Research and organic farming in Europe

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Philippe Baret, Pascal Marcq, Carolin Mayer
Earth & Life Institute, Université catholique de Louvain, Belgium

Susanne Padel
Organic Research Centre, UK

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Table of contents

List of figures v

List of tables v

List of acronyms vi

Executive summary vii

Objectives and content of the report 1

1. Investment in organic farming research and agricultural biotechnology research 3
1.1. Agricultural research and innovation in the European Union 3
1.2. France 6
1.3. Belgium 8
1.4. Germany 9
1.5. The Netherlands 12
1.6. Synthesis for the four countries 13

2. Specific National Programs for Organic Farming 15

3. Assessing Organic Farming in comparison to Intensive Conventional Farming 19
3.1. Introduction 19
3.2. Environmental Impacts 21
3.3. Food Productivity Impacts 24
3.4. Socio-Economic Impacts 30
3.5. Cross-cutting issues 34

4. Case Studies 39
4.1. CORE Organic 39
4.2. ICROFS 42
4.3. Hessian State Domain Frankenhausen (Germany) 44
4.4. The low-input crop-livestock farming system in Mirecourt (France) 47
4.5. Elements of success of organic farming research initiatives 51

Conclusions 53

Acknowledgements 55

Annex 65

LIST OF FIGURES

Figure 1 : Share of organic farming and biotechnologies in the agricultural research budget of FP5, FP6 and FP7 research programs ... 6
Figure 2: Germany: Public investment in agricultural R&D (Mio EUR) ... 11
Figure 3 : Examples of national research programs for organic farming 16
Figure 4 : General framework of organic farming and sustainability ... 19
Figure 5 : Comparison of impacts of organic and conventional farming ... 22
Figure 6 : Six selected differences between conventional and organic farming for cereals, fruits and vegetables from Baransky study ... 27
Figure 7 : Findings from a survey of 253 organic and 1803 conventional samples in Baden-Württemberg (Germany) ... 27
Figure 8 : Frequency of occurrence of relative yields of organic/conventional farming (10% intervals) ... 30
Figure 9 : Comparison of financial performances of organic and conventional farms based on a meta-analysis of 44 comparisons across the world ... 32
Figure 10 : Stages in the CORE Organic initiative ... 40
Figure 11 : Steps in the ICROFS initiative ... 43
Figure 12 : Hessian state Domain Frankenhausen - Area of the different field crops (in ha) in 2012 ... 45
Figure 13 : A schematic history of the Domain Frankenhausen ... 46
Figure 14 : Key elements in the success of the experimental INRA station in Mirecourt (France) ... 49

LIST OF TABLES

Table 1: France: Budget appropriations for agricultural research and estimates for expenditure in organic research (Mio€) ... 8
Table 2: Belgium: Budget appropriations in agricultural research and estimates for expenditure in organic research (Mio€) ... 9
Table 3: Germany: Expenses of Bund and Laender in agricultural sciences and estimates for expenditures in organic research (Mio€) ... 10
Table 4: Germany: Expenses in biotechnological and organic R&D listed in fisaonline.de (Mio EUR) ... 11
Table 5 : Netherlands: Budget appropriations in agricultural sciences and estimates for expenditure in organic research (Mio €) ... 12
Table 6: Examples of national research programs for organic farming in the European Union ... 17
Table 7 : Peer-reviewed literature on the environmental impacts ... 23
Table 8 : Peer-reviewed literature of the impacts on the quality and quantity of food ... 26
Table 9: Peer-reviewed literature on the socio-economic impacts ... 31
Table 10: Mirecourt annual financial Results (on average from 2005 to 2013) in Euros ... 50
Table 11: Main dimensions of micro-level initiatives ... 51

LIST OF ACRONYMS

ASTER	Agro-Systems territories and Resources
BELSPO	Federal Public Planning Service Science Policy (Belgium)
BIOTECH	Agricultural Biotechnology
CASDAR	Organic strand in national program for rural and agricultural development
CORDIS	Community Research and Development Information Service
CRA-W	Centre wallon de Recherche Agronomiques (Belgium)
DARCOF	Danish Research Centre for Organic Farming
EIP AGRI	The agricultural European Innovation Partnership
FADN	Farmn Accountancy Data Network
FIBL	Research Institute of Organic Agriculture (Germany)
Fisa-Online	Information System for Agriculture and Food Research
GBAORD	Government Budget Appropriations for R&D
GDP	Gross Domestic Product
GOP	Gross Operating Profit
GVA	Gross Value Added
ICROFS	International Centre for Research in Organic Food Systems
IFOAM	nternational Federation of Organic Agriculture Movements
ILVO	Institute for Agricultural and Fisheries Research (Belgium)
IMPRESA	The Impact of Research on EU Agriculture
INRA	National Institue for Agronomic Research (France)
IRSTEA	National Institute of Science and Technology for Environment and Agriculture (France)
LBI	Louis Bolk Institute
LCA	Life cycle analysis
MIPAA	Organic strand in multiannual program of Ministry of Agriculture
NABS	Nomenclature for the Analysis and comparison of Scientific programs and Budget
ORG	Organic Farming
Organic RDD	Organic Research Development and Demonstration
PFEIL	Program for Research and Development at the Ministry of Agriculture (Austria)
QLIF	QualityLowInputFood
RDP	Rural Development Programs
SLU	Swedish University of Agricultural Science
STIS	Scientific and Technical Information Service (Belgium)
VFL	Knowledge Centre for Agriculture
WUR	Wageningen University Research centre

EXECUTIVE SUMMARY

Organic farming research: poor funding for a sustainable food system option

Executive summary of the research and organic farming report by teams of the Earth & Life Institute (Université catholique de Louvain, Belgium) and the Organic Research Centre (UK), available on October 22, 2015

Research is a key element in the exploration of new pathways in farming systems. Organic farming relies on specific methods and strict regulation. By design, organic farming harmonizes the environmental and productive dimensions of farming systems.

1. Funding of organic farming research is low both at EU and national levels

At the EU and national levels, statistics on the financial support to the different models of agriculture are neither precise nor comprehensive. This lack of transparency impairs any comparative analysis.

In order to assess the investment in research into organic farming, data has been collected at the EU level (Cordis database) and at a national level for four countries: France, Belgium, Germany and the Netherlands. The analysis of the CORDIS database showed a serious imbalance between agricultural biotechnologies and organic/low input farming. The total funding for FP5, FP6 and FP7 research programs amounted respectively to 14, 18 and 50 billions Euros. The share of research in agriculture is between 3 and 4 % of this total budget. Between 1998 and 2013, the amount spent on biotechnology increases from 20 to 70 % of the total agricultural research budget. In comparison, funding for research into organic farming does not exceed 12 %; spending was highest in FP6 and has declined during the most recent years.

In the four countries studied in more detail, an estimate of public and private expenses on biotechnology is not available, making a comparative assessment of the investment in organic farming and biotechnology impossible. Estimates of the share of public agricultural research budgets allocated to organic farming point to an overall investment of less than 5 %. The Netherlands and Belgium devote respectively 3 and 5 % of the total agricultural research budget to organic farming. France and Germany lay behind with a share of only 1 % for organic farming research but data for France are only based on additional costs and do not take into account the salaries of INRA and other research institutions implied in organic farming research projects. Funding of research into organic farming remains the exception both at EU and national levels.

2. Several countries have specific programs for organic farming research

In different countries, specific programs are devoted to organic farming. The total amounts of money are limited but in most cases the programs are multi-annual and help to build long-term expertise for the sector. Countries with long-term programs include Denmark, France, Germany and Sweden.

3. Organic farming provides better answers to sustainability challenges than conventional farming.

Funding of organic farming research is important because organic farming represents an efficient pathway to sustainable agriculture.

A comparison of organic and conventional farming for the different dimensions of sustainability has been compiled based on scientific publications. This assessment does not claim to be fully comprehensive in all areas but it may serve to illustrate the potential of organic farming.

Environmental issues

Organic farming clearly performs better than conventional farming in the case of biodiversity, both in terms of number of species and diversity of habitats and landscapes.

The conservation of soil fertility and system stability is helped by higher organic matter contents and biological activity in the soil of organic farms. A review paper found that the median soil organic matter was 7% higher in organic farming than in conventional farming, and this is directly linked with the use of organic fertilizers (manure, compost and the use of fertility building/green manure crops) in organic farming. Organic farming also has a high erosion control potential. In top soils under organic management, the soil organic carbon concentrations and stocks of C per ha are higher.

The absence of synthetic pesticides has an obviously positive impact on ground and surface water pollution and organic farming is the first choice agricultural system for water reclamation areas.

Nitrate leaching and greenhouse gas emissions per ha are up to 60 % lower in organic farming. However, when assessed by unit of product, impacts of both organic and conventional farming on greenhouse gas emissions are very similar.

Quality and quantity of food

In terms of quality of food, results for mineral contents, proteins, vitamins are either better or equivalent in organic farming depending on studies and type of production. Organic farming products are richer in healthy fatty acids and phenols.

By design, contamination by pesticide residues, nitrates and cadmium is lower in organic products. The difference is substantial for pesticide residues. The positive impact of the absence of synthetic pesticides in organic farming is both direct and indirect. A direct beneficial effect occurs on the health of the consumer through the reduction of the ingestion of toxic substances such as pesticide residues or cadmium (assigned a group 1-human carcinogen by the International Agency for Research on Cancer) and there also is an indirect effect on the citizens by a decrease of harmful substances in ground and surface water.

The health status of animals bred in organic farming is better than in conventional livestock systems: less metabolic disorders, a lower prevalence of lameness and fewer respiratory problems in pigs. The enterprises participating in organic farming are more likely to comply with welfare legislation and animals in organic farms have more living space. The use of chemically synthesized allopathic veterinary medicinal products or antibiotics for preventive treatments is prohibited in organic farming, it being at the forefront of a postantibiotic era recommended by the WHO to avoid the significant impacts of an increase in antibiotic resistance.

Most of the comparisons between organic farming and conventional farming are based on yield as the main indicator. The average organic yield is estimated at about 75 to 80 % of conventional with variations according to regional conditions and crop types. However, the purpose of organic farming is the optimisation of production within the limits of natural constraints and not its maximisation by the use of external inputs. When other dimensions of productivity such as cost or externalities are considered the picture becomes more complex.

Farm profitability and labour

A recent comparative study across the world shows that the profitability of organic farming is 13 % higher on average than conventional farming. This is explained by a compensation of lower yield by lower input costs and higher premiums.

Considering the benefits for health and the environment of organic farming, it is noteworthy that raising premiums by just 7% ensures an equivalent income to organic and conventional farmers.

Labour use is higher on organic than non-organic farms. More labour is needed for the recycling of nutrients (e.g. composting), more diverse crop rotations with legumes for biological nitrogen fixation (such as green manures or leys), greater diversity of crops and enterprises including a higher share of more labour intensive crops (e.g. vegetables, potatoes) that require hand weeding. Organic farms use less family labour and more paid labour. More research is needed concerning questions such as: labour use by farm-type and influence of particular crops or activities, labour productivity (i.e. financial output per worker), breakdown of labour type (e.g. seasonal versus permanent) by farm type, gender of employees, analysis of processing and direct sales activities separate from production, salaries and quality of work provided (e.g. skilled versus unskilled labour).

Cross-cutting issues

In the debate between organic farming and conventional farming, the lower level of yield in organic farming is often put forward as a drawback. In fact, the productivity of food systems has exceeded the needs of the world population since the 1960s. If more than 800 millions people are still hungry it is a matter of poverty and inequity and not a production related issue. A better balance between environmental and social dimensions (including human health) vs. quantity of food is possible and would favour organic farming. Moreover, as the productivity of conventional farming systems is reaching a limit despite huge investment in research and the intensive use of fossil energy and non-renewable inputs, the potential of the productivity of organic farming has still to be explored. More research into organic farming will probably increase productivity through the development of new technological and organizational practices.

Competitiveness is often put forward in favour of maintaining conventional farming systems. This strategy is inappropriate for two reasons. First, competitiveness is exclusively defined in economic terms and doesn't include other relevant dimensions such as environmental and social impacts. Second, competitiveness is by definition a distinction between winners and losers and the comparative advantages of European agriculture in a competition between industrial farming systems are limited due to the high cost of land and labour, high level of urbanisation. In contrast, it appears promising for European farms to establish themselves as leaders in biological and social diversity with pioneering farming systems based on organic and agroecological principles.

4. Inspiring case studies

By design, organic farming is multifunctional and based on an ecosystem approach rather than the use of artificial inputs that boost production.

This is also reflected in the organization of knowledge exchanges. Most organic farmers are in favour of a participatory vision of research, with active exchange of experience between scientists and practitioners, a collective assessment of problems and a co-design of solutions. Programs such as the European Innovation Partnership are in line with this research and innovation process. Experience in organic farming shows the potential of such an approach.

Case studies at meso and micro levels illustrate new ways of producing knowledge in a participatory way.

Coordination of organic research programs favours partnerships and long-term strategies

CORE Organic is a transnational partnership of 24 countries collaborating to enhance the quality, relevance and utilisation of resources in European research in organic food and farming. The total budget of three stages (from 2007 to 2015) exceeds 35 million € comprising of national contributions of partner countries and some budgets from the EU. This budget is allocated to projects after a common call and selection. All research conducted under CORE is documented in Organic Eprints, an open source archive for research in organic farming (www.orgprints.org).

ICROFS is a Danish centre without walls with the aim to make "the principles of organic agriculture become a global reference for sustainability in agriculture and food systems due to evidence based on research and adaptive management." ICROFS coordinates the ERAnet CORE Organic. The development strategy of ICROFS is defined by farmers, researchers, consumers and politicians. A total of 63 million € has been spent since the centre started and the share of organic farming in Denmark has increased from 1.8 % of land area in 1996 to 6.7 % in 2010).

Experimental farms in Germany and France demonstrate the feasibility of organic farming

For more than ten years, the experiences of conversion to organic farming of the Hessian State Domain Frankenhausen (Germany) and the farm at Mirecourt (North-East France) are particularly successful examples of new research design and project governance at the farm level.

The Hessian State Domain Frankenhausen, an experimental farm and research project of the University of Kassel, aims to serve as a model for ecological, economic and socially sustainable management. Intense exchange between farmers and scientists via joint manufacturing and marketing guarantees the knowledge exchange between scientific findings and praxis. Amongst other things, new alternatives have been developed to increase the potential of winter peas as a harvest crop by increasing winter hardiness and endorsing their value for cultivation in organic farming. The propagation area of the winter pea has tremendously increased from 2 to 270 ha in ten years.

Each year, 800 to 1,000 people (farmers, scientists and institutional actors) visit the organic and self-sustaining crop-livestock farming system in Mirecourt that has been piloted by INRA for 10 years. Numerous interactions with researchers have demonstrated that agricultural models giving preference to autonomy and resilience, and taking into account environmental impacts can achieve profitability. Organic agriculture is redefined as a driver for socio-technical innovations and a field of opportunities rather than a set of restrictive norms.

The developing of alternative models favouring self-reliant agro-systems remains a difficult political choice in a context in which conventional agriculture is overwhelming dominant. For example, among the 50 experimental projects within INRA in France, the Mirecourt experiment is the only one which is 100% organic.

The potential of funding research into organic farming

The conclusion of this report on research into organic farming is paradoxical. On the one hand, scientific evidence points to the potential of organic farming as an alternative to conventional farming and research projects based on organic farming as a paradigm are successful. On the other hand, the funding of research into organic farming is very low both at European and national levels.

