfaces. While urban and industrial pollution has significantly decreased over the last 40 years, **farming pollution has increased in nearly every single region**. These contaminations are mostly due to herbicides and arise from current usage – glyphosate and its metabolite AMPA are, respectively, the #2 and #1 most commonly found substance in groundwater in mainland France – but also, because of the stability of certain molecules, from ‘historic’ pollution – atrazine has been banned since 2003, but its main metabolite (DEA) is still the 3rd most commonly found molecule in groundwater. Because of these remnants, simply abandoning the use of pesticides does not translate to a significant drop in the concentration found in groundwater, in the short or medium term. The dynamic evolution of pesticides in the environment, which is much more complex than the evolution of nitrate, remains difficult to predict.

The pollution of inland and coastal waters is responsible for environmental damage, as well as the restriction of certain recreational and economic uses of these environments. The most serious problem is the contamination of resources used for drinking water: 45% of the water abstracted for this use has been treated for pesticides, and 5-10% for nitrate. Two thousand drinking water sources have been abandoned over the last 15 years because of their pollution levels.

There is consensus around the fact that **reducing farming pollution upfront is much cheaper than treating drinking water prior to distribution** (according to, among others, the French Court of Audit, French water agencies and CGAAER, the French advisory board for food, agriculture and rural spaces). This assessment was based on the case of foreign regions or cities – and a few French communities – which chose prevention over treatment. Depending on the region, the cost decreased by a factor of 2.5-7. Organic farming is often used in plans to reduce pollution, and a few success stories can be highlighted. However, some INRA studies have put organic farming's impact in these evolutions into perspective, since reducing pollution requires a (sometimes difficult) convergence of numerous conditions. In Munich, the development of organic farming seems to have some favourable initial conditions (very extensive systems of production). In Augsburg (Bavaria), despite changing farming practices, organic farming was not adopted in the end. In Long-le-Saulnier (Jura, France), the creation of certain opportunities for collective restoration did in fact allow for the development of organic production, but it occurred outside of the region where organic farming was being targeted.

The technical and economic data used come from the CGDD, France's General Commission for Sustainable Development. In the 2011 study (and the subsequent updates), all the additional costs and losses attributed to pesticide and/or nitrate pollution were calculated: the costs of processing and sanitising water (drinking water treatments on waste water, abandoning or cleaning existing sources, etc.), avoidance costs to households (buying bottled water or filters), costs of cleaning shores and loss of income due to eutrophication (affecting fishing, tourism, etc.). The total cost was estimated at between €940 and €1,490/year. In our calculations, we have considered that the entirety of costs tied to pesticide pollution are avoided when using organic farming (this is a little high because organic farming does use a small amount of pesticides), as well as 40% of nitrate-pollution related costs. These savings, in terms of one hectare of major French crop, are around €20-46/ha/yr total, split evenly between pesticides and nitrate.
In catchment areas, where water quality is even more important, a 2010 study in the Ile-de-France region gave estimates of €49-309/ha/yr (depending on the source and the method of calculation, these areas represent 6-22% of AA in France).

c. Air quality

Farming contributes to the emission of nitrogen compounds, volatile organic compounds (COVs), methane and pesticides, as well as primary particles. Atmospheric pollution is a serious public health risk (see below), but it also leads to the contamination of the environment, through the particles that fall to earth and into water.

Ammonia volatilisation occurs on the soil surface, when mineral fertilisers are used and during the storage and spraying of animal waste. These emissions have direct effects on the environment (acidification and eutrophication due to deposits), as well as more serious indirect effects, because ammonia is a precursor of secondary fine particles and affects the ozone. While mineral fertilisation contributes to as much as 22% of ammonia emissions, it is not possible to determine the benefit of organic farming in this instance because ammonia emissions mostly come from livestock and can vary depending on how waste is managed.

As for pesticides, France does not currently have any specific regulation concerning air contamination and the data is limited. The few attempts at measuring air pollution demonstrated that air pesticide levels are highly correlated to the location and timing of farming treatments.

d. Soil

It is important to remember that not using synthetic pesticides **reduces the risk of chemical degradation of soil** (soil contamination) and reduces the risk of organic degradation of soil, even though the use of copper is problematic because of how it accumulates in soil – especially in viticulture.

As for the physical degradation of soil, it has been found that nearly 20% of French soil is at serious risk for erosion, with high associated costs: pollution of waterways, flooding, mudslides on roads, etc. The parameters which determine erosion risk have components that are not related to organic farming (topography, vulnerability to erosion which mostly depends on structural stability), as well as components that are associated with organic farming. Thus, certain organic practices are subject to discussion, such as the negative effects of more frequent tillage in order to control pests. However, because vegetation is the determining factor in terms of protecting soil from rain, and because ground cover was determined in a meta-analysis of soil in major crops to be, on average, utilised more in organic than in conventional farming (intermediate crops, cover crops, etc.), the risk of erosion can potentially be reduced.

In addition to reducing the negative externalities mentioned above, organic farming also emphasises the importance of organic matter (OM) and soil life. A 2013 INRA report for the CGSP (France's general commission for strategy and planning) indicates that the majority of publications conclude that concentration of organic matter (OM) is higher in organic farming soil than in conventional farming soil. Increased OM plays a role in the two following environmental services:

- One is related to **water cycle regulation**. Higher levels of OM and more continuous ground cover help to retain water in the soil and encourage surplus infiltration, which contributes to groundwater recharge.

- The other is related to **soil carbon sequestration**. The benefits for society are twofold: **maintaining existing levels and additional carbon fixation**.

Certain characteristics of organic farming can limit carbon storage in soil: a lower productivity (which limits underground biomass and biomass from incorporated crop residues) and tillage – even though the benefit of not ploughing certain years as practiced in conventional farming (where some simple tillage is done as well as periodic ploughing to control certain pesticide-resistant weeds) remains up for debate (see "The kinetics of storage and use" in Box D). Increased carbon capture appears to be a more efficient means of carbon storage than reducing carbon loss through mineralisation.

The main advantage of organic farming is that it conserves existing stores, through the use of more grasslands and hedgerows. Additional stores are more a result of specific practices implemented. The advantage of organic farming is more obvious in major crop regions when the OM concentration in the crop land using conventional farming has been significantly reduced, and where the switch to organic farming with more livestock provides more organic matter input, not to mention a higher use of ground cover and increased grasslands.

One meta-analysis[4] of 74 studies (carried out mainly in Europe, America and Australia, on all types of production) indicates that **stores of organic carbon are greater in the soil of organic farming** (37.4 tonnes/hectare) than in conventional farming (26.7 tonnes/hectare). However, this article has been criticised, particularly on the matchings it established, since the matter inputs were not comparable. Gattinger et al. responded that

[4] *Gattinger et al., 2012 Enhanced top soil carbon stocks under organic farming, PNAS,vol. 109 no.44, 6p.*

organic farms necessarily use more livestock (with farmyard manure inputs and the presence of forage crops) than conventional farming (see our presentation of a typical organic farm in France).

Carbon sequestration must be evaluated as part of the global carbon footprint. Indeed, particularly with ruminant farming, it is considered that carbon sequestration compensates for gross greenhouse gas emissions (see below), for a net-zero result.

The reference value for one tonne of carbon in France in 2016 is €46. If we account for the above elements, in particular those of Gattinger et al. (2012), indicating a sequestration differential between organic and conventional farming of 0.5 tonnes Carbon per hectare, all while keeping in mind that certain tillage practices can release carbon, we can assume benefits of between 0 and 0.5 tonnes of Carbon a year, or €0-23/ha/yr.