Organic farming is relevant and profitable at both the farm level and for society as a whole. Increased investment in research into organic farming will help to provide some answers to many environmental and social issues of our farming systems

OBJECTIVES AND CONTENT OF THE REPORT

Organic farming is gaining legitimacy in the media and political agenda, but is still considered as alternative in the research agenda.

Comparing the funding of research programs in agriculture, biotechnology and organic farming at the EU level and in four countries (France, Belgium, Germany and The Netherlands) will render this imbalance more visible (part 1).

Within this unfavourable context, a series of specific research initiatives should be emphasized (part 2).

The potential of organic farming in the transition towards more sustainable food systems will be demonstrated along two lines. On the one hand, a review of scientific literature across the different dimensions of sustainability demonstrates the relative efficiency of the organic farming approach to address the main issues of the XXIst century in agriculture and food systems (part 3). On the other hand, four case studies illustrate the specificities and impact of research specifically supporting organic farming (part 4)

1. INVESTMENT IN ORGANIC FARMING RESEARCH AND AGRICULTURAL BIOTECHNOLOGY RESEARCH

Sources of funding for research in agriculture and organic farming are diverse:

- EU Frameworks projects
- EU trans/international co-ordination efforts, in particular CORE organic, but also COST actions
- National programs
- National ministries/agricultural institutions doing Organic farming research (eg. INRA, Trenthorst in Germany, some Universities)
- Funding under national funding councils
- Applied research funding (e.g. variety testing by agricultural chambers)
- Industry funding
- Private foundations

The scope of the present report is limited to EU Framework projects and national projects in four countries (Germany, France, Belgium and the Netherlands) as data on the others sources of funding is incomplete. When possible, a comparison will be made with funding of research projects in biotechnology.

1.1. Agricultural research and innovation in the European Union

It is a common agreement in the EU that knowledge generation is indispensable to face future challenges in agriculture and food production to improve competitiveness while at the same time the sustainability of resources and ecosystemic services need to be guaranteed. So far, the Framework Programs have been one major instrument of the EU to support agricultural research and development. Other EU policies funding innovation in general via skill improvement, facilitation of coordination or investment in infrastructures may contribute to agricultural research and innovation (e.g. Cohesion Policy, Eurostars, LIFE+, The European Innovation Partnership).

To illustrate the development of expenditures for agricultural R&D from 2003 to 2013, the example of the European Framework Programs (FP5 – FP7) has been used here. Projects funded within these programs are easily available via the CORDIS database[1].

Extractions of this database are available via the European Union Open Data Portal CORDIS[2]. However, there are quite a few inconsistencies in the datasets as indicated in the detailed methods used (see Annex), thus the figures given here may not show the full picture.

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[1] CORDIS http://cordis.europa.eu/home_en.html

[2] CORDIS http://open-data.europa.eu/en/data

Methodological insights and availability of data

To compile the data on national investment in agricultural Research & Development, various sources had to be used since no general data basis exists. Even in the EUROSTAT database[3], data are not consistent or lacking for single countries. For the period 2003-2011, the data on intramural R&D expenditure (dataset [rd_e_gerdsc]) is less complete as the variable 'major field of science' was optional and only collected for 'higher education' and 'government' sectors (European Union, 2004, p. 6)[4]. Thus, the comparability of the results for the presented countries remains extremely limited. This study put a lot of effort into the search for significant figures for each country. Statistical services in charge of agriculture, ministries and administrations were contacted (see for example acknowledgments below), but, as already stated by the IMPRESA project ("The IMPact of RESearch on EU Agriculture"), data were very limited or not existent (Chartier et al., 2015). The sources used are given in the equivalent sections.

To guarantee comparability, we provide in the following budget appropriations or outlays, i.e. GBAORD (Government Budget Appropriations for R&D), which were the only figures available for all example countries. These are not real expenditures of governments, which may differ from the presented budget appropriations. No private expenses into research are treated in this report.

Two data bases providing quite exhaustive data have to be mentioned: the CORDIS data bank of the European Commission (Community Research and Development Information Service)[5] and the Fisa-Online Catalogue (Information System for Agriculture and Food Research)[6] of the German Federal and State Governments. Further methods applied and data limitations are shortly discussed in the corresponding sections and in the online supplement: Methods.

(Lack of) Transparency

No reporting to any authorities seems to be provided at sub-discipline level (investment into research on organic farming and on agricultural biotechnology). Though within the EUROSTAT database[7] the division of the 'major field of science' into subdivisions such as 'agricultural biotechnology' (Code: FOS404) is foreseen, member countries are not demanded to report figures in such detail. Thus, while a few figures for investment into organic agriculture are available via different organizations (e.g. FIBL)[8] or evaluation reports (Lange et al., 2006) no consistent sources could be detected for biotechnology.

Prospective

Concerning EUROSTAT regulations after 2012, the variable 'major field of science' is no longer optional but still collected only for 'higher education' and 'government' sectors. A new Commission Regulation (European union, 2012)[9] requests that the variables shall be provided every two years in each odd year (i.e. 2013). The first data are to be transmitted to EUROSTAT in June 2015 and disseminated via the EUROSTAT website in November 2015. Nevertheless, the data for more detailed fields of science (e.g. agricultural biotechnology) will probably not be available (N. Nowakowska, EUROSTAT User Support, pers. comm.).

If more detailed and consistent data is desired in future, the Commission Regulations regulating statistics on science and technology would need further adaptation.

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[3] EUROSTAT http://ec.europa.eu/eurostat/en/data/database

[4] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R0753&from=EN

[5] CORDIS http://cordis.europa.eu/

[6] FISA http://www.fisaonline.de/

[7] EUROSTAThttp://ec.europa.eu/eurostat/en/data/database

[8] FiBL http://www.FiBL.org/en/homepage.html

[9] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:299:0018:0030:EN:PDF

The total budget for FP5 (1998-2002) sums up to 13,700 Mio€ (excluding EURATOM), of which 520 Mio€ (3.8%) are said to be spent on "Sustainable agriculture, fisheries and forestry and integrated development of rural areas including mountain areas" (CORDIS)[10]. We found 909 projects dealing with agriculture in total, summing up to 523.8 Mio€ (

). Of these, 167 (100.1 Mio€) were classified as biotechnology and 20 (20.4 Mio€) as organic farming projects (see Annex).

For FP6 (2002-2007), the total budget was raised to 17,500 Mio€, of which 4.3% were grants for research projects linking scientific knowledge to public health, as regards agriculture, environment and food. We could identify 353 projects referring to agricultural issues with a total budget of 758.4 Mio€ (

). Of these, 108 were classified as biotechnology and 18 as organic farming related projects with budgets of 322.7 Mio€ and 87.6 Mio€, respectively (

).

[10] CORDIS http://cordis.europa.eu/fp5/src/budget1.htm

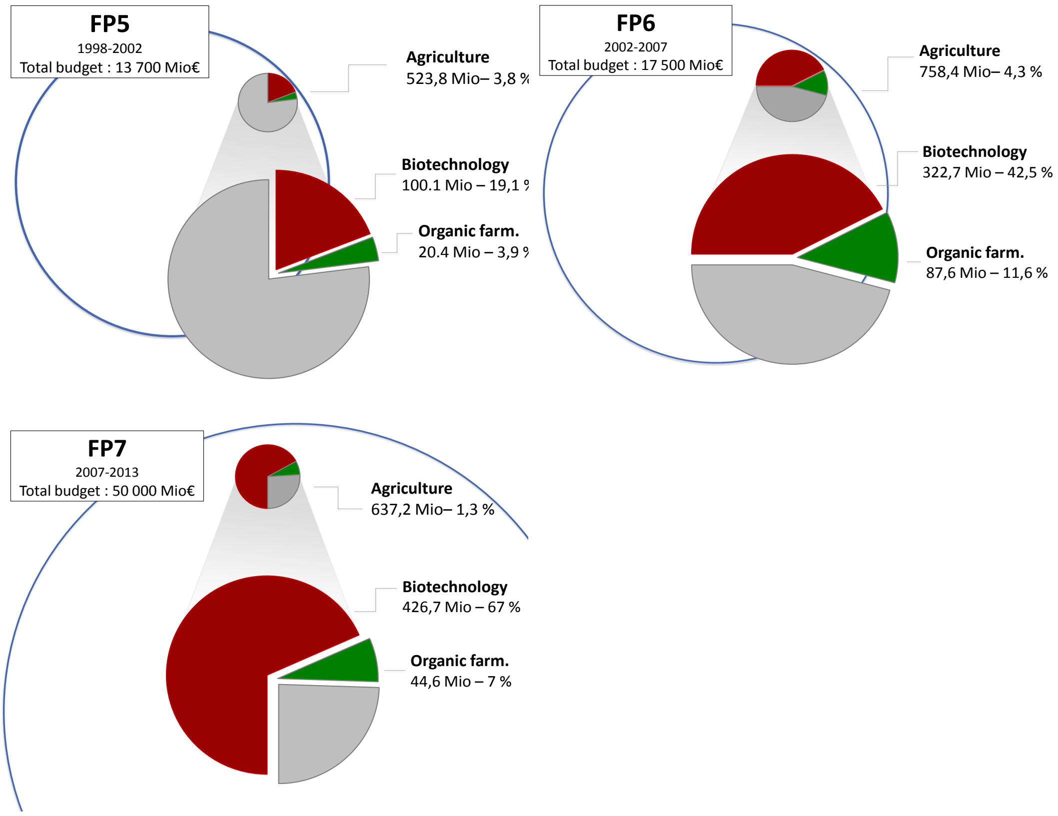


Figure 1 : Share of organic farming and biotechnologies in the agricultural research budget of FP5, FP6 and FP7 research programs

Though the total budget for FP7 (2007-2013) rose up to 50 billion€, and thus, a 63% increase compared to FP6, the share preserved for agricultural projects (now called 'knowledge based bioeconomy') diminished to 3.5%, i.e. 1,760 Mio€. From the available database for FP7, we could retrieve 367 projects for agriculture in general (starting before 2014), summing up to 637.2 Mio€ that were spend between 2007 and 2013. Of these, 247 biotechnological projects received 426.7 Mio€ and 18 organic projects received 44.6 Mio€ before 2014.

The presented data may contain deficiencies and the results have to be taken with care, nevertheless it is quite evident that the funding for agricultural biotechnology has become extremely important over the past years. Its budget share rose continuously from about 20% to almost 75% within ten years. Research on organic farming on the other hand, might be considered only marginally important within the EU with a share between 3 and 11%.

1.2. France

The agricultural sector in France is quite important, representing 1.7% of the Gross Value Added (GVA) to the Gross Domestic Product (GDP) in 2010 (European Commission, 2015a)[11].

[11] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/fr_en.pdf.

Despite agricultural research being largely performed by two national organizations, i.e. the National Institute for Agronomic Research (INRA)[12] and the National Institute of Science and Technology for Environment and Agriculture (IRSTEA)[13], documentation about precise public investment into agricultural research is not at all available (Chartier, Doghmi, and Van den Broek 2014). Nevertheless, budget appropriations (Table 1) show that the investment into agricultural research is quite high compared to other countries (Belgium for example, see below). We further collected estimates for investment into research on organic farming from two different sources: FiBL[14];(2006). France has two specific national programs for organic farming (see Section 2). No data on funding for agricultural biotechnology could be retrieved. It is noteworthy that data for France are only based on additional costs and do not take into account the salaries of INRA and other research institutions implied in organic farming research projects.

Even with the total expenditures for agricultural research being only appropriations, it is obvious that funding for studies in the organic sector is almost negligible, hardly ever exceeding 2% of the total agricultural grants.

[12] INRA http://institut.inra.en/

[13] IRSTEA http://www.irstea.fr/en/home-page

[14] Willer H (2015). Personal communication based on unpublished data on research funding status collected by FIBL, Frick.

Table 1: **France: Budget appropriations for agricultural research and estimates for expenditure in organic research (Mio€)**

Year	Total[15]	Organic[16]
2001	308	16.3
2002	331	17.8
2003	333	2.5
2004	341	1.3
2005	363	6.7
2006	221	3.1
2007	237	4.7
2008	269	4.4
2009	289	0.5
2010	312	Na
2011	368	Na
2012	288	4.3
2013	307	4.3

1.3. Belgium

Compared to France, the agricultural sector is less important, adding only 0.7% of the total GVA to the GDP in 2010 (European Commission, 2015b)[17]. This is reflected in the governmental budget appropriations for R&D in agriculture, being almost ten times lower than in France.

No official data for investment into agricultural biotechnology or organic research is available for Belgium[18] As in France, only very marginal budgets nourish the research into organic farming. The information on funding of research in the organic sector is based on personal communication from Flanders and Wallonia. In 2014, the newly established 'Plan global Agriculture biologique' in Wallonia was developed and for the period until 2020 1 Mio€ has been mobilised to support research in the organic sector[19].

More explicit data on agricultural research funding could be collected for Flanders, for the period from 2008 to 2013/2014. While the total funding for agricultural research has increased during the past years[20], it seems that the investment into the biotechnological sector decreased from almost 35% in 2009 to 16% in 2013. But the data on biotechnology might not be complete, since they were taken from one institute (Agency for Innovation by Science and

[15] EUROSTAT France's Government Budget Appropriations or outlays for R&D https://stats.oecd.org/Index.aspx?DataSetCode=GBAORD_NABS2007

[16] Lange et al., 2006

[17] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/be_en.pdf

[18] Monard, E., BELSPO/STIS, personal communication

[19] Stilmant. D., CRA, personal communication.

CRA-W http://www.cra.wallonie.be/fr/52/Brochures-et-dossiers/714).

[20] Viaene, P., BELSPO/STIS, Departement Economie, Wetenschap & Innovatie, Personal Communication

Technology[21]. The figures for organic funding given by the Department of agriculture and fisheries[22] are also approximations. Since 2008, all the expenditures of the Flemish Government for organic research funding (approximately 0.3 to 0.4 Mio €) come under the umbrella of the 'Strategic Action Plan for Organic Food and Farming in Flanders'. Nevertheless, compared to biotechnologies and agriculture in total, the funding available for organic research is again negligible, remaining at about 2% or the total investment into agricultural research in Flanders.

Table 2: **Belgium: Budget appropriations in agricultural research and estimates for expenditure in organic research (Mio€)**

Year	Agriculture in total[23]	Organic agriculture[24]
2003	35.3	0.51
2004	32.6	0.52
2005	23.8	0.52
2006	25.0	0.51
2007	29.3	0.52
2008	30.1	0.58
2009	31.7	0.79
2010	32.2	1.06
2011	37.4	1.68
2012	39.5	1.87
2013	32.3	1.71
2014	33.5	2.09

1.4. Germany

As for Belgium, the agricultural sector plays a minor role in the economy with a share of only 0.9% of the total Gross Value adding to the GDP in 2010 (European Commission, 2015c)[25].

[21] IWT, Agency for Innovation by Science and technology http://www.iwt.be/publicaties/Jaarverslag

[22] De Cock, L., ILVO, personnal communication.

[23] (Except for 2014) EUROSTAT http://ec.europa.eu/eurostat/data/database (

Total GBAORD by NABS 2007 socio-economic objectives (gba_nabsfin07)

Total GBAORD by NABS 1992 socio-economic objectives (gba_nabsfin92)

(For 2014 only) BELSPO/STIS http://www.stis.belspo.be/en/statisticsCredits.asp#part3

Government budget appropriations or outlays for R&D (GBAORD)" - Overview 1989-2014 per socioeconomic objective (current prices); All the Belgian authorities

[24] De Cock, L., ILVO, Personal communication.

ILVO, Institute for Agricultural and Fisheries Research http://www.ilvo.vlaanderen.be/language/en-US/EN/Home

Stilmant, D., CRA, Personal communication.

Nevertheless, governmental budget appropriations for R&D in the agricultural sector are quite high and rather comparable to France (Table 3). Since 2007, the budget has even increased and doubled between 2001 and 2013. As for other countries, no data on funding for agricultural biotechnology were available on a comparable national level. Again, the funding given for research on organic farming remains very low, despite the large Federal funding program for organic farming (BöL) that had already started in 2001 (see Section 4).

More detailed data about agricultural and nutrient science financed with public means can be found in the online databank Fisaonline.de. This databank was initiated at the Agriculture Ministers Conference in 2006. Its objectives are to improve transparency and thus optimize the coordination of publicly funded research.

All tables relevant for agriculture (excluding sea and fisheries and forestry) were considered for assemblage of the following data. These contained over 15,000 projects (including duplicates), 46% including monetary information. For detailed methods for filtering and cleaning the data, see Annex.

Table 3: **Germany: Expenses of Bund and Laender in agricultural sciences and estimates for expenditures in organic research (Mio€)**

Year	Total[26]	Organic[27]
2001	340.6	1.8
2002	333.7	7.4
2003	333.8	14.7
2004	332.3	6.5
2005	310.2	8.5
2006	397.2	8.1
2007	489.2	6.0
2008	559.8	6.8
2009	662.9	7.1
2010	770.7	7.1
2011	743.4	0.7
2012	691.2	8.9
2013	719.1	8.0

Though the web-site was only proposed in 2006, a few projects are included that had already started before 2004. From 2003 to 2013, figures are given for 3,617 agricultural projects. Of these, 911 were classified as biotechnology projects and 500 as organic. The funding for these projects comes from different national and regional ministries, the biggest money source (2/3)

[25] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/de_en.pdf

[26] EUROSTAT : http://ec.europa.eu/eurostat/data/database:

Total GBAORD by NABS 2007 socio-economic objectives (gba_nabsfin07)

Total GBAORD by NABS 1992 socio-economic objectives (gba_nabsfin92)

http://www.datenportal.bmbf.de/portal/1.2.3

[27] Willer (2015) Personal communication http://www.fisaonline.de/

being the Federal Ministry of Agriculture[28]. Comparing the total investment into agricultural research indicates that between 20 and 30% of the national funding is reported on fisaonline.de.

Table 4: **Germany: Expenses in biotechnological and organic R&D listed in fisaonline.de (Mio EUR)**[29]

Year	Total	% of national investment as given in Table 4	Biotech	Organic	% of total investment Biotech	% of total investment Organic
2004	34.3	10.3	14.4	6.5	41.8	16.1
2005	64.5	20.8	28.8	8.5	44.6	9.9
2006	91.6	23.1	39.8	8.1	43.4	11.6
2007	123.8	25.3	50.5	6.0	40.8	9.0
2008	171.8	30.7	60.6	6.8	35.3	7.4
2009	207.6	31.3	70.0	7.1	33.7	5.3
2010	206.8	26.8	68.5	7.1	33.1	5.5
2011	173.7	23.4	58.7	0.7	33.8	5.1
2012	152.7	22.1	49.6	8.9	32.5	4.5

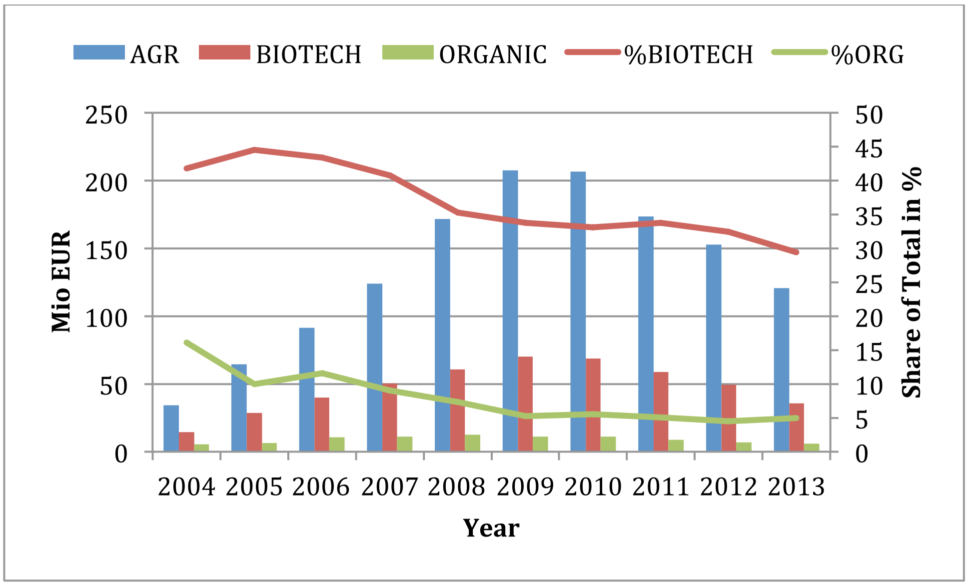


Figure 2: Germany: Public investment in agricultural R&D (Mio EUR)

[28] http://www.bmel.de/EN/Homepage/homepage_node.html

[29] http://www.fisaonline.de/index.php?lang=dt&act=subject&subjectview=yes&lang=en

Looking at the figures it is quite obvious that – as in other countries –relatively low amounts (<10%) are invested into science dealing with organic agriculture.

The fisaonline databank is already very informative and a very valuable initiative to promote the elaborate documentation of research funding. Nevertheless, to effectively guarantee transparency, it would be desirable to stipulate the declaration of figures for all projects and not to leave this point optional.

1.5. The Netherlands

Agriculture and horticulture play a pivotal role in the Netherlands, accounting for 2% of the Gross Value adding to the GDPin 2010 ((European Commission 2015)[30] Agricultural research is centralised in Wageningen UR, which resulted from the fusion of of Wageningen University of Agriculture and of the DLO institutes (formerly the Agricultural Research Departments of the Ministry of Agriculture) (Geerling, Linderhof, and Poppe 2014).

Table 5 : **Netherlands: Budget appropriations in agricultural sciences and estimates for expenditure in organic research (Mio €)**

Year	Total[31]	Organic[32]
2001	100	7.2
2002	105	10.5
2003	153	12.4
2004	209	10.6
2005	216	8.9
2006	208	11.1
2007	202	9.0
2008	237	9.0
2009	165	7.0
2010	176	7.0
2011	163	7.0
2012	148	2.0
2013	161	2.0

[30] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/nl_en.pdf

o

nline.de/index.php?lang=dt&act=subject&subjectview=yes&lang=en

[32] http://ec.europa.eu/agriculture/statistics/factsheets/pdf/nl_en.pdf

[32] Statistics Netherlands Infoservice, personal communication

[32] 2001-2006 : Lange et al., 2006 ; 2007-2013 : Koopmans, C.J., personal communication, Director R&D Louis Bolk Institute, http://www.louisbolk.org/

Though Statistics Netherlands conducts annual surveys on Research and Development Expenditures of the private and public sector, only total expenditures are asked for and no distinctions into 'fields of science' are made[33]. Thus, concerning investment into agricultural research, only budget appropriations can be found for the past years in EUROSTAT.

WUR collaborated with the Louis Bolk Institute in a specialist program for organic farming research between 2003-2011 but since 2012 the policy has changed from a preferred area of expenditures to a competitive tendering approach. The main focus in science does, as for other countries, not seem to lie on organic agriculture, as the low amounts spent on research in organic farming indicate.

1.6. Synthesis for the four countries

In the four countries studied in more detail, estimates of public and private expenses on biotechnology are not available, making a comparative assessment of the investment in organic farming and biotechnology impossible. Estimates of the share of public agricultural research budgets allocated to organic farming point to an overall investment of less than 5 percent. The Netherlands and Belgium devote respectively 3 and 5 % of the total agricultural research budget to organic farming. France and Germany lay behind with a share of only 1 % for organic farming research but data for France are only based on additional costs and do not take into account the salaries of INRA and other research institutions implied in organic farming research projects. Funding of research into organic farming remains the exception both at EU and national levels.

Table 6 : **Funding of organic farming research in four European countries**

	France	Belgium	Germany	The Netherlands
Gross Value added by Agriculture to GDP (a)	1.7%	0.7 %	0.9%	2.0 %
Share of area in organic (2013)	3.9 %	4.6 %	6.4 %	2.6 %
Estimated spending in agricultural sciences (Mio €) (b)	313	35	718	163
Estimated spending in organic farming (Mio €) (c)	3.6	1.7	6.4	5.0
Share of spending for organic (%) (d)	1.15%	4.85%	0.90 %	3.06%

(a) In 2010
(b) Average of the five last available years (Mio€)
(c) Average of the five last available years (Mio€)
(d) Average of the five last available years

33 Statistics Netherlands Infoservice, personal communication

2. Specific National Programs for Organic Farming

A number of EU member states have developed their own specific national research programs (Table 7). The programs have an organic focus in common but vary considerably in scope, allocated funding and specific aims. In most countries, researchers of organic farming also have access to other funding streams, but these program aim to specifically address the needs of the organic sector. All the ministries that have specialist programs are members of the CORE organic initiative (see Section 4).

The Danish Government has been supporting a specific organic research program since 1996/97, when the first Danish Action Plan was introduced. The large Federal Government Program in Germany started in 2001, introduced by the Green Minister Renate Künast and has continued until today under different Governments. In 2011 it was broadened to cover other forms of sustainable agriculture in addition to organic farming. Some specific organic programs are delivered by one or two research organizations (e.g. INRA in FR, SLU in Sweden, LBI/WUR in the Netherlands). Other countries have specialist thematic areas to develop organic agriculture under the agricultural research programs of the Ministries. For example, the Federal Ministry of Agriculture, Forestry, Environment and Water in Austria has a dedicated program (PFEIL 10 and 15) with a current spending target of about 15% of the total program (including CORE Organic projects/program). Also, the French, Italian and the Spanish ministries have had some dedicated regular spending for organic farming, some only for a limited period of time.

Evaluations found that the specialist organic farming programs have had a positive impact on the development of the organic sector and are relevant to meeting specific technical needs (Andreasen, Rasmussen, and Halberg 2015; Rasmussen and Halberg 2014; Vieweger et al. 2014). This contributes to develop organic farming practises, but is likely to be relevant for other agricultural producers. For example, using more legumes in crop rotation is recognised as a way to reduce impact of agriculture on the climate. Also selective breeding of new plant varieties for greater resistance and resource use efficiency, strategies for control of specific weeds, reduced antibiotic use, grazing management and nutrition of different livestock are all likely to have wider impact. In this way, the specific programs link to societal goals of soil protection, climate change and rural development. For example, projects funded under the Swedish Ekoforsk program should contribute to the development of a sustainable production in terms of environmental concerns, animal welfare, resource management, income level and productivity[34]. An analysis of research under the Danish national organic research programs showed that the projects have been applied to and directed at the barriers in the sector in order to support the general market and growth conditions for the organic sector (Andreasen, Rasmussen, and Halberg 2015).

If the most recent program spending under such national programs is set in relation to the total agriculture area of the country, the annual spending per hectare UAA is highest in Germany and Denmark (~ €0.47/ha UAA) followed by the Netherlands (€0.37/ha UAA), Sweden (€0.26/ha UAA) and France (€0.10/ha).

[34] www.slu.se/ekoforsk

In several countries, research priorities and topics were identified systematically involving stakeholder consultation with various actors in the sector. For example, the ICROFS research and development strategy of 2012, prepared as the result of extensive consultation-identified growth, credibility and resilience as primary themes with focus areas considering existing organic production as well as societal goals (Mathiesen and Sørensen 2012). Also, the priorities for the Dutch research program of WUR/LBI that started in 1993 were fully directed by the organic sector. Denmark identified growth, credibility and resilience as primary themes with focus areas considering existing organic production as well as societal goals. The Swedish Research Agenda of 2013 listed robust systems, value for the environment and society and competitiveness for thriving rural communities as overarching themes for research funding (Wivstad 2013). Most programs also have a clear aim to enhance knowledge exchange for the organic sector and run websites, seminars, conference etc. to highlight the findings of their research. The programs make the findings accessible to a wide range of user through organic E-prints as well as through national websites, workshops, conferences and encourage coverage in the (organic) farming press (Andreasen, Rasmussen, and Halberg 2015; Ekert et al. 2012).

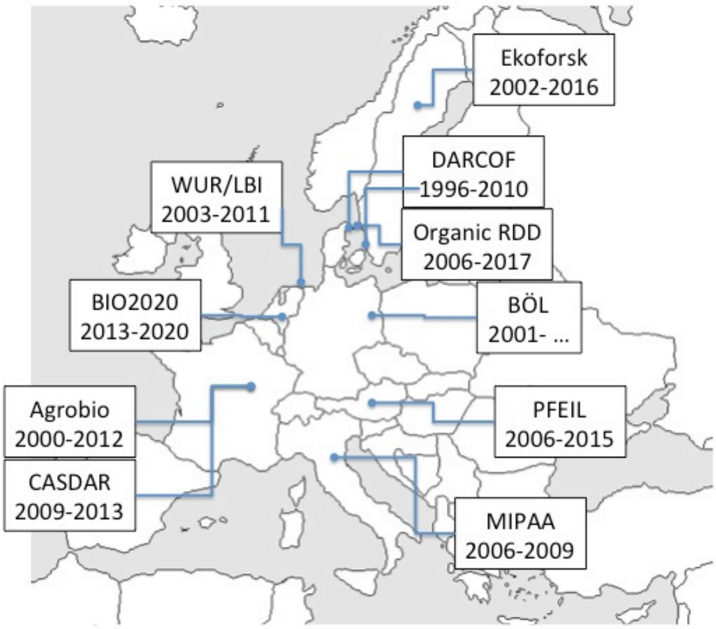


Figure 3 : Examples of national research programs for organic farming

Projects bring together various actors and approaches along the whole supply chains from producer to consumer (Rasmussen and Halberg 2014; Vieweger et al. 2014). Organic projects are now among those leading the way in developing the model and ideas for bottom-up innovation and knowledge exchange of the European Innovation Platform EIP AGRI.

However, there is uncertainty about the long-term security of specialist organic funding streams and some of the examples listed here were only open for specific periods of time, for example in conjunction with an Organic Action Plan. In several cases they were replaced with a competitive tendering process without specifically ring-fencing budgets for organic spending Uncertainty about such funding streams is likely to impact programming strategy and prevents capacity building for the specific topics and approaches that support the organic sector (Ekert et al. 2012).