D – Farmland carbon sequestration

There is a difference between carbon stores in the soil and additional storage that comes from certain changes in soil management. Store levels depend first on soil use: 80 tonnes of Carbon per hectare in untilled soil with permanent ground cover (e.g. forests, permanent grasslands), and 50 tonnes of Carbon per hectare for annual crops and orchards.

The concentration of organic carbon in the soil depends on an equilibrium between OM deposits and carbon release through mineralisation, which cancel each other out when management systems are stable. This balance is upset by additional OM deposits or by any other factors that accelerate mineralisation (e.g. global warming, tillage).

Changes in soil management have different kinetic effects; carbon release can become faster than carbon capture. The effects of no till farming appear to be weaker than indicated by initial estimates (which only evaluated topsoil and did not account for the transitory nature of storage surplus) (C. Chenu, 2016)

e. Greenhouse gas emissions

It is estimated that farming is responsible for 20% of total greenhouse gas emissions in France, if we include the emissions from energy consumption (which national inventories calculate separately) – not including land use change (‘LULUCF’). N_2O (nitrous oxide), CH_4 (methane) and CO_2 (carbon dioxide) account for 50%, 40% and 10%, respectively, of sector emissions, in terms of carbon dioxide equivalent. The weight of N_2O and CH_4 emissions is due to their ‘global warming potential’, which is much higher than that of CO_2 (298 and 25 times higher, respectively). N_2O emissions are mostly due to the volatilisation of synthetic nitrogen fertilisers during application and to livestock manure. CH_4 emissions come from the enteric fermentation of ruminants (digestion in the rumen) and the fermentation of waste stored under anaerobic conditions – which can actually be used as a form of energy recovery in anaerobic digestion.

Organic farming severely limits N_2O emissions by not using mineral nitrogen fertilisers, which require significant amounts of energy to fabricate. Methane emissions from enteric fermentation can be modified by diet. A small reduction is observed by reducing concentrate-rich feed rations, but adding fat to feed rations has an even bigger effect. As for emissions from livestock waste, it is difficult to establish global comparisons between organic and conventional farming, given the extreme variety of methods of waste management in the two systems (and whether they use compost or not).

Generally, greenhouse gas levels calculated on the performance of individual animals show that intensive systems are better (lower levels – see Box E). However, **studies carried out on entire units or farms** tend to show a much different relative performance of the different systems of production, and are comparable in organic farming, when compared with the kg produced (of meat, milk, eggs, etc.). For ruminants, the levels are always better when they are calculated in terms of hectare used. When measurements are calculated for an entire herd – for instance, the increased length of service of milk cows as practiced in organic farming, which reduces the number of replacement heifers (with low productivity and high methane emissions) – the GHG levels of the herd improve.

Moreover, with grazing livestock, the use of grassland limits the use of other crops (grains, maize silage, etc.) and increases soil carbon sequestration, particularly for long-term or permanent grasslands. The ‘net-zero’ GHG emissions (gross CO_2 emissions offset by equivalent soil carbon sequestration) increase the interest in organic farming systems, especially because, with a lower yield than in conventional farming (and thus the production of meat per hectare), carbon sequestration per kg of meat or milk is much higher than in conventional farming systems.

E – The importance of the feed to gain ratio in the environmental performance of livestock systems

The feed to gain ratio (food produced compared with feed consumed) measures how effectively feed ingested by animals is converted into animal products that can be consumed by humans. Given the high proportion of production costs that is spent on feed, this ratio ends up being maximised in intensive conventional livestock systems. Thanks to high individual productions, the GHG emissions tied to the maintenance needs of animals (which do not change much) are “spread out” over an increased quantity of product. On the other hand, any increase in the rearing period, because of breeds that mature more slowly (the flipside of a better-tasting meat or animal hardiness) or because of less calorie-rich rations (focus on coarse feed, especially grass), and any increased energy expenditure by the animals – for instance, because they have access to rangelands (movement, thermoregulation) – negatively affects the animals’ feed to gain ratio and thus the GHG emission level of the system. In this way, organic farming is “penalised”, but so are all ‘label’ systems, grass-fed systems or those that try to improve animal welfare.

f. Consumption of non-renewable and/or scarce resources (fossil fuel, phosphor, land resources)

• Fossil fuel

As with GHG emissions, the levels of non-renewable energy consumption in organic and conventional farming have been assessed in order to determine different offsets (the results are established using the life-cycle assessment or LCA approach). While input use is limited in organic farming – particularly inputs that require significant amounts of energy, such as synthetic nitrogen fertilisers – the lower productivity means that we do not see the same level of 'dilution' as observed in conventional farming. However, assessments are generally comparable between organic and conventional farming when measured against one kg produced (with significant differences depending on the type of production and the context) and, as with GHGs, show organic farming to be favourable when expressed in terms of one hectare used.

• Phosphorous (P)

All synthetic phosphate fertilisers come from rocks extracted from mineral deposits. The availability and accessibility of these rocks could become a major issue throughout the world in the decades to come. Organic farming is allowed to use mineral phosphate fertilisers in their crude form, such as crushed rock. However, farmers do not use them much, because their effectiveness is debatable (low bioavailability of phosphorous in these fertilisers), there is already a high level of phosphate in the soil after decades of excess inputs before switching to organic farming and yield targets of these crops are limited. They thus prefer to use the phosphorous found in livestock waste, which is available in much higher quantities. These modest fertilisation practices mean that there is often less phosphorous present in organic farming. It is important to note that organic farms without livestock are very dependent (for almost 75% of their supply) on the phosphorous from manure and farmyard manure from conventional livestock farms, as has been demonstrated by a study carried out on three small farming regions in France.

• Land resources

Because organic farming has lower yields than conventional farming, and thus requires more surface area in order to produce the same amount of food, it appears to use up more land. Consequently, it can seem like an increase in organic farming throughout the world would require an increase in crop land, to the detriment of forests or prairies which present numerous advantages (e.g. carbon sequestration, biodiversity).

However, when comparing modes of production, we would be wise to take into account organic farming's goal of food self-sufficiency, which limits its need to use additional surface area (tied to the production of concentrates), which is not considered in the surface area used by livestock farms.

In a worldwide analysis, other considerations can also be taken into account, such as the different uses of agricultural land (energy in particular), diets, and the level of waste partly due to distribution channels and eating habits. Thus, this question of land use could be explored in worldwide analyses, by introducing alternatives into land use and food scenarios. This could potentially lead to a large-scale conversion towards organic farming.

2. Externalities affecting human health

a. Health impacts from synthetic pesticide use

Pesticides have three methods of entering the human body: through the respiratory tract, the digestive tract (or orally) or through the skin (by contacting contaminated surfaces). In professional agriculture, it has been demonstrated that the main penetration path is through the skin. For the general population, who are exposed to agricultural and domestic pesticide use, it is often considered that pesticides are most commonly ingested orally, by eating or drinking contaminated foods or drinks, or through non-food ingestion (e.g. dust), mostly seen in children. Communities who live near pesticide-treated fields are also often exposed through the respiratory tract.

Pesticides can cause acute poisoning, as well as negative effects from chronic exposure. The former is relatively easy to define: in France, poison control centres and toxicovigilance organisations have documented 5,000-10,000 cases of pesticide **poisoning** each year, including numerous poisonings of young children, after accidentally ingesting a pesticide or through contact with the skin or eyes.

The links between **chronic exposure to pesticides and various diseases, established using varying degrees of proof, was catalogued by a collective scientific report released by INSERM** (the French National Institute of Health and Medical Research) in 2013. The numerous epidemiological studies carried out on populations that work in agriculture show a **significant correlation between pesticide exposure and various pathologies** (Parkinson's disease, prostate cancer and certain hematopoietic cancers), some of which have since been recognised as occupational diseases (e.g., Parkinson's, malignant non-Hodgkin lymphoma). It is difficult to establish causality because of the multifactorial nature of diseases, the length of time between exposure and the effects, and the lack of data on pesticide exposure of agriculture professionals, much less the general public. However, there are some proven or plausible links between chronic pesticide exposure and certain types of cancers, neurological diseases and reproductive and developmental disorders. Pesticide effects are also suspected to be the cause of other pathologies, including respiratory diseases, immune disorders and behavioural disorders.

These suspicions of pesticide toxicity were reinforced by the discovery of mechanisms of action, particularly the effects of endocrine disruptors (see Box F), and the demonstration of the 'cocktail' effect (synergetic effect between the components of a mixture, which creates a toxicity that is higher than the sum of the toxicity of each individual molecule). These observations bring into question the approach of classic toxicology, founded on simple dose-effect relationships and the determination of the ADI (acceptable daily intake) of substances.

Concerning **pesticide exposure through food in France**, control campaigns led by public administrations (DGAL, the French General Directorate for Food, and CGCCRF, the French General Directorate for Competition Policy, Consumer Affairs and Fraud Control) have shown that that are few instances where the Maximum Residue Limit (MRL)[5] is exceeded in mainland France production. The rate of 1.1% is comparable to that of other EU countries. Data-based calculations of pesticide exposure of the general public through food has led ANSES (the French Agency for Food, Environmental and Occupational Health & Safety) to identify seven pesticide residues (dimethoate, lindane, carbofuran, imazalil, dithiocarbamates, Fipronil and nicotine) that pose a chronic risk and 17 substances that pose an acute risk.
On the European level, the EFSA report from 2016 (based on data from 2014) confirmed that pesticide residue levels are significantly lower in organic products than in conventional farming products, in terms of the number of detections (12% of analyses versus 45%) and in exceeding MRLs (1.2% versus 3%). Organic farming is not exempt from contamination, because of contaminated inherited soil and exposure to spraying from conventional farming.

F – Endocrine-disrupting chemicals (EDCs)

These substances mimic the action of natural hormones, disrupt different endocrine functions and have (proven or plausible) effects on embryo development (especially the brain), metabolism (e.g. diabetes, obesity), reproduction (e.g. fertility problems) and behaviour (e.g. autism, hyperactivity). Many molecules have been identified as endocrine disruptors, from a wide variety of chemical families, with a wide variety of uses (pesticides, solvents, plasticisers, flame retardants, etc.) and are thus present in many consumer goods (food, cosmetics, packaging, toys, furniture, etc.). EDCs are unique in that they can induce effects at very low doses and that some have atypical, non-monotonic response curves.

Studies have shown that maternal thyroid deficiencies negatively affect the IQ and behaviour of children. The hypothesis of one group of researches is that xenobiotics (including organophosphate insecticides – OPs – which are endocrine disruptors) can interfere with thyroid hormone signalling and early neurogenesis, which contributes to neurodevelopmental disorders and lower IQs.

Based on these estimates of the risk factors, a study of lowered IQs in children tied to their foetal exposure to OPs estimated the cost to society at €46-194 billion for the entire EU (or 508 million inhabitants). We have examined these references, but it seems to us that this evaluation is based on debatable data, both in terms of epidemiology (two studies, on 119 and 200 children, establishing a correlation between the IQ measurements of the children and the concentration of OP metabolites in their urine or their mothers' urine, with one study indicating that the variations in the results should be analysed), but also in terms of the economic evaluation, because translating lost IQ points into lowered inventiveness and individual performances, and extrapolating this to costs and lost benefits to society, is problematic. In October 2016, one researcher from the previous study and his team reproduced the work, but this time using the health costs of endocrine disruptors in the United States (325 million inhabitants) and estimated costs tied to OP effects at $42 billion.

These figures seem particularly high to us, and we believe it is important to find stable bases of comparison, before being able to draw any numerical conclusions on the benefits of organic farming on EDCs.

The numbers used come from the B&G study carried out in the United States. For **acute intoxication**, this study took into account the cost of medical care for the sick, sick leave, deaths (45 a year), and indirect impacts on the sick and those close to them. For the effects of **chronic toxicity**, it calculated the costs of cancers caused by pesticides, with the presumed rate of cancers declared to be attributed to pesticides of 1% (of 10,000 cases per year), and a mortality of 20% for those with cancer. This rate of 1% is based solely on the (already outdated) opinion of just one expert. We were not able to find any other figures in the

[5] MRLs are not toxicological norms but the concentration levels maintained by good phytosanitary practices.

literature, so this data remains fairly fragile, even though it is crucial to our evaluations. Another leading parameter in the calculations is VSL (see Box Y). B&G uses a very high value – $9 million – and estimates the cost of death as 93% of the total cost of health effects, estimated at $19.8 billion/year.

We propose a lower assumption, applying a VSL of $3 million to B&G's data, and a higher assumption attributing 5% of cancers to pesticides, which is corroborated by the growing recognition of the harmful impacts of these substances and of the 'cocktail' effect. Using these calculations, we obtained values of €52 and €262/ha/yr. This estimate does not take into account the cost of other pathologies with proven or plausible ties to pesticides (such as Parkinson's disease) and the two studies available on endocrine disruptors were not adopted (Box G).

G. Value attributed to lives saved

For this parameter, which is crucial to our calculations, one solution was to use the reference value that has been used to calculate risk mitigation in public policy decisions. Called 'value of a statistical life', this VSL should not be understood as the value attributed to a particular human life, but as the effort that a community is ready to expend to reduce a risk of death. In France, the reference guide recommends a VSL of €3 million euros, which falls within the range of VSLs used in OECD countries: between $1.5 and $4.5 million. The B&G, on the other hand, uses a much higher figure: $9 million (or €8 million).

b. Health impacts of nitrogen pollution (ammonia, nitrogen oxide, nitrate)

The World Health Organization considers **atmospheric pollution** to be the biggest environmental risk to human health. In 2012, the WHO attributed around 7 million deaths (1/8 of annual deaths worldwide) to pollution (all types of pollution combined). Estimates of the health costs and impacts from these pollutions exist – on the scale of the EU (400,000 premature deaths; €330-940 billion/year) and France (€68-97 billion/year), but these evaluations do not highlight the portion that is attributed to farming, which is impossible to isolate given the numerous interferences between farming emissions, industrial pollutants and transport-related pollution.

Despite this, farming's contribution to pollution is significant: it accounts for 40% of methane emissions and more than 90% of ammonia emissions. Ammonia is an irritant gas (for the lungs and eyes) but also contributes to the creation – along with other farming-related pollutants (NOx) or not – of secondary fine particles. These particles are considered a major public health issue. The impact that farming has on health issues is thus difficult to quantify.

It does not seem possible to determine how beneficial eliminating synthetic nitrogen fertilisers on its own would be, let alone to differentiate the respective contributions of organic and conventional farming to the air pollution that is caused by nitrogen fertilisers. As a matter of fact, these types of pollution are also tied to the presence of livestock in a farming system, and organic farming encourages the association of livestock with plant productions in order to close the fertility cycle.

In terms of **food contamination**, **nitrate** can cause the formation of i) nitrates, which in infants can affect haemoglobin and oxygen transport, and ii) nitrosamines, which are a proven carcinogen in animals but the effect of which on humans is still debated. Ingested nitrate comes mainly from food (vegetables in particular), with drinking water accounting for 20%. According to a meta-analysis in 2014 (compiling data from 79 publications), organic products have, on average, 30% less nitrate concentration and 87% less nitrite concentration (taking the average of the differences, but the deviations are smaller if we use the average deviation).

c. The impact of antibiotic resistance on health

The development of antibiotic resistance is also considered to be a major public health issue, with 25,000 deaths per year secondary to an infection tied to one of the five most common multidrug-resistant bacteria in the European Union. On this scale (in 2009), the total of direct medical costs, indirect medical costs and productivity losses amount to €1.5 billion/year, or €76.5 billion/year if we include the social cost of death (using a VSL of €3 million). If we convert this amount to France on a per capita basis, without accounting for the more or less relatively strong consumption of antibiotics in France, the societal cost of antibiotic resistance would be €10 billion/year.