Table 7: **Examples of national research programs for organic farming in the European Union**

	Program	Key Aims	Period	Estimated funding (mil €/year)	Total no of Projects
AT	PFEIL 10	Theme Organic farming within the Research Program of the Federal Ministry of Agriculture, Forestry, Environment and Water to develop the organic sector. Key areas of research are product quality and marketing, crop production and animal husbandry.	2006-2010	2.3	41
AT	PFEIL 15		2011-2015	2.5	33
BE (Wal)	BIO2020	Supporting the development of the sector in identifying research needs with the actors and in carring out the research and support CORE organic program	2013-2020	1	n/a
DE	BOEL Bundes program ökologischer Landbau	To strengthen development of the sector and reduce risks at all levels of organic farming from production to consumption; includes training and information measures and knowledge exchange and CORE organic projects	2001-2003	6.8	~700
			2004-2006	6.6	
			2007-2010	5.3	
	BOELN	The remit of BÖL was broadened to cover sustainable agriculture	2011-2013	8	n/a
DK	DARCOF I	Coordinate Danish research across institutes and disciplines.	1996-1999	3.4	33
	DARCOF II	To produce knowledge that can be used to promote increased production and a closer relationship between the inherent and organic qualities of organic foods	2000-2005	4.7	43
	DARCOF III	Integrity and efficiency in the whole organic food chain – from farmer to consumer and a sustainable development of society as a whole	2006-2010	4.6	15
	Organic RDD 1	Organic Research, Development and Demonstration, Growth, credibility and robust systems	2011- 2013	4.1	11
	Organic RDD 2		2014-2017	3.0	10
FR	Agrobio 1	To better understand organic farming,	2000-2003	11.3	n/a

	(INRA & ACTA)	transfer and discuss scientific results, develop new projects and understand and support organic agriculture as a prototype for sustainable agriculture			
	Agrobio 2 (INRA)		2004-2007	2.5	n/a
	Agrobio3 (INRA)		2010-2012	3	n/a
FR	CASDAR	Organic strand in national program for rural and agricultural development	2009-2013	0.5	n/a
IT	MIPAA	Organic strand in multiannual programs of Ministry of Agriculture (Mipaaf) in cooperation with the Ministry for research education and university related to the Italian Action Plan	2006-2009	0.5 - 1.5	n/a
NL	WUR/LBI	Co-ordinated organic program between Wageningen University and the Louis Bolk Institute	2003-2011	0.7	?
SE	Ekoforsk I (SLU)	Improve the knowledge base for the development of crop cultivation, animal husbandry and the production of fruit, berries and vegetables.	2002-2004	0.80	21
SE	Ekoforsk II		2005-2007	0.80	17
SE	Ekoforsk III		2008-2010	0.73	16
SE	Ekoforsk IV		2011-2013	0.83	16
SE	Ekoforsk V		2014-2016	0.80	14

Websites

Austria http://www.bmlfuw.gv.at/forst/forst-bbf/Forschung/pfeil15.html

Denmark http://icrofs.dk/en/research/danish-research/

Germany http://www.ble.de/DE/04_Program/01_Oekolandbau/OekolandbauNachhaltigeLandwirtschaft_node.html

www.oekelandbau.de

France https://www6.inra.fr/comite_agriculture_biologique/Les-recherches/Par-program/Inra-AgriBio

Sweden www.slu.se/ekoforsk

Belgium http://www.cra.wallonie.be/img/page/Conference/presentation.pdf

http://agriculture.wallonie.be/apps/spip_wolwin/IMG/pdf/plan_bio_final_juin_2013.pdf

http://www.cra.wallonie.be/fr/52/Brochures-et-dossiers/714

3. Assessing Organic Farming in comparison to Intensive Conventional Farming

3.1. Introduction

Rooted in the overall issue of the sustainability of agro-food systems, this chapter offers a comparative assessment of the impacts of organic and intensive conventional farming. The key questions raised are: does organic farming perform better, equivalent or less well socio-environmentally and economically than intensive conventional farming? What are the methodological assumptions and caveats of such comparisons?

3.1.1. Conceptual background

Many farming alternatives to intensive conventional systems have been developed. These include integrated crop management, integrated pest management, low external input agriculture, permaculture, biodynamic farming, agroforesty, conservation agriculture and organic agriculture (N. H. Lampkin et al. 2015). In some respect, all of them share the same agroecological objectives: implementing stable and self-reliable agro-food systems limiting external inputs whether chemical or organic and in using renewable resources, adaptable to internal changes and resilient to external shocks (De Schutter 2011).

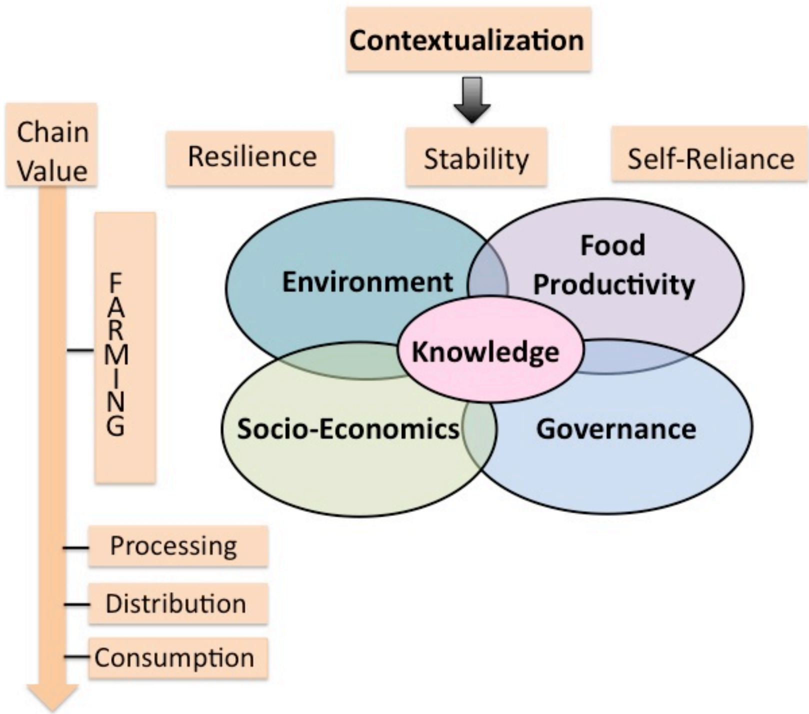


Figure 4 : General framework of organic farming and sustainability

Such overall objectives imply managing contextual resources at the farm and regional scales (climate, landscape topography, etc.). Alternative farming approaches are therefore highly site-specific (Lamine and Bellon 2009; Rigby and Cáceres 2001) the time and space scales and the socio-environmental context should be considered with care.

Amongst these agroecological alternatives, low external input agriculture and organic farming are often considered very similar, but only organic farming has been regulated by the European Union since 1991 and has received policy support as part of the CAP since 1993. (Rigby and Cáceres 2001). Besides, in direct relation to overall sustainability, organic farming encompasses key objectives relating to achieving high levels of environmental protection, acceptable levels of food productivity in both qualitative terms (human nutrition, food safety and animal welfare) and quantitative terms (food security) (N. H. Lampkin et al. 2015). Regarding socio-economics, organic farming aims to provide social justice and financially appropriate return to the human and other resources employed. Moreover, as a response to the fundamental interconnections between the different stages of the vertical value chain – farming, processing, distribution and consumption – organic farming impacts the process of making and implementing decisions, the governance design (Hage 2012). And finally, due to its holistic approach and the importance of stakeholder interactions, organic farming has a strong effect on knowledge systems (Freibauer et al. 2011). All of these features are fundamentally covered by the IFOAM definition and principles of organic farming (see textbox bellow).

IFOAM ORGANICS INTERNATIONAL

Organic agriculture: definition and principles

For IFOAM, organic agriculture can be defined as a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved"[35]. Four fundamental principles are at work in such a definition[36](IFOAM):

- √ *Principle of Health*: Organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one indivisible;
- √ *Principle of Ecology*: Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them;
- √ *Principle of Fairness*: Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities;
- √ *Principle of Care*: Organic agriculture is to be managed in a precautionary and responsible manner to protect the health and wellbeing of current and future generations and the environment.

[35] http://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture

[36] http://www.ifoam.bio/en/organic-landmarks/principles-organic-agriculture

3.1.2. Methodology, scope of the assessment and summary of the findings

In order to practically compare the performance of organic and intensive conventional farming systems, in line with Lebacq et al. (2013), environment, food productivity and socio-economics have been divided into various issues of concern (called in this research themes and sub-themes). Relevant indicators of performance have been identified against which success or failure has been assessed in peer-reviewed publications (and, to a lesser extent, grey literature).

As the literature offers a very wide range of themes and sub-themes of concern, metrics and indicators with variable data quality and comparability, some constraint to the assessment and reliance on judgement are required. It is thereby important to note that the final assessment is based on the authors' judgment informed by available material.

Environmental and food productivity impacts are extensively discussed in literature whereas insights to, for instance, animal welfare are less available. A specific emphasis is intentionally placed on the key issue of employment while impacts in terms of governance and knowledge are addressed in the last section dealing with some cross-cutting issues.

An important distinction between indicators for environmental impacts per unit of product and per area ratios is applied. As the yield of organic farming is generally lower, results for the former are typically worse than for the latter.

Besides, although sustainability of agro-food systems encompasses the entire chain value from farming to consumption (Hage 2012), this assessment is mainly restricted to the farm scale.

Scorings of organic *versus* conventional in relation to themes, sub-themes and indicators are summarised Figure 5.

3.2. Environmental Impacts

The environmental impacts of organic farming in comparison to conventional farming were peer-reviewed through different scientific sources (Matthias Stolze 2000; Hole et al. 2005; Mondelaers, Aertsens, and Van Huylenbroeck 2009; Norton et al. 2009; Leifeld and Fuhrer 2010; Tuomisto et al. 2012; Gattinger et al. 2012; Tuck et al. 2014).

3.2.1. Ecosystem

Organic farming clearly performs better than conventional farming in the case of biodiversity (M. Stolze et al. 2000). For a wide range of taxa, organic farming has positive impacts on species abundance/richness (Hole et al. 2005). Importantly, these findings concerned species that have been in decline, arguably as a direct result of intensive farming. Bengtsson et al. (2005) cited in Tuomisto et al. (2012) found that organic farms have up to 30% higher species richness and 50% higher abundance of organisms than conventional farms. Of the 99 studies reviewed by Hole et al. (2005), only 8 found negative effects of organic farming on diverse individual taxon. Numerous other studies (i.e. Romero et al., 2008; cited in Tuomisto et al. (2012), Mondelaers, Aertsens, and Van Huylenbroeck 2009; Tuck et al. 2014) put forward that organic farming has positive impacts on the diversity of non-crop plant richness compared with conventional farming. However, the effect of organic farming is function of taxa, crop and the proportion of arable land in the surrounding landscape. Considering the latter, the higher the land use, the greater the positive impact of organic farming (Tuck et al. 2014). In contrast, the relative impact of organic farming is logically reduced in the context of a more natural preserved surrounding.

Figure 5 : Comparison of impacts of organic and conventional farming

Considering habitats and landscape, the more diverse living conditions and heterogeneous landscape types (Norton et al. 2009) [in the case of England]) offered by organic farming produces increased wildlife habitats (wide range of housing, etc.).

3.2.1. Soil

The conservation of soil fertility and system stability is helped by higher organic matter contents and biological activity in the soil of organic farms (M. Stolze et al. 2000). Tuomisto et al. ((2012) found that the median soil organic matter for all the reviewed case studies was 7%

higher in organic farming than in conventional farming, and is directly linked with the use of organic fertilizers (manure, compost) in organic farming.

Table 8 : Peer-reviewed literature on the environmental impacts

Topics	Authors	Method
Overall environment	Stolze et al. (2000)	Survey of specialists in 18 European countries; international data base
	Tuomisto et al. (2012)	109 studies
	Mondelaers et al. (2009)	Around 100 studies
Biodiversity	Hole et al. (2005)	76 studies
	Tuck et al. (2014)	94 studies
Soil Carbon sequestration	Liefeld and Furher (2010)	32 studies
	(Gattinger et al. 2012)	74 studies
Landscape complexity	Norton et al. (2009)	89 pairs of organic and non-organic fields on 161 farms in England

Organic farming has a high erosion control potential. This relates to fewer crop rows, a sustained supply of stable manure, resulting in higher soil intrinsic stability due to higher stability of aggregates and biopores (i.e. Dabbert and Piorr, 1998(2009); cited in (M. Stolze et al. 2000); (Mondelaers, Aertsens, and Van Huylenbroeck 2009). However, for Niggli et al. (1995; cited in (M. Stolze et al. 2000), on long-term trials (of about 15 years), no significant differences in soil structure parameters (stability of aggregates, air capacity, water holding capacity, etc.) have been observed.

In terms of carbon sequestration, Leifeld and Furher (2010) found that after conversion, soil carbon content in organic systems increased annually by 2.2% on average, whereas in conventional systems soil carbon content was stable. However, when comparing soil carbon content rather than concentrations and this, in relation to crop rotation and organic fertilization, the relatively positive effect of organic farming seems less striking. Accordingly, the important use of organic fertilizer in organic farming compared to conventional farming significantly determines the soil carbon content (Leifeld and Furher, (2010)). In turn, for them, this means that carbon sequestration in organic farming is rather similar to conventional farming. However, Gattinger et al(Gattinger et al. 2012). (2012) recently confirm higher soil organic carbon concentrations (0.18 ± 0.06%) and stocks (3.50 ± 1.08 Mg C ha−1) in top soils under organic management. It is likely that these benefits will be greatest where a fertility-building (N and C fixing) phase involving grass/legume leys or green manures is introduced into exploitive arable/horticultural cropping sequences, as these cover crops can compensate for the use of plough-based tillage and cultivations for weed control in the absence of herbicides.

3.2.2. Ground surface water

According to Tuomisto et al. (2012), agriculture is the main contributor of aquatic eutrophication (50-80% of the total aquatic nitrogen load). Acidification and eutrophication are due to nitrate, phosphate, ammonia and sulphur dioxide leaching resulting in the abnormal growth of plant and algae in ground surface water.

Based on a statistical comparison of 12 studies, Mondelaers et al. (2009) concluded that the nitrate leaching rate is on average 9 kg ha-1 in organic production versus 21 kg ha-1 in conventional agriculture. Important differences are noted among the studies due to differences in soil, regions, fertilisation practices and measurement. In contrast to the results mentioned above, in some comparative crop rotation experiments nitrate leaching has been reported at the same levels in organic and conventional rotations, especially if calculated per kilogram of harvest (Korsaeth and Eltun 2000; Mondelaers, Aertsens, and Van Huylenbroeck 2009). In considering per unit of area ratios, leaching rates per hectare are up to 57% lower on organic.

With respect to the standards, the absence of synthetic pesticides has obviously positive impact on ground and surface water pollution. Thereby, organic farming is the champion agricultural system for water reclamation areas.

However, from a per unit of product ratio perspective, organic farming performance is less striking as the mean production per ha is lower in organic farming than in conventional farming. Indeed, nitrate leaching per unit of organic product is quasi-similar to nitrate leaching per unit of conventional product (M. Stolze et al. 2000). For Tuomisto et al. (2012), still in a per unit of product perspective, due to significantly lower animal and crop yields as compared to conventional systems, eutrophication potential may even be higher in organic farming and thereby largely underestimated. However, it is worth mentioning that this potential is directly correlated to the type of product. In that sense, it has been shown that lower eutrophication potential of organic farming is observed for dairy production whereas in the other food categories organic products may have a higher impact per unit of product than conventional (*Ibid.*).

Considering phosphorous leaching (Mondelaers, Aertsens, and Van Huylenbroeck 2009) and acidification of ground surface water (Tuomisto et al., 2012), the findings are basically identical: much better for per-hectare while disputable at least per unit of product. Potential of acidification directly relates to the type of product.

3.2.3. Climate and air

Climate and air impact of organic farming when compared to the conventional depend greatly of the unit of analysis of the research. Per-hectare, for instance, CO_2 emissions in organic farming are between 40% and 60% lower than conventional farming (M. Stolze et al. 2000), In a review of studies based on LCA, Knudsen et al. (2011) found no significant difference overall when comparisons are made per unit of product. The effect of lower yields under organic management being offset by lower inputs, greenhouse gases (GHG) emissions per kg are much lower for plant than for animal products, and the variability in results for plant products is also low. In the case of a per-unit of product comparison in animal production, organic practices perform the same or even worse than conventional ones (Mondelaers, Aertsens, and Van Huylenbroeck 2009). For instance, GHG emissions are higher for organic milk and organic pork productions compared to conventional one whereas it has been found that organic beef production has lower GHG emissions (Tuomisto et al., 2012).