The contribution of livestock to the development of antibiotic resistance has been proven – veterinary uses account for half of all antibiotic consumption – but has not been quantified. The use of antibiotics in livestock favours the selection of resistant pathogens (and yet 60% of pathogens and 75% of infectious diseases that affect humans are zoonotic – meaning they are common to humans and animals) and resistant genes that are susceptible to being transmitted to other human pathogens. The spread of waste then disseminates these resistances and antibiotics themselves into the environment (30-90% of the doses administrated to animals are excreted without being metabolised).

The benefit of organic farming, with its lower use of antibiotics, is undeniable, but it is not possible to put an exact number on it, despite the fact that the proportion of antibiotics used in livestock is known. Indeed, the transfer of resistances between human and animals bacteria exists, but researchers point out how difficult it is to estimate the effects of this process.

d. The benefits of consuming organic products and organic diets

Food safety

Besides having **less pesticide residue** as already mentioned, organic products also have **lower cadmium concentrations** (25-50%), because of a lower use of phosphate fertilisers, according to the meta-analysis in 2014 cited above.

It was suspected that organic farming runs the risk of higher levels of **mycotoxins** (toxins produced by fungal pathogens in crops) because fungus control is less pronounced. Since the French Food Safety Agency (AFSSA) report of 2003, it has been established that these contaminations are not higher in organic farming than in conventional farming.

For **microbiological contaminations**, the 2013 INRA report indicated that the comparative studies between organic and conventional farming did not allow for a conclusive decision on if one of these two modes was better or worse.

Nutrient quality and intake

There are frequent debates over the nutritional quality of organic products. A meta-analysis in 2014, which compiled the results of 160 studies, concluded that organic farming had 18-69% more antioxidant concentrations (which are recognised for their role in preventing neurodegenerative diseases, cardiovascular diseases and certain cancers). It is tricky to interpret these distinctions, because numerous factors which can play in organic farming's favour are not specific to this system (for example, the variety cultivated or the maturity of the fruit due to a later harvest because the sales cycle is shorter). For **animal products**, the key issues are mostly around fatty acid concentrations. Two meta-analyses in 2016, one dedicated to meat and one to fruit (and compiling 67 and 170 publications, respectively) underscored the wide variety of results which still all showed that organic farming is favourable because of the proven health benefits of fatty acids to humans: one type of polyunsaturated fatty acid in meat, and omega-3 in milk. This effect, especially in organic lamb, seems to be tied to how the animals are fed (the amount of grass and legumes in the rations), thus to practices that are favoured by the principles and the regulations of organic farming (but which are not specific to organic farming).

While it has been shown that organic farming products likely have a favourable effect on human health, the effect on human health (assuming that the effect of micronutrients can be quantified) will depend on the amount in a person's diet, the risk of deficiency in the population, the bioavailability of compounds, etc.).

The effects of organic diets

In an experiment where people switched to a diet that is high in organic foods, there was a rapid decrease in the amount of pesticides found in their urine. However, demonstrating health effects on those consuming an organic diet requires in-depth epidemiological studies (see Box H), because the consumption of organic products is highly correlated to numerous other factors: health practices (consumption of tobacco and alcohol, physical activity, etc.), the quality of the living environment and, more globally, belonging to a higher socio-economic group.

A project called **BioNutriNet**, which included 54,311 adult participants in the French NutriNet-Santé cohort (with 248,000 total volunteers) during the eligibility phase of the 2009-2011 study, was able to identify typical profiles of consumers and their relationship to organic products: 3 groups of non-consumers (NC) for various reasons (no interest, avoidance or cost) and two groups of consumers – occasional consumers (OC) and regular consumers (RC). The preliminary results of the study show that consumers of organic products are less likely to be overweight or obese, and thus have fewer diseases related to these issues. However, this line of research needs to be extended in order to draw conclusions, because it is difficult to isolate the exact effects of food on health, as people who eat organic food also tend to have a generally healthier lifestyle.

The advantages of eating organic may come not only from the specificity of organic foods, but also from the mere fact of changing the type of food eaten.

H – Epidemiological studies

These case-control studies (where a group of individuals exposed to one factor is studied against a control group) are limited in their methodology and thus do not produce many proofs, especially if the health effects being researched are delayed and cumulative, and the diseases are multifactorial. This is the case for the effects of chronic pesticide exposure and of organic food on the occurrence of metabolic diseases, cardiovascular diseases, neurodegenerative diseases and cancer.

Demonstrating this kind of effect requires cohorts (groups of subjects studied over the course of several years) that are big enough, enough data to be collected on the other variables that might influence the effects being studied (confounding factors) and monitoring that is long enough in order for the diseases being researched to present themselves.

3. Social performance (other than health)

a. Jobs and farming

The data from the 2010 agricultural census showed very different results depending on the type of product of the farm. For 2/3 of types of farming, or TFs (major crop, viticulture, crop-livestock and monogastric), the number of Annual Work Units (UWAs) per hectare is greater in organic farming, but the differences can also depend on average farm size. Because the cost to society of one unemployed person has been estimated at €11,000-21,000/year, the benefit of additional jobs, converted to one hectare of major crop, can be estimated at €19-37/ha/yr. In August 2016, the French office of statistics and forecasting published a study that applied a more sophisticated statistical model to individual farm data (technique of pairing between organic and conventional farms). In terms of total farm labour, it shows that, three years after converting, organic farms have a significantly larger volume of work than comparable conventional farms (average increase of 0.08 UWA). For farms that sell directly to customers, the differential in favour of organic farming is around 0.14 UWA. For farms with salaried employees, organic farms have an average increase of 0.07 UWA, and 0.14 UWA for farms with short supply chains (for all FTs combined). These results substantiate the hypothesis that organic farming can help create jobs (€10-18/hectare in terms of the average surface area of major French crops).

While this approach gives an analysis on the level of the farm, for a complete view, it is still necessary to examine the larger scale, because the development of organic agriculture – which uses fewer inputs, produces less and uses shorter supply chains – might generate job losses upstream (manufacture and distribution of synthetic inputs) and downstream (collection, long processing and distribution chains). The downstream jobs are significant, though some of these are outsourced. On the other hand, some studies do mention reinforced job creation, for instance tied to synergies with other industries such as tourism. A global evaluation of how organic farming impacts jobs is difficult to create, and few studies address this question.

Organic farming should make it possible in certain cases for conventional farmers in precarious situations to keep their jobs, as they can fall back on converting to organic farming (by taking advantage of available aid and better prices). This effect has been shown to work for fruit and vegetable systems in South-Eastern France, as well as for grazing cattle farms in Western France. Organic farming could thus lead to **keeping farmers** on farms and maintaining land use; these benefits balance out the aid dedicated to organic farming.

b. Fairness and community

The fact that organic farming typically has higher associated prices means that the **accessibility of products** is problematic for lower-income consumers. Several elements however can limit how high prices are: a short sales cycles, which reduces or eliminates the price differential with conventional products sold in large distribution; buying cheaper goods, such as vegetables and/or less processed products; the reduction of food waste.

A shorter sales cycle, especially by using associations such as AMAP (associations supporting small farming), reinforces the **relationship between farmers and consumers** which urbanisation had stretched out.