3.3. Food Productivity Impacts

Farming practice impacts the production of food in terms of quality and quantity.

The quality of food is usually assessed with respect to the content levels of individual substances in food and selected ingredients [37]. Regarding human nutrition and thereby in direct relation to human health, these substances are split into two main categories: positively-rated substances such as minerals, proteins, vitamins, healthy fatty acids and phytochemicals and negatively-rated substances (or value-reducing substances) such as nitrates, pesticide residues and heavy metals (for example cadmium) (*Ibid.*). Qualitative features of food depend on the category: vegetables, fruits, cereals, milk products and meat.

Food quantity is generally assessed through the yield: the food output per unit area and time (Seufert, Ramankutty, and Foley 2012)[38]. We will refer to organic-conventional comparative yield as the relative yield of organically grown crops versus those grown conventionally. It means that the smaller this relative yield the larger the yield gap of organic farming. Yield differences are very contextual depending on the farming system, (good) management practices, site characteristics (rainfall, soil structure, etc.) and crop types.

The food productivity impacts of organic farming in both its qualitative and quantitative facets were scrutinized through the following meta-analysis: FiBL (2015), Hunter et al. (2011), Barański et al. (2014), Palupi et al. (2012), Smith-Spangler et al. (2012), Brandt et al. (2011), Seufert et al. (2012) and de Ponti et al. (2012)

For Palupi et al. (2012) measuring organic and conventional milk for proteins and healthy fatty acids produced positive results for organic milk. However, for Smith-Spangler et al. (2012), the literature reviewed lacks strong evidence that organic foods (vegetables, fruits, cereals, milk products) are significantly more nutritious than conventional foods. In the same vein, Barański et al. (2014) found that conventional cereals have an higher protein content than their organic counterpart (due to decreased nitrogen supplies). Contrastingly, a study carried out on 500 hundred organic wheat samples between 2010 and 2013 found the gluten content (the complex gluten-protein being of great importance for the production of bread) of Swiss organic wheat to be very high but more susceptible to fluctuations (FIBL, 2015)[39] Annual variations in weather, along with location, were seen to have more negative impacts on stability than for conventional wheat (*Ibid.*).

Vitamin C contents were favourable in organic fruits and vegetables for Brandt et al. (2011). However, for other scholars, vitamin A, C and E levels were equal in both organic and conventional cereals, vegetables, fruits (Barański et al., 2014; Hunter et al., 2011; Smith-Spangler et al., 2012) and milk products (Palupi et al., 2012).

Considering phyto-chemicals such as antioxidants and phenol for vegetables, fruits and cereals (Barański et al., 2014; Brandt et al., 2011) and healthy fatty acids for milk (Palupi et al., 2012), organic is more favourable than conventional. For instance, Barański et al. (2014), in reviewing more than 300 hundred comparative studies found an almost 20 % rise in phyto-chemical antioxidants in organic produce (Table 9).

[37] https://www.FiBL.org/fileadmin/documents/shop/1413-organic-products.pdf

[38] Comparing the yields of organic and conventional agriculture (doi: 10.1038/nature11069).

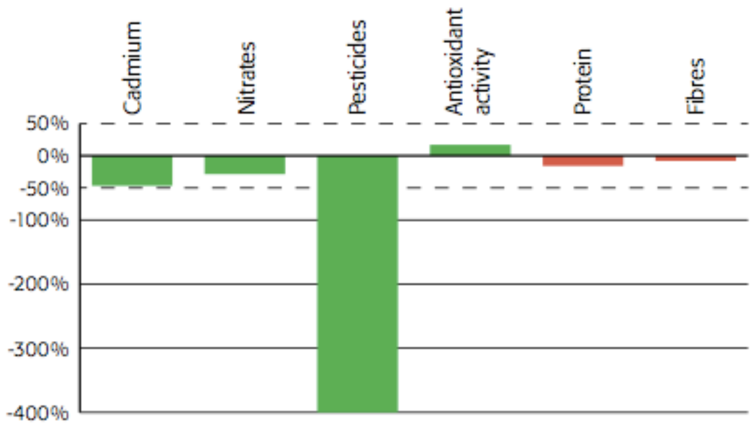
[39] https://www.FiBL.org/fileadmin/documents/shop/1413-organic-products.pdf

Table 9 : Peer-reviewed literature of the impacts on the quality and quantity of food

Topics	Sub-topics	Authors	Method
	Overall	FIBL, 2015 Smith-Spangler (2012) Barański et al. (2014)	Review of the most recent meta-analyses Review of 200 individual studies
Quality of food	Vitamins and minerals	Hunter (2011)	Meta-analysis of 33 studies (908 micronutrient comparisons)
	Phytochemicals in fruits and vegetables	Brandt (2011)	Meta-analysis of published comparisons
	Nutritious quality of milk products	Palupi (2012)	Meta-analyse of 13 articles on dairy product comparison
	Animal welfare	Leenstra et al. (2011) Lund et Algers (2003) Sundrum (2001)	Symposium report Review of 22 papers
Quantity of food		Seufert et al. (2012)	Synthesis of sixty-six studies
		De Ponti et al. (2012)	Review of 362 studies

3.3.1.1. Negatively-rated substances

Some major studies, such as Barański et al. (2014) revealed contamination levels of pesticide residues (four time less!), nitrates and cadmium to be notable lower in organic crops (see figure above). In addition, according to Smith-Spangler et al. (2012), consumption or organic foods probably reduces exposure to pesticide residues (moreover antibiotic-resistant bacteria). As another example, on the basis of 253 organic and 1803 conventional samples, in the German region of Baden-Württemberg, MLR (2013; cited in FIBL, 2015) found that while a small percentage of organic crops presented more than 0.01 mg of pesticides per kg of produce, roughly 75 % of their conventional equivalents were significantly contaminated (Figure 7). In addition, this study discovered 180 times less pesticide contamination in organic fruit and vegetables (*Ibid.*) Throughout Europe such substances were both found in small quantities and less often in organic fresh produce (FIBL, 2015).



Legend: In green: organic performs better; in red: organic performs less

Source: FIBL, 2015, p. 5. http://www.FiBL.org/en/homepage.html

Figure 6 : Six selected differences between conventional and organic farming for cereals, fruits and vegetables from Baransky study

3.3.1.2.

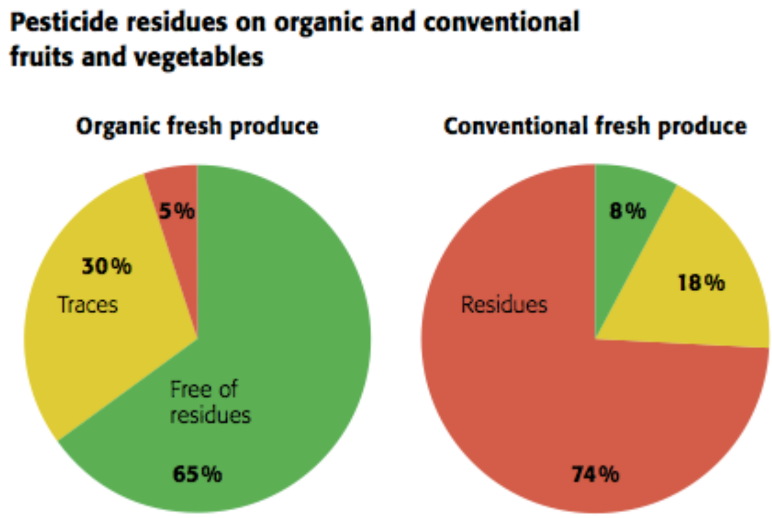


Figure 7 : Findings from a survey of 253 organic and 1803 conventional samples in Baden-Württemberg (Germany)

Source: FIBL, 2015, p. 6. http://www.FiBL.org/en/homepage.html

Food production and indirect and direct effects on human health

The 'health' of the environment indirectly impacts human health. For instance, as noted elsewhere, synthetic pesticides used by conventional farming and prohibited in organic farming have a negative impact on ground and surface water pollution and on the ecosystem as a whole. In turn, this potentially has a negative effect on the human beings that are part of such an ecosystem.

Furthermore, the injuriousness of such toxic substances may include effects and health threats to future generations (Pisanello 2014), which are obviously difficult to estimate.

Besides, through nutrition, some substances have a direct beneficial or non-beneficial effect on human health. For instance, as Barański et al. (2014) put it, there is strong scientific evidence that consumption of organic crops particularly rich in phyto-chemical antioxidants such as (poly)phenolics enhance protection against cardiovascular diseases, neurodegenerative diseases and certain cancers (e.g. prostate cancer).

On the other hand, Cadmium, a highly toxic metal notably more present in conventional than organic products, can remain in human tissues (half-life between 10 and 30 years) and may induce bone demineralisation and renal diseases (Pisanello 2014). In addition, Cadmium has also been assigned a group 1-human carcinogen by the International Agency for Research on Cancer (*Ibid.*)

3.3.2. Animal welfare

High animal welfare is a central objective of organic farming and the EU Regulations for organic food contain detailed rules for animal health care, feeding and housing. These were found to be on a high level compared with the requirements of the general EU legislation (Ferrari and De Roest 2010). Animal welfare can be a problematic issue due to both a lack of a shared "understanding of the concept of animal welfare" (Leenstra 2011) and because of lack of accepted tools for assessment and comparisons in particular of animal welfare.

Very few recent studies directly compare animal health and welfare on organic with other farming systems and no meta-analysis of peer reviewed studies across all species could be identified. The following discussion presents some results comparing organic with conventional farming systems in relation to animal health followed by animal welfare comparisons.

The results studies of the health-status of farm animals using quantitative indicators are variable with the majority pointing towards better performance of organic farms. For example, Sundrum (2001) cites a reduction in metabolic disorders, thought to be linked to less intensive production levels, high producing milk cattle reacting more sensitively to poor conditions. He also points that the reproductive life span of dairy cows in organic system is significantly higher (i.e. Wanner, 1995 cited in Sundrum (2001). In a study of paired dairy farms in the UK (40 organic and 40 conventional), Rutherford et al. (2008) found lameness to be less prevalent on organic farms. No differences between organic and conventional were found by Haskell et al. (2009) in relation to somatic cell counts of dairy cows the UK paired farm study and similarly, Fall et al. (2009) and Müller et al. (2010) found no difference in udder health in paired farm studies in Sweden and Germany respectively. Lindgreen et al (2014) found better performance of organic than conventional on several indicators of pig health. Conventional Danish pig herds consumed three times as much antibiotics (anthelmintics not included) as the organic herds, whilst there was no difference in mortality rate nor more pigs in need of treatment in the organic herds. Slaughter data indicated that organic pigs had fewer respiratory problems, skin lesions (including abscesses and hernias) and tail wounds compared to conventional pigs, but remarks about joint lesions and white spot livers were more common among organic pigs and the risk of parasitic infections in organic fattening pigs was confirmed. Ermakov (2012) found no indication of a better health status of organic turkeys, based on a comparison meat inspection data of organic and conventional carcasses in one German slaughter house between 2004 and 2009. Some EU funder research has focused on the robustness of certain breeds (e.g. Low-Input Breeds Project) and it can be expected that breeding techniques may over time provide natural solutions to combat this issue to develop resilience to parasites and mastitis (Gjerris 2011).

Differences between organic and other welfare standards exist and are related to the prohibition of certain housing systems (e.g. fully slatted floors for cattle) and improvements in existing ones (e.g. access to bedding) (Schmid and Knutti 2012). Kilbride et al. (2012) analysed data from statutory animal health inspections in the UK and concluded that enterprises participating in organic or farm assurance inspections were more likely to comply with welfare legislation than farms not participating in such schemes. In contrast, in the paired study of dairy farms Langford et al. (2009) found no significant differences in building dimensions and in other aspects of cow housing and health between conventional and organic herds. Membership in organic and in other high welfare certification schemes was found to be one factor affecting the mortality rate for piglets (KilBride et al. 2014).

3.3.3. Quantity of food

Seufert et al. (2012) found that in most of the cases, organic yields are lower. Indeed, the average organic-conventional comparative yield ratio was 0.75 (with a 95% confidence interval of 0.71 to 0.79). The ratio varies according to crop types and species. Results for fruits and oilseed crops showed small comparative ratios (-3% and -11% respectively) whereas these ratios were much larger for cereals and vegetables (-26% and -33% respectively) (see Figure 8). Amongst the different contextual variables to take into account, use of water dramatically influences the comparative performances. Indeed, Seufert et al. (2012) found a variation of -35% to -17% between irrigated and rain-fed systems.

De Ponti et al. (2012) compiled and analysed a meta-data set of 362 published organic/conventional crop yield comparisons. 180 paired sets of organic-conventional yield came from Europe and 126 ones from North America. Organic case studies have been selected with respect to the IFOAM's definition of organic farming (see supra). Farming has been considered as conventional when chemical inputs were used. Data concerned different crop types (vegetables, fruits, oilseed crops, etc) but cereals accounted for 43% of data. One-third of the data were from commercial farms, the rest being experimental ones, it may induce an over-estimation of the ratio. They found that the average organic-conventional comparative yield ratio was 0.80 but with a high standard deviation (21%). Both regional variations (for instance, in Denmark and the Netherlands, the organic-conventional yield gap was significantly more important) and differences between crop types had an important impact on the ration. For example, barley, potato and wheat had a lower score than 80% whereas for corn the ratio was higher.

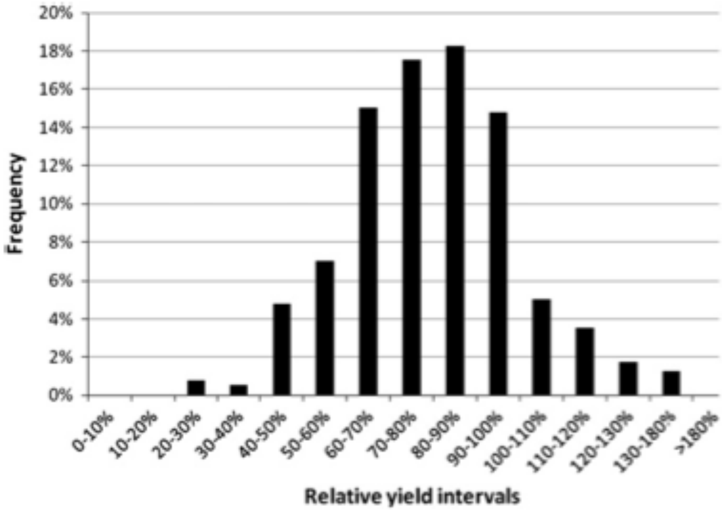


Figure 8 : Frequency of occurrence of relative yields of organic/conventional farming (10% intervals)

Source: De Ponti et al. (2012, p. 5)

3.4. Socio-Economic Impacts

The socio-economic benefits of organic and conventional farming are discussed at two inter-connected levels. First, at a local/regional scale, the issue of the impact of organic farming in terms of rural development is tackled. Emphasis is placed on the critical issue of employment since the question of whether or not organic farms use similar amounts of labour to non-organic farms has implications with regards to local development, resource efficiency and business competitiveness. Second, deepening the latter, farm profitability of organic farming is compared to its conventional counterpart.