Certain modalities of the implementation of organic farming reinforce the **social link** through local initiatives that are not specific to organic farming, but which are often used in organic farming. It plays a role to help unify and stimulate numerous local development projects which integrate broader perspectives, such as food education, community restoration, food sovereignty, social equity, professional integration of disabled workers, etc. It is not possible to provide an economic quantification of the effect this investment has on local communities.

The effects of organic farming on social ties and on landscapes – which become more diversified (statistics from Agreste, the bureau for statistics of the French Ministry of Agriculture and Fisheries, indicate more vegetable species, and more workshops in general) – are real, but difficult to evaluate. In particular, it depends on the interests that citizens have in the ties or the landscapes that are created, and the preferences citizens have for these efforts are generally very diverse.

c. Animal welfare

Organic farming regulations impose **stricter norms in terms of animal welfare**. Mutilations can only happen under analgesia or anaesthesia, and they should not be practiced systematically. While castration is usually still practiced (because of how it helps animals fatten and improves the quality of the meat), other procedures that are common in intensive farming (e.g. cutting off the tails and removing the teeth of piglets) are extremely rare in organic farming. Organic farming norms allow for animal housing that is big enough and has an access to the outside, straw litter, longer periods of suckling (for pigs), breeds that grow more slowly (fewer musculoskeletal disorders), etc. These measures lead to breeding constraints and additional costs (which can sometimes be financially difficult for small farms) and lower productivity (per animal, per m² of building, per worker, etc.).

Evaluating animal welfare (identifying measurable criteria) is a difficult exercise. If animal health, which is part of the fundamental principles of organic farming, is correctly maintained as one of the criteria, organic systems will have an advantage over conventional systems in terms of welfare. However, comparisons on criteria such as animal cleanliness, fattening, lameness and injury do not always demonstrate significant differences between organic and conventional farming (for dairy farming). Certain practices which favour animal welfare such as free-range farming can potentially create a risk of negative effects: parasites (especially digestive ones) are easier to catch and the risk of predators increases. However, **access to pastures has numerous advantages for animals**: it allows them to express their natural behaviour, such as choosing what to eat from diversified grasslands; being able to graze on vegetation has been proven to benefits animals in terms of parasite control (by eating tannin-rich plants, for instance).

In terms of slaughter, while organic farming's general principle is to reduce all suffering to a minimum, this has not been translated into any concrete or verifiable rule.

d. Cross-functional externalities

One cross-functional externality which is often omitted from evaluations is the externality of information procured by organic farming. As a form of farming that succeeds in eliminating the use of synthetic chemical pesticides and mineral nitrogen fertilisers, and limiting the use of antibiotics, **organic farming provides references** for the analysis and conception of other modes of production that use fewer inputs. This externality of knowledge, learning and expertise far outreaches the organic farming industry. Some authors believe that the most important benefit of organic farming might be that it helps push conventional farming systems towards agro-ecology.

More globally, the question of organic farming's benefits includes considerations in terms of **intergenerational responsibility**, especially because of how long pesticide pollution lasts, the health effects that are tied to in-utero pesticide exposure, and effects that could even be transmitted to the next generation (this is the assumption for certain endocrine disruptors).

Data elements of the externality differentials between organic and conventional farming

	Components	Type of externality	Impact, service, resource used	Organic farming characteristic involved	Effect
	Cross-functional	Regulatory	Mechanisms for pesticide management	lower use of pesticides	
		Information	References produced for agro-ecology	requirements specification	
		Job creation	At the farm level	generally increased workforce	
ENVIRONMENTAL EXTERNALITIES	Soil	Less degradation of soil quality (physical, chemical and biological)	Physical degradation	more soil cover, less tillage	
			Acidification	more types of soil	
			Salinisation	lower use of pesticides	
			Toxification	lower use of pesticides	
				pay attention to copper	
			Eutrophication	fewer nitrogen and phosphorous inputs	
			Physical degradation	lower use of pesticides	
		More ecosystem services	Carbon sequestration	more grasslands, more legumes, more tillage	
			Water cycle regulation (retention)	more organic matter	
	Farming area	Resource	Land use (if the scale changing)	lower yields	
	Water	Resource	Water consumption	less irrigation	
		Fewer impacts on quality	Pesticide pollution	lower use of pesticides	
			Nitrate pollution	fewer nitrogen inputs	
	Air	Impacts on air quality	Particulate pollution, ammonia	?	
		GHG emissions	GSG emission levels	Lower levels of GSG emissions per hectare	
				GHG/kg is more variable	
	Fossil fuel	Consumption for production	Energy consumption report (LCA)	Lower levels of energy consumption per hectare	
				energy/kg is more variable	
		Downstream consumption	Trash, packaging, waste	?	
	Phosphorous	Resource consumption	Lower consumption		
	Biodiversity	Fewer negative externalities	Pesticide-related animal deaths (birds, fish, etc.)	less pesticide pollution	
			Impacts of nitrate on aquatic life	less nitrogen pollution	
			GMOs: reduction in # of crop varieties		
		More ecosystem services	Increased pollination service	little or no pesticides	
			Increased biological pest control	little or no pesticides	
HUMAN HEALTH	Negative impact of inputs	Little or no pesticides	Acute pesticide toxicity	little or no pesticides	
			Chronic toxicity (Parkinson's, cancer, etc.)	Uncertainty on the ratio due to pesticides for different diseases	
			Family suffering and disease		
		Nitrogen fertilisers	Toxicity of NOx nitrogen compounds and fine particles N_2O and NH_3	? / role of livestock in farming	
		Veterinary medicines	Development of antibiotic resistance	lower use of antibiotics	
		Additives	Risk of allergies	47 additives in organic farming vs. 300 in conventional	
	Nutrition	Sanitary quality	Microbiological contamination, mycotoxins, heavy metals, organic pollutants		
		Inputs	More of certain beneficial components	omega-3, antioxidants	
		Diet	Correlation with a healthier lifestyle		
ANIMAL WELFARE	Health Living conditions Pain management	Animal integrity	Fewer mutilations and greater use of analgesia	Requirements and consequences	
		Accessible area for animals	Free range: greater risk of predators		
			Grazing: more exposure to parasites but access to a variety of plants that help control parasites		
			Lower yield. Fewer parasites.		
			More space per animal in buildings, access to the outside		

	Positive effect of organic farming		Positive effect of organic farming, but not systematic		Organic farming might have negative effects		Negative effect of organic farming

Positive externalities	Fewer negative externalities	Resource consumption

4. Discussion points and methodological difficulties

The adjacent table summarises the qualitative and quantitative evaluations that were able to be proposed based on the literature. It highlights the **benefits of organic farming for the large majority of the externalities studied,** without giving economic costs. After examining each externality individually, there are several cross-functional or global questions to be raised.

• From a juxtaposition of single-service evaluations to combined, multi-service evaluations

This requirement to **evaluate multi-dimensional** performances has been affirmed in numerous articles, which highlight the importance of a 'multi-service' approach, or a 'service package' approach, which integrates the links, synergies and conflicts that exist between services, at different scales. These studies demonstrate the complexity of this kind of approach, and the need to discuss what tools must be developed in order to take into account these articulations, as well as the compromises to strike.

LCA-type methods are a partial response to this goal of multi-criteria analysis: they take into account GHG emissions, energy consumption and the impacts of acidification and eutrophication on the environment. However, they still rely on impacts for which there is a common unit of measure, in order to make calculations, which excludes for instance the evaluation of the effects on biodiversity or the services that biodiversity provides.

Other approaches select just a few criteria and indicators. For instance, we could cite Syswerda and Robertson (2014), a study which proceeded with a comparison of systems (organic, low input, no till, conventional) and proposed to take into account a set of services. Their results indicated that no till allowed for an improvement of water retention capacities, but necessitated the use of more herbicides and led to increased N_2O emissions, especially in hydromorphic soils, while organic farming, despite a lower supply service, better integrates the various issues.

Other methods propose consolidating the 'scores' obtained on each of the indicators analysed, for one final score. It is important to note however that caution must be taken when using weighted averages. In order to limit the effects of compensation between good and bad scores, there should be rules attributing a much greater weight to bad scores, or some scores should be considered disqualifying.

Finally, we cannot ignore the question of competition between animal and human food, critical for grains and high-protein oil crops which are widely used in conventional livestock farming, and nonexistent for grass produced on surfaces that are unfit for farming. Recent methodological developments have proposed indicators that would allow us to refine this analysis (for instance, ECPCH, *Efficience de conversion des Protéines Potentiellement Comestibles par l'Etre humain*, or Efficiency of Conversion of Proteins Potentially Consumable by Humans).

• The different lengths of time it takes for different amenities to become apparent

Certain benefits to society appear in the short term: improvement of the quality of surface water, reduction of acute pesticide intoxications, energy savings (nitrogen fertilisers). Other effects will not be perceptible until the medium term: restoration of the quality of groundwater, reconstitution of an efficient, functional biodiversity. Finally others will not be apparent until the long term, such as the reduction of diseases tied to chronic pesticide exposure.

• The question of functional units

There are frequent debates about the functional units (kg of product of hectare used) used to express resource consumption or pollution, especially. Estimates related to area, which are favourable to organic farming, are helpful in evaluating local impacts, for instance reduced nitrate leakage per hectare to evaluate water quality. However, they are less relevant when evaluating energy consumption or GHG emissions, which are global impacts that are independent of their place of origin, from the perspective of a global evaluation of agri-food systems.

• Economic integration of different externalities

Having calculations of the costs avoided and gains in terms of one hectare of major crop could prompt some people to add them together. The low relevance of the value in terms of hectare for some externalities (the cost of disease attributable to pesticides, for instance), the different meanings of values according to the externality (value of equipment, of a death, of a bird, etc.), the risk of counting certain externalities twice and the extreme uncertainty of the amounts all make this an extremely delicate – even 'dangerous' – task, because of the erroneous interpretations it could encourage. The amount calculated absolutely does not mean that converting one hectare of major crop to organic farming would help the community save or earn that amount.

• Possible redefinitions of performance in case the scope of organic farming is changed

The externality differentials between organic and conventional farming depend on the practices of each system, which are likely to evolve:

- In conventional farming, with regulated restrictions in terms of the synthetic inputs authorised and the conditions of their use, or with new norms on the conditions of livestock rearing for instance, and under the desired effects of several action plans: soil winter cover requirement imposed by the 'Nitrates' Directive, planned reductions in pesticide use (EcoPhyto Plan) and antibiotic use (EcoAntibio Plan).
- In organic farming, with the conversion of farms focused more on respecting the requirements and less on the 'principles' of organic farming, and thus not making many changes to their specialised systems of production (farms without livestock, with less diversified crop rotations, planted in major crop zones which lack much ecological infrastructure).

More globally, the level of externalities is susceptible to evolve with a **change in the scope of organic farming**, which could go from 5% currently to, for instance, 20% of AA in France. An evolution of this kind would influence the impacts of organic farming and could necessitate redefining its performance. The meaning of certain evolutions is also up for debate: for instance, the effects on pest populations could increase because of decreased insecticide use, or on the other hand could be reduced because of more global and efficient biological regulation. A change in the scope of organic farming would also affect the technical and economic operations of farms and their insertion in the processing chain. We might see a '**conventionalisation**' of organic farming, as has been pointed out by some authors (closing the gap between the norms and practices of conventional farming) and which has been cause for debate. Some believe that organic farming would lose a certain consistency in its principles (and the support of 'historic' consumers); others that it is a condition of the development of organic farming and it will make its products much more accessible (increase in the volume of available products and lowered prices).

Lessons learned from this study

The summary table **highlights the numerous favourable effects of organic farming, for nearly all the externalities studied. However, the level of these benefits is not always easy to establish, and the economic costs are often missing.**

• Proven fewer negatives externalities in organic versus conventional farming

The literature agrees that there are **fewer negative externalities** in organic farming compared with conventional farming: the most significant ones are tied to the ban on synthetic pesticides and, to a lesser extent, the ban on synthetic nitrogen fertilisers (organic fertilisers can also cause pollution), but also to the reduction of antibiotics used, and additives authorised.

The effects that have been quantified the best are those related to **the pollution of water resources** used to produce drinking water, the cost to society of which is real and high. It has been demonstrated that preventative measures to reduce pollution at the source are much less expensive than measures taken to treat the water later, which France is more likely to do. However, only a fairly significant conversion to organic farming near water catchment areas would allow communities to benefit from savings in terms of water treatment.

For **biodiversity**, it has been proven that the non-use of synthetic pesticides generates fewer negative impacts on animals. In the case of birds, even if the reduction of specialist species in agricultural environments is not solely tied to the use of synthetic pesticides (habitat loss is an especially big factor), a part of this reduction can still be attributed to these pesticides. Same for bees, whose population decline comes from a combination of stresses: chemical (pesticides), disease and food.

As for **health**, because organic farming uses fewer pesticides in plant production and fewer antibiotics in livestock farming, **it reduces the risks posed to human health by pesticide residue exposure through food and the development of antibiotic resistant bacteria.** The **challenges facing society in terms of health are critical.** The benefits of fewer acute pesticide intoxications are fairly simple to calculate. The effects of chronic synthetic pesticide exposure are becoming better and better known and recognised, but they have still not been quantified. Concerning antibiotic resistance – an important issue that justifies putting into place the EcoAntibio Plan for livestock – while the benefit of organic farming is evident because of the limitation of antibiotic use that it imposes, it remains difficult to quantify.
In addition, organic food is likely to have a lower concentration of cadmium (a heavy metal that tends to accumulate in living organisms and ecosystems).

• Increased positive externalities with organic farming versus conventional farming, but the exact amounts are difficult to quantify

The increase in **environmental** amenities has to do with **regulation services** and affects the water cycle and erosion, the climate (GHG emissions and soil carbon sequestration) and populations of pests and pollinators. As far as services tied to bioregulation and pollination are concerned, organic farming has certain advantages because the biodiversity involved is less affected by the use of synthetic pesticides. For soil, the level of carbon storage seems to be higher in organic farming, according to numerous studies, but it is difficult to identify the potential for additional carbon storage that converting to organic farming would allow. For the practices associated with soil management (regular OM deposits, portion of legumes, more ground cover, importance given to permanent grassland and ecological infrastructure, etc.), these practices are not systematic and vary from farm to farm, even though many of the studies show that they are used more in organic farming than in conventional farming.

As for the **consumption of organic food**, differences in the concentration of certain beneficial components (e.g. antioxidants, omega-3) between organic and conventional food products have been identified, but it is not currently possible to deduce a specific effect of these differences on human health. Long-term studies which directly analyse the health effects of organic food preferences are rare. The BioNutrinet cohort did allow us to show that regular consumers of organic food have fewer problems with obesity and related diseases, but their **food habits and behaviours or lifestyles are also healthier** (systemic change).

As for the **social and socio-economic benefits, on the scale of farms**, statistical studies have **demonstrated that more jobs are created in organic farming than in conventional farming**. Beyond that, evaluating the impact on employment from a global perspective would have necessitated taking into account the entirety of the agri-food processing chain, as well as the industries where there could be a domino effect (farm supply companies, tourism, etc.). As for the more qualitative impacts (proximity between consumers and producers, respect of animal welfare, etc.), it is difficult to assign an economic value to them. Finally, one positive externality that is often ignored, but is very important, is the **information externality** that organic farming provides, by producing references for designing systems that use fewer inputs (organic farming as a prototype for sustainable agriculture).