3.4.1. Rural Development

3.4.1.1. Overview

There is no consensus on a definition of rural development ((Van Der Ploeg and Renting 2000); cited in Lobley et al. (2009). Aside from economic factors, there are also social elements to be taken into account that are difficult to measure. For instance, well-being, revitalization of the community, social links and participation in local civil institutions (MacRae, Frick, and Martin 2007). Indeed, Lobley et al. (2009) state that any potential impacts of organic farming in this context are a mixture of the philosophies and business configurations generally adopted. However, despite insisting that rural development is more than just about employment and income, it should be accepted that these are central as the foundations on which viable communities may be built (Ibid.).

Table 10: Peer-reviewed literature on the socio-economic impacts

Topics	Sub-topics	Authors	Method
Rural development	Overview	MacRae et al. (2007)	Review of Peer-reviewed literature and governmental and extra-governmental reports
		Lobley et al. (2009)	Review/survey in England
	Employment	Nieberg and Offerman (2000)	Review and FADN data/studies (EU)
		Jansen (2000)	Review (EU)
		Chambru (2011)	Report (France)
		Cisilino and Madau (2007)	Paper based on FADN data in Italy
		Lobley et al. (2009, 2005)	Survey of Rural Development contribution in England.
		Morison *et al.*, (2005)	Survey of ~1000 organic farms, compared with national data
		Lampkin et al. (2014, 2015)	FADN data for England/Wales
	Financial competiveness	Crowder et al. (2015)	Meta-analysis of 44 studies representing 55 crop grown in 44 countries and 4 other meta-analysis comparing crops

3.4.1.1. Financial competiveness

Crowder and Reganold (2015) found that, despite lower yields (see supra), organic farming financially performs better than intensive conventional. Indeed, when organic premiums are not taken into account, the benefit/cost ratios are significantly lower than conventional farming (-27 to -23%). However, when actual premiums are applied, organic farming is significantly more profitable than conventional farming: the benefit/cost ratios are 20 to 24% higher. Therefore, since breakeven premiums are notably lower, this suggests that organic farming can continue to progress even if the financial bonus generated by premiums decrease.

Besides, in terms of cost structure, Crowder and Reganold (2015) found that interestingly the total costs (variable and fixed costs) for organic and conventional farming were relatively similar. Specifically in terms of variable costs, due to more resources devoted to pest control and the trend to diversify economic activities (for instance, through processing and direct marketing), labour cost for organic were higher than for its conventional counterpart. However, this higher labour cost was offset by the limited use of purchased inputs (chemical pesticides and fertilizers). Therefore, in line with the International Fund for Agriculture Development (2005; cited in Crowder and Reganold (2015), this suggests that extra labour requirements of organic farming is beneficial by enhancing the redistribution of resources and promoting rural development.

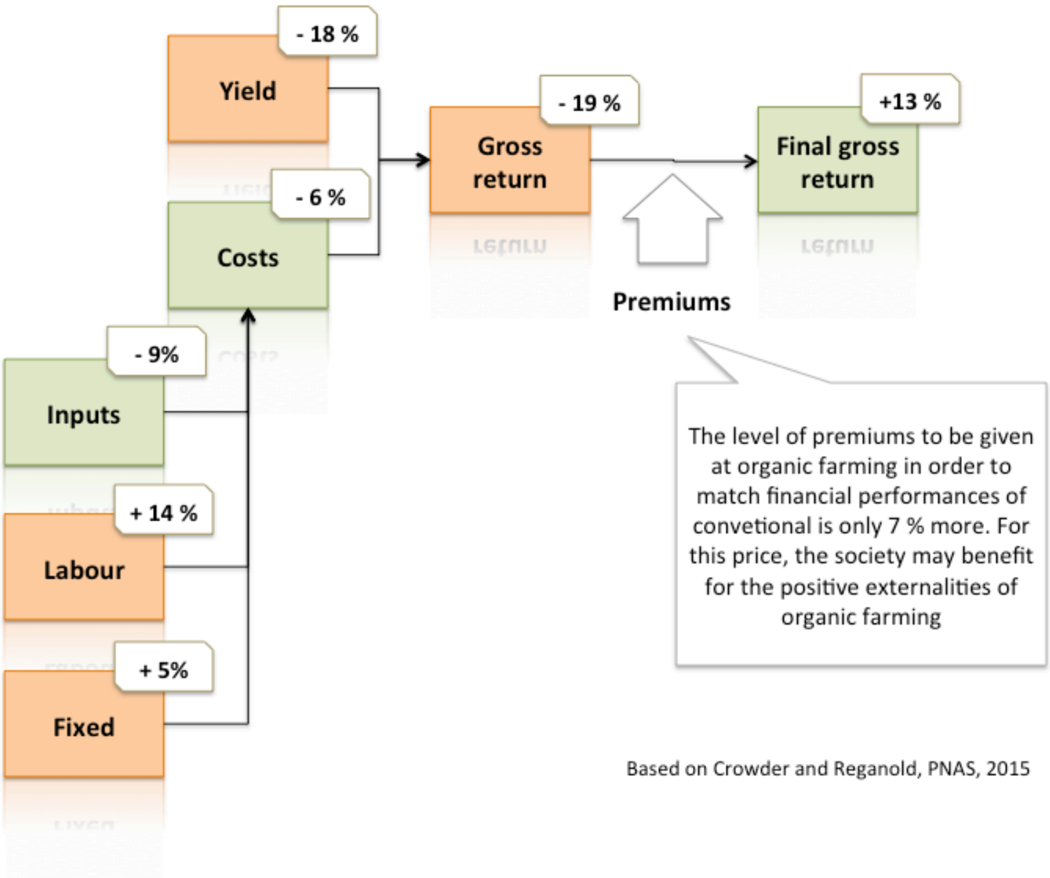


Figure 9 : Comparison of financial performances of organic and conventional farms based on a meta-analysis of 44 comparisons across the world.

Green boxes : when the comparison is in favour of organic farming.

3.4.1.2. Employment

From a rural development point of view generating employment for the rural economy is a key objective of rural development policy particularly if the financial returns generated also contribute to enhanced labour incomes or if opportunities for other members of the farm family are created. Therefore not just the amount of labour used is important but also the type of labour (e.g. family labour versus paid staff, permanent hired staff versus casual/seasonal staff).

Most authors suggest that on average labour use is higher on organic than on non-organic farms, but also comment on considerable variability of the results. Labour use is higher on organic horticultural and arable farms compared with non-organic, but the results are less striking for livestock and pasture farms, possible related to the lower stocking rates (Lobley, Butler, and Reed 2009; Lobley et al. 2005; Nieberg and Offermann 2000). Considering Europe as a whole, for instance, Nieberg and Offerman (2000) suggest on average a 10-20% increase of labour use for organic farming.

Several studies found increases in processing and direct sales activities on organic farms that lead to increase the labour use (Jansen 2000; Lobley et al. 2005; Morison, Hine, and Pretty 2005).

In contrast, in the UK and more recently, it was observed that horticulture labour use on organic farms appeared less on a per hectare or per farm basis, but labour productivity (financial output per full-time labour unit) for organic and non-organic horticultural samples was almost identical over the same period, indicating that business size and land use intensity may be a more important factor determining employment than the management system alone (N. H. Lampkin et al. 2015).

Labour use on organic farms might also increase due to a range of other factors, leading to the conclusion that farm activities, farm size, full/part-time farming, farm type are important factors that illustrate the importance of the choice of the comparators for such studies. Most of these factors have not been studied systematically (Jansen 2000; Nieberg and Offermann 2000). Work is required for recycling of nutrients (e.g. composting), more diverse crop rotations with legumes for biological nitrogen fixation (as green manures or leys), greater diversity of crops and enterprises including a higher share of more labour intensive crops (e.g. vegetables, potatoes) that require hand weeding.

Some differences are also observed in relation to the differences in the work-force. Organic farms appear to use less family labour and more paid labour (Jansen, 2000; Lobley et al., 2009; Nieberg and Offermann, 2000). Organic farms also seem to use a higher proportion of seasonal/casual labour which gives less job security, however this may be influenced by farm-type and the different balance of farm-types between organic and non-organic farms (Lobley et al., 2009).

Looking at it from a farmers' point of view, the use of labour has a cost that many farmers are keen to minimise, and increasing labour productivity is seen as an important driver for economic growth. Also looking for information maybe more time consuming for organic than for conventional farmers. It is therefore possible that if farmers perceive organic farming as requiring more labour then that may deter them from converting to organic production (Nettier et al., 2012).

Methodological insights on employment

Generalising results on employment is difficult because of differences in the approach (Nieberg and Offermann 2000). Labour use is either studied through analysis of existing data sets (e.g. Farm Accountancy Data Network [FADN], Agricultural Census) or through specific surveys of organic farms. How the comparison is carried out might have impact on the results. The organic sample can be defined in different ways (e.g. fully certified farms only, threshold of a certain proportion of the land being organic, self-assessment of farmers). Also, how the non-organic comparator is chosen can vary. In some studies (e.g. (Morison, Hine, and Pretty 2005) the non-organic sample includes all non-organic farms, whereas other studies (e.g. (N. Lampkin, Gerrard, and Moakes 2014; N. H. Lampkin et al. 2015) compare with non-organic farms that are similar to the organic ones (e.g. same size, same activities, same resource base, same region and selected either through clustering or through pairing of organic and non-organic farms). Labour use is generally expressed either be per hectare or per farm whereas per unit of product approach would be of great interest.

For instance, in one UK study organic farms were found to employ 35% more labour per farm than non-organic, whereas the non-organic farms employed 80% more labour per hectare. These contradicting trends were explained because the organic farms in the sample were larger than non-organic pointing to size as one important factor that impact on labour use (Morison, Hine, and Pretty 2005). Finally, most studies do not publish statistical tests making it difficult to evaluate the significance of any differences observed.

More research is needed, especially using statistical tests, not just treating "organic" or "non-organic" as homogenous but recognising that there is a great deal of variability within these systems and looking at questions such as:

- Labour use by farm-type and influence of particular crops or activities
- Labour productivity (i.e. financial output per worker)
- Breakdown of labour type (e.g. seasonal versus permanent) by farm type,
- Gender of employees
- Analysis of processing and direct sales activities separate from production
- Salaries and quality of work provided (e.g. skilled versus unskilled labour).

In addition, more work is also needed to provide farmers that are interested in organic farming with more accurate predictions of what impact such a change would have on the labour requirements on their holding.

3.5. Cross-cutting issues

3.5.1. The integration of productivity and socio-economic impacts

As the lower productivity of organic farming in comparison to intensive conventional farming in some systems is a matter of fact, it is often used to disparage organic farming. However, through a more systemic approach to food systems, keeping these insights on the comparative assessment of the impacts of organic and intensive conventional farming in mind, this issue should integrate two elements.

First, for the last thirty years, despite the fact that the rate of increase of food production is higher than the rate of increase of the world population, issues such as hunger and inequities remain with more than 800 millions people suffering from hunger. Indeed, part of agricultural production is used for non-food commodities such as biofuels and a significant share of food produced is wasted. Therefore, the link between production and social-environmental issues should be discussed within this context.

Second, taking into account the diversity of challenges in terms of the sustainability of future food systems, raw yield alone is no longer a relevant indicator. Instead, what is required is an indicator, which integrates both raw yield with the production of good quality food and positive socio-environmental impacts. According to the fact that organic farming appears on average 20% less productive than conventional farming but the externalities of organic farming are more positive than or at least equal to conventional farming. By contrast, a significant decrease in the negative impacts of conventional farming on, for instance, environmental dimensions such as climate change will necessitate a decrease in yield as the current level is highly dependant on polluting inputs such as pesticides, herbicides and the inappropriate use of water and non-renewable energy.

3.5.2. Competitiveness

Competitiveness is often put forward in favour of maintaining conventional farming systems. This strategy is inappropriate for two reasons. First, competitiveness is exclusively defined in economic terms and doesn't include other relevant dimensions such as environmental and social impact. Second, competitiveness is by definition a distinction between winners and losers and the comparative advantages of European agriculture in a competition between industrial farming systems are limited due to the high cost of land and labour, high level of urbanisation. In contrast, it appears promising for European farms to establish themselves as leaders in biological and social diversity with pioneering farming systems based on organic and agroecological principles.

3.5.1. Dynamics

Most of the comparative assessments of conventional and organic systems productivity began at the beginning of the XXIst century in two very different long-term dynamics. At this point in time, the two types of agriculture are at very different stages of development. On the one hand, n conventional farming systems, the yields tend to stall and the expectation of further growth is limited as past increases in yield were clearly related to higher use of inputs, in particular nitrogen. On the other hand, considering the limited availability of long-term data on organic farming yields, predictions on yield trend are difficult to make. However, the potential for increases in yields via technical and systemic improvements is probably higher in organic farming. For example, in the most recent meta-analysis using data from 115 studies (Ponisio et al. 2015), it was found that through the use of multi-cropping (polycultures) and crop rotations the yield gap between organic and conventional systems could substantially be reduced. This indicates that there is a potential to increase organic farming yields through more research, development and innovation through eco-functional intensification support as well as for improving the delivery of ecosystemic services and improving the overall performance of organic farming systems.

3.5.2. Multi-functionality of agriculture

Whether organic or conventional, agriculture is fundamentally multifunctional. This means that, a part from its economic function (providing food, feed, fiber, fuel), it drastically influences natural cycles and essential ecosystem services (water supply, carbon sequestration, etc.) as well as impacting social context (employment, life conditions, human health, etc.) Such agroecosystems are rooted in political, economic, social and cultural contexts (McIntyre et al. 2009) By essence, agriculture is thereby at the crossroads between the social sciences, economics and technical agronomic approaches

The main difference between organic (and other alternatives rooted in agroecological principles) and conventional farming research resides in the fact that only the former recognises this multi-functionality as a pre-requisite. Indeed, while the scientific spring of conventional agriculture is bio-technological, focusing on the scale of the crop, the animal or their genome in order to increase raw yield (Baret 2014). Each farm as part of an agro-food system interrelates with its context (Lamine and Bellon 2009) at a micro, meso and macro-level. Indeed, most of the research requirements of conventional farming relate to the best, most efficient, use of external inputs whereas organic systems concentrate in how best to recycle resources within a more closed system (Atkinson 2006).

3.5.3. Knowledge and governance: modes 1 and 2

Knowledge is generally generated in organic systems and this, in two ways. First, in order to capture the internal dynamics of agriculture in their 'wholeness' and in relation to sustainability challenges, organic farming induces cross-fertilization between different research fields. Beyond interdisciplinarity, secondly, organic farming impacts the way of considering knowledge in a more inclusive design (transdisciplinarity) (see, (Dedeurwaerdere 2014)) as integrated agricultural knowledge systems (Freibauer et al, 2011). As underlined throughout the case studies, expertise from scientists and extra-scientific actors in the organization of the scientific agenda are combined.

This means that knowledge in organic contexts is co-produced by researchers, practitioners, civil society actors, and public administrations. How these different groups are impacted by the results of such co-production, the distribution of knowledge, technologies and resources (financial or otherwise) depends on the inter-relationships between them.

Where generally in conventional farming systems science (mode 1) is seen to concern itself with the production and validation of knowledge, which technology may then apply to production methods (thereby economic and social welfare), this outlook is now widely criticised. Here, some proponents of organic systems assert the importance of embedding scientific concerns into general innovative systems (mode 2): a part of the process rather than an independent 'starting block' (Gibbons et al., 1994; Nowotny et al., 2003; cited in McIntyre et al., 2009).

This fosters new forms of cooperation between multiple stakeholders such as citizens/consumers and enterprises, which are translated into original institutional innovations. The centrality of the involvement of multi-stakeholders in the process of making and implementing decisions within a project impacts the institutional dimension of organic farming and thereby its governance.

The European Innovation Partnership is a good example of this mode of thought (mode 2).

The European Innovation Partnership (EIP)

EIPs are new approaches within the Europe 2020 Initiative to boost research and innovation in the EU[40]. Among the five main objectives launched by the European Commission in 2012 is the EIP for Agricultural productivity and Sustainability (EIP-AGRI), governed by the European Rural Networks' Assembly. The overarching aim is to push the agriculture and forestry sector by becoming at the same time competitive and sustainable. To speed up innovation and put solutions into practice, an "interactive innovation model" is applied, where different "Operational Groups" (farmers, advisors, researchers, businesses, etc.) shall tackle problems in a joint movement. This bottom-up approach should connect researchers and practitioners in multi-actor projects as well as via the EIP-AGRI network. The EIP-AGRI Service Point was established to promote knowledge exchange, to collect and give feedback on research needs by different focus groups and to associate the various actors in seminars, workshops, social media etc. One of the first EIP-AGRI groups focussed on the optimisation of yields in organic farming[41]. (EIP-AGRI 2013)

Funding is available through the regional Rural Development Programs (RDP) as well as Horizon 2020. Organic farming and the establishment of agroforestry systems are explicitly mentioned to contribute to the key concerns of RDP's regulation (restoration and preservation of ecosystems and the promotion of resource efficiency and the shift to a low carbon economy). Agroecological farming associations should seize the chance and encourage their regional authorities to adapt EIP-AGRI and participate in the decision-making process about the content of the 2014-2020 RDP [2]. Also calls within Horizon 2020 (esp. sub-program Societal Challenge 2: "Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy") particularly refer to organic farming and offer opportunities to apply for funding on various issues. EIP-AGRI may thus be considered as a valuable and adapted instrument to promote research in organic farming.

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[40] http://ec.europa.eu/eip/agriculture/en (EIP-AGRI 2015)

[41] https://ec.europa.eu/eip/agriculture/en/content/focus-group-organic-farming-optimising-arable-yields-recommendations-and-outputs

4. Case Studies

Research for organic farming is long term and systemic. Four case studies are presented in this section. The two first ones are actions of networking and coordination at a meso-level covering different countries and sectors. Two micro-level cases are also presented to show the effectiveness of research initiatives embedded in local dynamics.

At the meso-level, we will scrutinize the CORE-organic trans-national partnership and the Danish ICROFS program. At the farming level, the two case studies are the crop-oriented, organic research and demonstration farm of the University of Kassel (the Hessian State Domain Frankenhausen) an the integrated crop-livestock farming system developed by the French *Institut National de Recherche Agronomique* (INRA) in Mirecourt (North-East of France).

4.1. CORE Organic

CORE Organic[42] is a transnational partnership joining resources within research in organic food and farming. The project part of the European Commission's ERA-NET Scheme CORE Organic stands for Coordination of European Transnational Research in Organic Food and Farming Systems. CORE Organic started as a collaboration between 11 national funding bodies in 11 European countries in 2004 (Core Organic I), increased to 26 bodies in stage II and currently has 24 member (CO Plus).

The aim of CORE Organic is to enhance the quality, relevance and utilisation of resources in European research in organic food and farming through coordination and collaboration. CORE Organic also aims to establish a joint pool for financing transnational research in organic food and farming. Public European research and development effort in organic food and farming are characterized by small research communities, often scattered and fragmented both geographically and institutionally. This generates a need for gathering the dispersed expertise into a critical mass, to maintain and increase the competitive quality and relevance of research.

CORE Organic is coordinated by the International Centre for Research in Organic Food Systems (ICROFS)[43]

[42] coreorganic@icrofs.org ; http://www.coreorganic.org/

[43] http://icrofs.dk/en/

4.1.1. Initiative trajectory

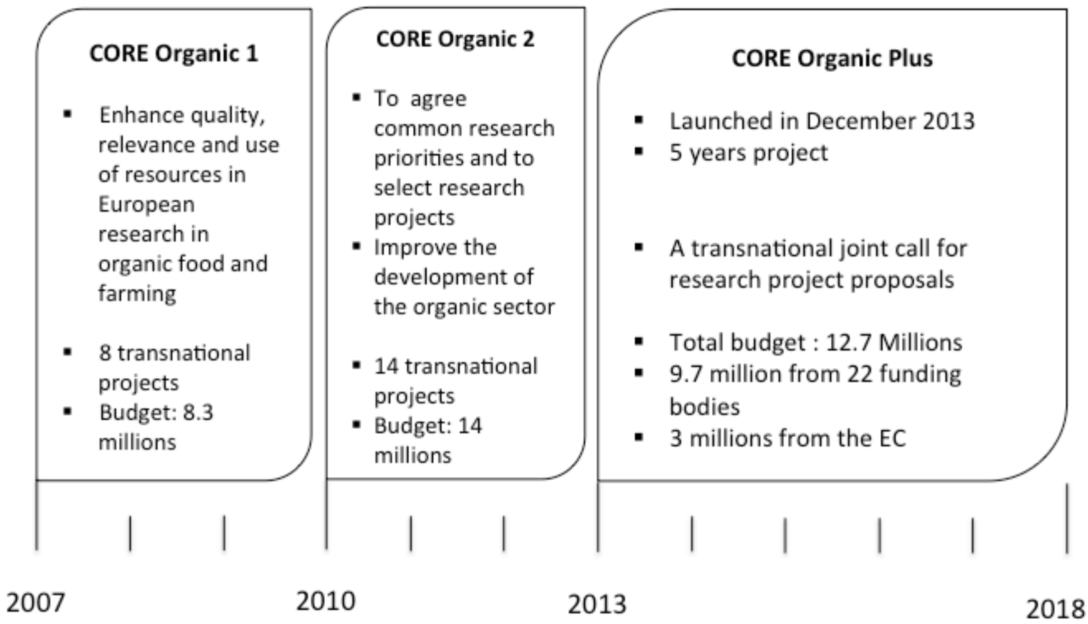

Figure 10 : Stages in the CORE Organic initiative

The CORE organic ERA net has received funding for three different stages from the EU funding programs for the co-ordination activities of the network. In addition, research calls are funded by national governments. The different stages and their aims are detailed in Figure 10 (Alföldi et al., 2010; Bertelsen personal communication)

In 2010, the CORE Organic II partner countries were asked about the political goals to support organic food and farming research. The answers were summarised as follows

- To improve the development of the organic sector (NL, PL, SL, SE, TK)
- To fulfil the market demand for organic products (EE, FI, BE, FR, IE, LV, NO)
- To use the environmental potential of organic farming (CZ, LT)
- To meet goals for the environment and market (DK, DE, IT, CH)

Organic farming is also seen as a chance to improve the income of farmers (PL), or to improve the relations between agriculture and the public as the organic sector has a good public image (NL). The possibility for trans-national collaboration is also mentioned as a reason to support such research (ES).

Several countries referred to political action plans or strategic documents related to organic food and farming when explaining their motivation. And the CORE Organic program has to also consider national research priorities when identifying organic farming related projects that gain added value through transnational research (Alföldi et al. 2010).

4.1.2. Interactions between research and practitioners

The national funding bodies participating in CORE Organic use various methods to identify research priorities for the organic sector, including stakeholder conferences or similar events as well as additional processes reflecting the past and future. Several countries have a research agenda as a basis for identifying research gaps, such as the ambition and the innovation-agenda in NL, a strategic agenda in BE, a Technology Platform in CZ or a knowledge synthesis in DK. The TP Organics Research Agenda (2009) played an important role in setting priorities for the calls under CORE Organic II.

4.1.3. Challenges

One of the challenges of CORE Organic relate to the difficult application and decision-making process, because in addition to common objectives that are reflected in the calls, national funding rules and priorities need to be considered.

Another challenge relates to the sharing of research activities and results across countries, as most research is mostly documented in national languages (Alföldi et al., 2010).

4.1.4. Impacts

The CORE Organic I evaluation of the pilot call and the recommendations made throughout the project regarding priorities, best practices and evaluation methods etc. provide continued and improved transnational collaboration between the partners (Jespersen, 2010).

Through the joint effort of national funding bodies, this ERA Net can successfully address the most important areas of common interest where organic farming and food systems need improvement in order to fulfil important objectives in terms of sustainability, food safety and quality, climate change adaptation, animal health and welfare and other important aspects of the organic food chain (Bertelsen and Halberg, 2012).

All research conducted under CORE organic is documented in Organic Eprints, an open source archive for research publications related to organic agriculture[44]. In July 2015 more than 800 items had been archived under the CORE Organic. Organic Eprints was made Open Air compliant, which means that FP7 projects with the Open Access Pilot can fulfil their obligations for Open Access by depositing their publications in Organic Eprints. This has also greatly enhanced the access to organic farming related research from FP7 projects and also several projects funded under previous framework projects have used Organic E-prints to archive the research, e.g. QLIF[45].

[44] www.orgprints.com

[45] A related second platform for knowledge exchange across Europe, unique in organic farming will be created as part of the H2020 project OK-Net Arable: http://www.ok-net-arable.eu/ .The platform will offer evidence-based advisory material as well as facilitating farmer-to-farmer learning. It is going to be a virtual meeting place for farmers, advisers and researchers that would otherwise not be able to meet. ICROFS will develop this open-access online knowledge platform, based on experiences with existing knowledge platforms and input from the other project partners.

4.2. ICROFS

In 1996, the Danish government established DARCOF, the Danish Agricultural Research Centre for Organic Farming, which coordinated several research programs in organic farming and foods. In 2008, the so-called 'centre without walls' changed into today's **ICROFS, the International Centre for Research in Organic Food Systems** with an international board. The overarching goal of ICROFS is that "the principles of organic agriculture become a global reference for sustainability in agriculture and food systems due to evidence based on research and adaptive management."[46] By managing interdisciplinary, international and user-oriented projects, ICROFS aims at providing scientific results that advance organic farming and food systems. It lobbies for the conversion of conventional into organic farming and supports sustainable development in general to face today's social challenges. Knowledge sharing is considered to be pivotal and publications are accessible online, workshops and events are organised to corroborate networking between researchers and stakeholders.

ICROFS is headed by a board of directors and advised by a Danish program committee composed of researchers, farmers and NGOs.

ICROFS coordinates the ERA-net CORE Organic (see above) and hosts and administrates Organic Eprints.

4.2.1. Initiative trajectory

The support of organic farming has concerned the Danish government since the middle of the 1980s. At that time, research was limited to private, organic farms and research stations. Still, investigations led to effective methods of organic milk production. To prioritise research on organic farming, facilitate conversion and increase organic food production, the Danish Research Centre for Organic Farming (DARCOF) was established in September 1995 by the Ministry of Food. At the same time, six research programs were initiated, together known as DARCOF I (see also *3.1.Specific National Programs for Organic Farming*). These focussed on plant breeding, soil, animal husbandry and the environment and nature.

4.2.1. Interactions between research and practitioners

Farmers are directly involved in projects. To formulate the above-mentioned research and development strategy in 2012[47], primary producers, advisors, researchers, consumers and

[46] http://icrofs.dk/en/

[47] http://icrofs.dk/fileadmin/icrofs/Diverse_materialer_til_download/Research_and_development_strategy_2012.pdf

politicians were involved from the beginning in meetings and discussions. The need to explore and develop new relations and interactions between the different participants (producers, consumers, researchers) was formulated as a future goal.

Research results are transferred to end-users and practitioners via several pathways: one important publication channel is the Landbrugsinfo[48], which is used by the Knowledge Centre for Agriculture (VFL) to keep the consultants up to date. Project results are further passed on

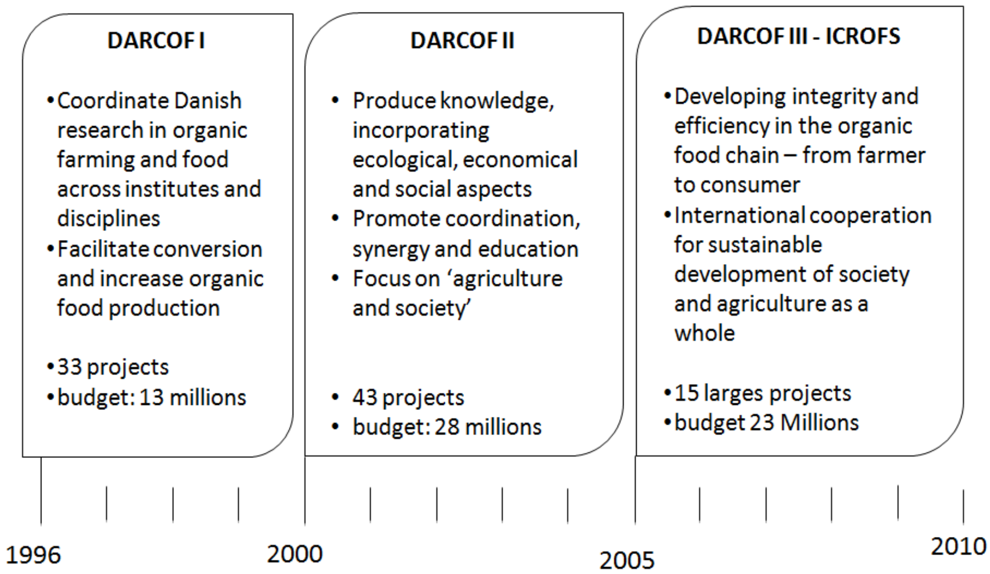

Figure 11 : Steps in the ICROFS initiative

via scientific publications, trade journals, internet and direct communication in meetings, seminars, field visits, etc. Demonstration of field experiments was considered as highly important for knowledge transfer. ICROFS further publishes newsletters in Danish and English and the external media publishes columns, technical features and notes in collaboration with the researchers (Halberg et al. 2012).

4.2.2. Challenges

A mid-term evaluation of DARCOF II (Watson et al. 2002), the advice given was to broaden the range of stakeholders in the steering committees to ensure end-user involvement. It was further encouraged to tighten the relationship to the Danish certification organization to augment certification/standard issues. Also, the inclusion of the food processing industry was proposed for possible inputs into production chain and societal aspects. Reinforcing international collaboration was another recommendation given. Looking at the primary objectives pursued in DARCOF III (see above), the suggestions had been included in the following program phases.

[48] https://www.landbrugsinfo.dk/Sider/Startside.aspx

4.2.3. Impacts

Regarding impact assessment of research for organic farming, ICROFS produced an analysis report on 15 years of research (1996-2010) based on interviews with end-users, inventories of R&D achievements for various thematic areas and documentation of the dissemination of results (Halberg et al. 2012).

In general, over the period of the three DARCOF programs, the organic sector has largely increased with for example a seven-fold increase in the number of ha cultivated and an increase in the share of organic farms from 1.8% in 1996 to 6.7% in 2010.

Interviewed advisors highlighted that research results have contributed to higher crop yields (including forage) and improved management of weeds and crop rotations, decreased calf mortality, higher milk yields and higher income from dairy cows. One specific example is the 50% reduction of the use of antibiotics (and thus, a significant reduction of costs!) in milk production through knowledge development and exchange of best practices within a network of participating farmers. Moreover, research and innovations in combined feeding and housing/outdoor keeping significantly improved health, welfare and productivity in pigs and poultry.(Andreasen, Rasmussen, and Halberg 2015; Halberg et al. 2012).

4.3. Hessian State Domain Frankenhausen (Germany)

In 1998, the Hessian state domain Frankenhausen[49]: was converted from intensive conventional farming into organic farming and since then serves as a research and demonstration farm of the University of Kassel. Today, 230 ha of the farm serve as cropland and about 35 ha have been converted into meadows and pastures. The rest is re-leased or serves as experimental areas (~40 ha), where research and demonstration plots with old cultural plants and a vegetable self-harvesting project are integrated. There is a dairy cattle herd of about 100 cows, 600 laying hens and a herd of free-range gees (only from June to December).