• Externality differentials where organic farming is not better than conventional farming, to be discussed in more global reports

Because of lower yields, converting from conventional to organic farming assumes, in order to produce the same quantity of food, an increase in crop surfaces. This extension would be at the expense of ecosystems that are potentially rich in biodiversity and/or stored carbon. When we establish LCA reports, the advantages of organic farming due to its lower use of inputs are generally cancelled out by the lower crop yields, long breeding periods and lower individual animal productivity in organic farming when calculations are done per unit of good produced (but not by hectare). All elements of the report should be taken into account simultaneously (in particular the link with the impacts of pollution by chemical products). We should also note that changes in soil use do not depend on farming practices: the question requires a global evaluation including in particular non-food uses of agricultural products, food waste and feeding practices (in particular the role of animal products).

I – Areas of work/research to improve our understanding of organic systems

This study highlights the necessity of improving our tools of observation and acquisitions of organic farming references, especially by allowing for an analysis of the practices employed. For all the effects associated with practices (crop techniques, cropping plans, farm land management, marketing choices, etc.) that are not imposed by the requirements of organic farming, it will be necessary to gather important data and references on the practices (diversity, changes) and their impacts, which can vary according to the environment (e.g. more or less sensitive) and the conditions under which the amenities are enjoyed. More globally, several areas could be explored:

- *The connection between existing data, which remain dispersed and difficult to access.* It would first be necessary to obtain descriptions of the content in the databases held by Agence Bio (the French agency for the development and promotion of organic farming), by other organisations (MSA – the French farmers' mutual fund –, SSP – the French office of statistics and forecasting –, ODR – INRA's rural development observatory –, etc.) and by *different networks of reference acquisition* (including *Instituts techniques* – technical institutions, DEPHY farms network from the Ecophyto French Plan, experimental research schemes, R&D, farming networks, agricultural training, etc.).

- The *improvement of existing tools of observation and acquisition of references, while integrating criteria that will allow us to have more in-depth analysis of practices, their diversity and the* level of services provided, *which could take the form of an* Organic farming practices observatory.

- The establishment of *long-term, multi-criteria evaluations, which would allow for an analysis of the variability of results (yields for instance) and their (eventual) stabilisation over time.*

- *Making the links between agro-ecological practices and processes more explicit. The EFESE-EA[6] mechanism could be used in order to differentiate different types of practices, systems and modes of production. This work would allow for a more precise measure of the value of ecosystem services provided according to the state of the ecosystem and how it is managed.*

- *An 'over-representation' of organic farming in statistical databases such as FADN (the representation of the current weight of organic farming – 5% of French AA – translates to a sample size of organic farms that is too small to analyse their economic performance).*

- *Establishing scenarios in order to conceive of the conditions of a development towards organic farming and the consequences of changing the scale of organic farming.*

Economic figures pulled from the literature for the externalities produced by organic farming

This study attempted to evaluate the different costs avoided and expected benefits identified in the literature in terms of one hectare of major French crop. These amounts allowed us to identify orders of magnitude (sometimes established in other contexts and at other times). The results show uncertainties and knowledge gaps. The elements that are easiest to assign numbers to are the evaluations of lower levels of pollution from synthetic pesticides. Among the main elements, we can highlight the following:

- The evaluations of the cost of lower water pollution levels give amounts from €20-46/hectare in areas with major crops (not including catchment areas). In catchment areas, the issues at stake are different, and the amounts are estimated at €49-309[7]/hectare (depending on the method of calculating perimeters, catchment areas represent between 6-22% of French AA).
- Estimates of the effect of pesticides on animals (with hypotheses as to the value attributed to the lives of birds and fish), based on the Bourguet & Guillemaud review (using the United States in the 1990s) gives an amount of €43-78/hectare, but the authors pointed out that these amounts cannot be extrapolated to France today.
- For the value of the entire pollination service, some authors have proposed worldwide estimates. We have arbitrarily 'assigned' them to one hectare of major French crop (€3.50-48.00/hectare), which is a theoretical exercise (major French crops have a low dependency on pollination). To determine the benefit of organic farming over conventional farming, it would be necessary to calculate an allocation ratio of additional bee deaths attributed to pesticides, for which we do not yet have data (due to interconnection between factors).
- For jobs, on the scale of the farm, if we calculate the job differentials against the average cost to society of an unemployed worker, the amounts vary between €10-37/hectare. Beyond the farm level, it would be necessary to study the entirety of jobs created and lost during the expansion of organic farming.
- As for the health effects of pesticides, while some reports (INSERM 2013, ANSES 2016) highlight the positive associations between professional farms and a certain number of diseases, it is difficult to establish an economic cost. Elements from the literature allow us to indicate estimates which are the highest among the diverse externalities studied, but the uncertainties are also the highest when it comes to the underlying hypotheses (percentage of cancers attributable to pesticides and, for other diseases, the methodological choice of using VSL, etc.) in order to propose any fixed amounts. We can nevertheless highlight the fact that numerous studies and being developed and that causal links have been established. Thus, Parkinson's disease and malignant non-Hodgkin lymphoma have been recognised as occupational diseases tied to pesticide exposure (in 2012 and 2015, respectively).

Finally, we have been able to indicate, in the general summary table, **all the facets for which the results show organic farming to be beneficial, without us having been able to attribute economic costs to them (lower contribution of antibiotic resistance, animal welfare, etc.).**

While for certain issues (jobs for instance), the acquisition of complementary data would allow us to better affix numbers to the externality, for others the methodological difficulties seem impossible to overcome. The study also demonstrates the weight of certain parameters, especially VSL[8] when deaths need to be considered: while this value makes sense in terms of the effort that society is ready to give in order to reduce the risk of death, it would be a hasty interpretation to assimilate this to a real societal cost.

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[6] *EFESE-EA (Evaluation française des écosystèmes et des services écosystémiques – French evaluation of ecosystems and ecosystem services) is an operation led by the MEEM (Ministère de l'Environnement, de l'Energie, et de la Mer – French Ministry for the Environment, Energy and Sea). INRA's DEPE mission works within the MEEM to evaluate services provided by one of the six ecosystems being studied (the farm ecosystem).*

[7] *Larroque M.M., 2010, Rémunération des services environnementaux rendus par l'agriculture biologique, Mémoire d'ingénieur Agroparistech, Conseil Régional d'Ile de France-INRA.*

[8] Value of a Statistical Life

Some authors believe that the usefulness of these **monetary evaluations lies more in the societal awareness they can incite than in their calculation of precise economic figures**.
One study on PESs and CAP (cited above) is reassuring to our conclusions that it is difficult to establish the cost of remunerating practices based on the value attributed to services. Indeed, these authors indicate that uncertainty remains and that it is "*tied in particular to the complexity and to the lack of data concerning the impacts of farming practices of ecosystem services, as well as the interdependence of services. This uncertainty is currently an obstacle, but […] economic evaluation* [can be used] *for the objective of political orientation, to prioritise the actions to put into place in the framework of the AEMS.*"

This study has demonstrated the numerous benefits of organic farming that would justify financial support based on the proven advantages of organic farming. However, the economic costs are more difficult to produce. The work that needs to be continued or started on the theme of evaluating and quantifying the externalities of organic farming are consequential (see Box I), and they cannot produce operational results in the short term. However, they could contribute, beyond organic farming, to the definition of more sustainable farming and agri-food systems.

Public support mechanisms for organic farming

✱ Finding a balance between higher-priced products and government support

Organic farming typically has higher prices for its certified products. This premium relies on consumers' **willingness to pay** for products that they recognise have additional qualities, one of which is coming from a mode of production that better respects the environment. The market thus somewhat remunerates the benefits organic farming provides to society. But it has been established, by studies of public economics, that this mechanism of consumers' voluntary contribution does not allow for a high enough level of financing of public services. In order to protect the environment, this financing through the purchasing of 'good' products should thus generally be complemented by government support, which would justify having an **organic farming subsidy to be added to the market remuneration**. Furthermore, the **higher prices of organic farming products are not guaranteed**: they are dependent on supply and demand (volumes and consumers' agreement to pay).
Finally, while the higher prices remunerate the farmers' efforts, they also tend to exclude less fortunate consumers, which goes against the goals of equity that are advocated by organic farming. **When finding a balance between higher prices and government support, the question of a greater equity of access to organic products must be taken into account.**

✱ Support for organic farming and the different policy instruments

Since 2005, France has implemented a measure called "Maintien en AB" (support organic farming) which aims to support the profitability of organic farms, whose yields are lower than conventional farms. This measure supports certain specific costs such as certification and equipment. Today, the support comes to €160/hectare for major crops, but these funds are managed by region, and some French Regions no longer offer it because of a lack of budget. The level of support of a measure involving organic farming must be thought out in terms of existing measures: the **measure dedicated to organic farming must systematically be more attractive** than partial measures (for instance, a measure to reduce or eliminate pesticides), because changes are put in place more systematically.
Organic farms may also benefit from an organic tax credit.
On the other hand, an efficient agri-environmental policy must combine several policy instruments while best exploiting their advantages. Thus, in order to reduce farm pollution, economists recommend first a tax on pollutant inputs, a measure that does not cost much from an administrative point of view and which stimulates demand for alternatives to these inputs. However, there is usually resistance to the introduction of truly dissuasive taxes ('socio-technical handcuffs' with pesticide use in particular).

✱ Regulatory framework and policy of remuneration for environmental services

The idea of valorisation of services is not new, and for the last decade numerous reports have recommend doing it. In 2010, the Ile-de-France region in France submitted a proposal to the European Commission that would provide remuneration for environmental services produced by organic farming (in particular, starting with the positive effects on water quality) – thus aiming to change the perspective from that of the AEMs, which are based on compensation for lost revenue (opportunity costs). This pilot proposal was not accepted, for legal reasons related to the justification of payments. Indeed, the remuneration of services comes into conflict with competition laws, so reimbursements must be limited to "*additional costs or loss of revenue stemming from the observation by a public programme*" regarding the rights of the WTO, as taken up by CAP.
Exceptions do exist, however, when it comes to environmental protection. A report commissioned by the CEP[9] on CAP and PESs[10] mentions some room for manoeuvre which, while not using the economic costs calculated for externalities, would allow for an increase in the amount of aid, by integrating transaction costs into the calculation of opportunity costs.

✱ Balancing diverse organic farming support

In conclusion, the amount currently attributed to organic farming aid is the result of political compromise and arbitration, because the same level of organic farming support would lead to very different amounts according to the EU countries, and the difference in production costs would not make it possible to explain these discrepancies.
Finally, additional support is sometimes implemented through initiatives at the community level, by provisioning land or buildings, help in creating opportunities for community-assisted restoration, etc. We could also imagine support for organic farming coming from direct employment aid paid out by UWAs or during hiring.

[9] *The French Ministry of Agriculture, Agrifood, and Forestry's Centre for Studies and Prospectives*

[10] *Duval L., et al.., 2016. Paiements pour services environnementaux et méthodes d'évaluation économique. Enseignements pour les mesures agro-environnementales de la politique agricole commune. Etude réalisée pour le ministère en charge de l'agriculture. Rapport final.*

Bibliographical references and experts consulted

Numerous studies were already dedicated to a multi-criteria evaluation of organic systems of production. In 2011, the *Réseau Mixte technologique Développement de l'Agriculture Biologique* (joint technological network for the development of organic farming – RMT DévAB) published a study on organic farming and the environment[11]. In 2013, at the request of the CGSP (*Commissariat général à la stratégie et à la prospective*, France's general commission for strategy and planning), INRA conducted a summary of the environmental, social and economic performances of organic farming[12]. Our study relied on the information established in this 2013 report, which benefited from the contributions of numerous researchers. This bibliographic summary was updated by more recent publications, and supplemented some of the points that had not been developed (for instance the negative externalities of conventional farming related to its use of synthetic inputs, especially pesticides).

Complementary references were found in international bibliographic databases and by consulting scientific experts from different domains. All 280 bibliographic references were used to create the report. However, here we only cite the summaries and reports that were the most formative for this study. Twenty-some experts were contacted individually, in order to receive updates on particular subjects. Most of these experts were public research scientists (from INRA, IRSTEA, CNRS or universities), with a few experts from agricultural technical institutes and other institutions. We also established connections with the studies being carried out within the EcoServ meta-programme[13]. With the help of INRA's 'farming' science branch and its Expertise, Planning and Studies Directorate, a seminar, focused mainly on methodology, was organised for researchers. The preliminary results of the study were presented at CIAB, INRA's Internal Organic Farming Committee, to discuss the different themes covered, and the work was submitted to CSAB (*Conseil Scientifique de l'AB* – organic farming scientific committee) to obtain input from its members.

This study relied primarily on scientific bibliographic summaries, including some meta-analyses[14], which means that it compiles studies from agronomists, ecologists, zoological technicians, epidemiologists, toxicologists, economists, sociologists, etc. We also included analytic studies and systemic studies. It is important to highlight the very interdisciplinary nature of this work, given the vast array of themes covered, as well as the different scales (publications on processes used for a few square meters to evaluations on a worldwide scale). The study also integrated more institutional sources: reports produced by the *Commissariat general au développement durable* (CGDD, France's General Commission for Sustainable Development)[15], the *Conseil général de l'alimentation, de l'agriculture et des espaces ruraux* (CGAAER, the French advisory board for food, agriculture and rural spaces), water agencies, the health agencies ANSES and ADEME, as well as European institutions (EFSA) and international institutions (WHO). We took into account both French and international references. However, the weight of the context (country, time period) in the values observed or attributed required particular attention, in terms of the pertinence of transferring data from one context to another or extrapolating.

To learn more

• Sautereau N., Benoit M., 2016. *Quantification et chiffrage économique des externalités de l'agriculture biologique*. Study report, ITAB, 136 p.
The report as well as this summary are available on ITAB's website (www.itab.asso.fr), INRA's website (www.inra.fr/comite_agriculture_biologique) and the Ministry of Agriculture, Agrifood, and Forestry's website

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[11] Fleury P. (coord.), 2011. *Agriculture biologique et environnement : des enjeux convergents*. Éducagri éditions / ACTA Publications, 270 p.

[12] Guyomard H. (under the direction of), 2013. *Vers des agricultures à hautes performances*. Volume 1. Analyse des performances de l'agriculture biologique. INRA. 368 p. (http://institut.inra.fr/Missions/Eclairer-les-decisions/Etudes/Tous-les-dossiers/L-agriculture-biologique-en-debat)

[13] This meta-programme carried out by INRA focused on the management of ecosystem services provided by agro-ecosystems, and their evaluation.

[14] Statistical analysis of the results of a series of independent studies on the same topic, with the goal of coming to a global conclusion thanks to an increased number of cases studied.

[15] CGDD, 2015. *Les pollutions par les engrais azotés et les produits phytosanitaires : coûts et solutions*. Etudes & documents, n° 136, 30 p.