The central aim is to serve as a model for ecological, economical and socially sustainable management following these objectives[50]

- Sustainable and efficient production of healthy food in agreement with landscape ecological purposes
- Integration of agricultural and technical manufacture and commercial processes to add value to the local region
- Creation of employment appropriate for human life
- Facilitation of the communication between the community and the land, science and praxis, business and the region
- Development of conscience and transparency for food and its production via a holistic approach
- Trial and realisation of alternative energy concepts to develop an energetically autarkic agricultural business

[49] https://www.uni-kassel.de/fb11agrar/fachgebiete-einrichtungen/lehr-und-versuchsbetrieb-hessische-staatsdomaene-frankenhausen/startseite.html

[50] https://www.uni-kassel.de/fb11agrar/fachgebiete-einrichtungen/lehr-und-versuchsbetrieb-hessische-staatsdomaene-frankenhausen/allgemeines.html

Goals of nature conservation have not been integrated as top-down-approach to landscape planning, but a participatory approach is implemented to inspire the farmers who run the farm to follow the aims of the project (Van Elsen 2000).

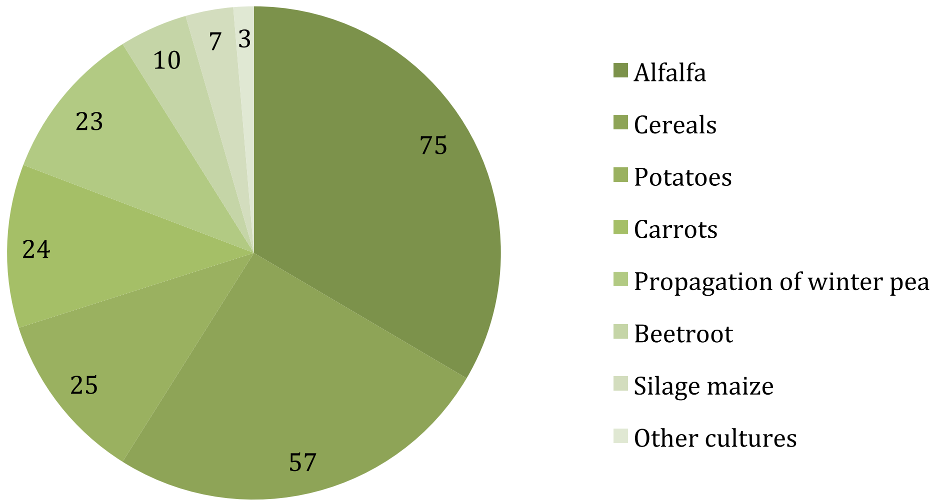

Figure 12 : Hessian state Domain Frankenhausen - Area of the different field crops (in ha) in 2012[51]

4.3.1. Initiative trajectory

The area had been under cultivation since the middle of the 17th century. At the beginning of the 19th century, sheep and dairy cattle prevailed while after 1870 more dairy cattle were introduced and parts of the farm were converted into potato and beet root farming. The farm was quite diversified until the 1970s, when intensive production of cereal seed and beet-root started. At the time, it was one of the most productive businesses in the region. As crop rotation practices were increasingly abandoned, along with structural elements, near-natural areas decreased and the farm lost its social, economic and communicative connections to the neighbourhood. In this condition, the domain was taken over by the University of Kassel in 1998. A two-year pilot study documented the actual condition of the highly productive farmland and developed a participatory action plan for the integration of nature conservation into the farm business. In 2006, a program implementing measures to restore permanent structural elements on the farmland was finally initiated with financial support by the German Federal Agency for Nature Conservation with funds from the Federal Environmental Ministry (Godt et al. 2007).

[51] https://www.uni-kassel.de/fb11agrar/fachgebiete-einrichtungen/lehr-und-versuchsbetrieb-hessische-staatsdomaene-frankenhausen/wirtschaftsbetrieb/betriebsspiegel.html

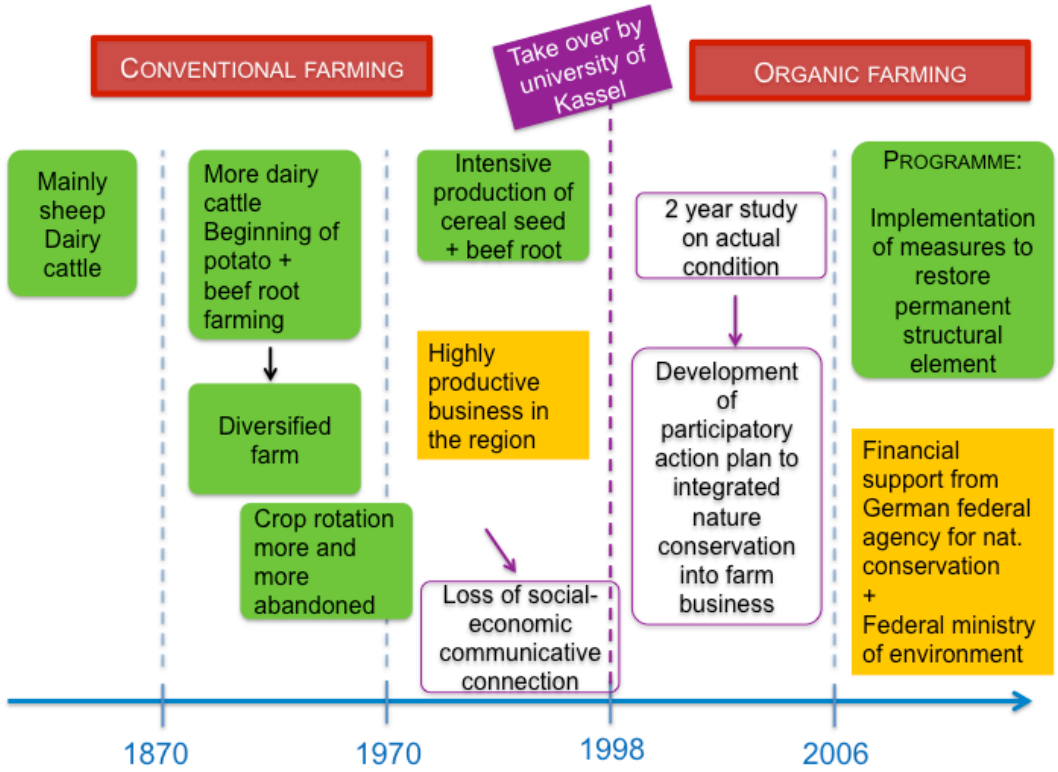

Figure 13 : A schematic history of the Domain Frankenhausen

4.3.2. Interactions between research and practitioners

The centre of the entire interdisciplinary project is the agricultural business, with part of the area serving explicitly for experimental research. Four groups of different actors interact: farmers integrating the measures into the cultivation, experimental technicians implementing the measures, researchers accompanying the measures and project leaders responsible for the project management. A participatory approach is deployed for any decision and development processes (Baumgart and Van Elsen 2007). An intense exchange via joint manufacturing and marketing with farms in the region guarantees the knowledge transfer of scientific findings into praxis. Public awareness is also raised through 'field days', 'barnyard parties' and action days. Those interested can cultivate organic vegetables on specific plots for a seasonal fee ("self-harvest-gardens").

4.3.3. Challenges

Major challenges for the participatory approach are the different objectives pursued by the participants (project leaders, researchers, technicians) and the farmers concerned. While the researchers aim at an optimisation of measures to conserve nature, the farmers fear that these might have negative effects on costs (also in terms of labour time) and profitability. Even if the overarching concept to act as a centre for teaching, trial and transfer including the goal to create a cultivated landscape had been well established during the conversion of the farm, a common identity of all participants is missing. A high amount of flexibility and attention to clarify the various goals and roles is therefore necessary to guarantee the success and sustainability of the nature conservation project (Halberg et al. 2012). Those measures, where initial conflicts could be resolved, which are outside the farmed areas, where a positive impact on nature is clearly visible, or where the conservation issues are valued to be solved, were the easiest accepted and pursued in the long run (Baumgart and Van Elsen 2009). Such confrontational processes may seem laborious and required the patience and willingness of all participants to be resolved. It has been shown, however, that they were fruitful for long-term ecological ambitions since new alternatives were developed that build on common agreement (Jonuschat et al. 2007).

4.3.4. Impacts

A project (BÖL-funded) from 2004-2007 investigated the potential of winter peas as a harvest crop in terms of winter hardiness and their value for cultivation in organic farming.

The winter pea had been neglected (due to soybean imports and the increasing input of mineral fertiliser). However, especially for organic (but also for conventional) farming, the winter pea has various advantages: weeds are effectively suppressed and soil erosion during winter is reduced (Graß 2003); yields are more stable compared to the summer pea (Stelling 1996); and even potential yield is higher (Charles 2001). Winter peas can be used as protein-rich green fodder or as a renewable resource e.g. for biogas-plants in two-crop systems (Urbatzka et al. 2007). The project found that yields and quality were comparable to the summer pea but weed emergence was minimal (Urbatzka et al. 2008; Urbatzka et al. 2007). It further established varieties showing enough resistance to frost to be cultivated under German weather conditions.

Before the start of the project, the area for grain legumes had been continuously decreasing in Germany. For example, the list of varieties of the 'Bundessortenamt' (German National Office) does not include the winter pea but a so-called winter arable bean. Its propagation area for 2003 is given as 2 ha (Vogt-Kaute 2004).Ten years later, the propagation area of the winter pea (variety E.F.B 33) has tremendously increased to over 270 ha (Bundessortenamt 2014)[52].

4.4. The low-input crop-livestock farming system in Mirecourt (France)

Ten years ago, the French *Institut National de Recherche Agronomique* (INRA) launched the research unit Agro-Systems, Territories and Resources (ASTER) in Mirecourt (Northeastern France). The ASTER research unit, involving about 40 people (engineers, researchers, PHD students, etc.), is working on three topics relating to sustainable agriculture at different dimensions: the use of biomass for energy production, the conservation and restoration of water (both at a regional level), and the implementation of a low-input crop-livestock farming system (at the farm level). Since the farm initially applied conventional dairy practises, it represents an interesting case of conversion to organic farming[53] followed step-by-step by scientists.

Currently, the 100 cows produce between 450,000 and 600,000 litres of organic milk per year. The 240 ha experimental farm is divided into two sub-systems: a livestock-grazing sub-system and a multi-crop-livestock sub-system. The livestock-grazing sub-system produces spring and

[52] http://www.bundessortenamt.de/internet30/fileadmin/Files/PDF/BlfS_2014_10.pdf

[53] For an overview of the conversion to organic issue, see Lamine and Bellon (2009).

summer milk and the 40 cow herd is fed on the hay provided by 78 ha of permanent grazing. The second sub-system comprises of 60 cows also producing milk. However, in order to complement the former, this is produced during autumn and winter. Here, chaff and grains (such as alfalfa) are produced for the livestock and cereals (milling wheat, spelt, rye and barley) for direct commercial purposes.

These two sub-systems are autonomous but interconnected in order to enhance the sustainability of the system as a whole. While the multi-crop-livestock sub-system provides chaff and grains for the livestock-grazing sub-system, the latter provides manure for the former in order to preserve the internal fertility.

Contrary to a conventional system that aims at optimising economies of scale through specialisation, the Mirecourt farming system favours the economy of scope in order to minimise the need for external inputs (Bonaudo et al. 2013). The backbone principle is 'get the best of contextual resources', limiting external inputs to fuel, electricity, seeds and some alternative veterinary drugs, thereby gaining in autonomy. Accordingly, the farming methods are adapted to the context and not (universally) implemented in accordance with the standard approach.

4.4.1. Initiative trajectory

Mirecourt has been converted from conventional to organic farming in three major steps. Before 1985 being still conventional, high petro-chemical inputs were necessary. From 1985 to 2004 during a transitory phase, the objective was to limit such inputs in order to achieve self-reliance. After 2004, the system finally shifted to organic and self-sustained farming.

While before 1985 the main objective was increasing or at least stabilizing farm yield thanks to external inputs, since then, it has been gaining self-reliance from these inputs.

Amongst other things, this new business model is characterised by a re-localisation of production with respect to the availability of contextual resources and, in terms of farming practices, by the increase of the integration between livestock and crop farming sub-systems. Besides, economically speaking and comparatively to the previous system, food productivity has decreased but the gross operating profit has significantly grown (Coquil, Béguin, and Dedieu 2014).

During this conversion two main elements have contributed to capacity building: on the one hand, the technical and financial support of the INRA and on the other, internally to the project, the multi-stakeholder participatory approach.

4.4.1. Interactions between researchers and practitioners

Each year, 800 to 1,000 people (farmers, scientists and institutional actors) visit the farm and thereby interact with Mirecourt's researchers. These numerous exchanges, as argued by the ASTER's director, allow for discovering that other agricultural models privileging autonomy and resilience while achieving relative profitability exist. In that sense, organic agriculture is redefined as a driver for socio-technical innovations and a field of opportunities rather than a set of restrictive norms.

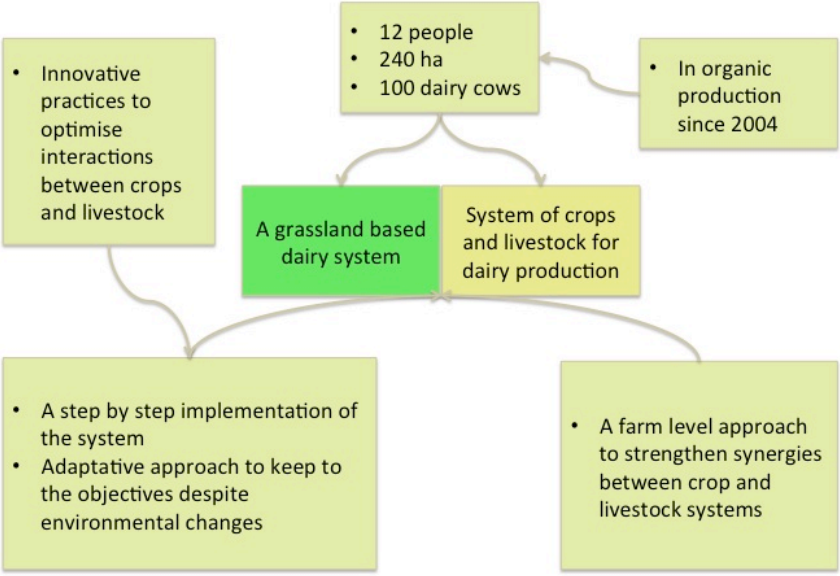

Figure 14 : Key elements in the success of the experimental INRA station in Mirecourt (France)

Besides, at a regional level, some scientists in Mirecourt lead a meta-research project involving nine commercial farms situated in the West of France and affiliated to the National network, the *Réseau Agriculture Durable*[54] (Coquil et al. 2014). The sample has been chosen on the basis of three criteria: its heterogeneity in terms of farming practices and, regarding farm promoters, the fact that they were willing to convert to organic farming and to participate to time-consuming meetings. These exchange meetings between farmers and scientists are considered central to the research design since the "real" practices of the former in their social and technical aspects are seen as the foundations for change.

4.4.2. Challenges

According to the project managers at Mirecourt, the challenge is primarily political. Indeed, the developing of alternative models favouring self-reliant agro-systems is a difficult political choice in a context in which conventional agriculture is overwhelming dominant. For example, within the INRA, it is worth mentioning that of the 50 experimental projects in France, the Mirecourt experiment is the only one which is 100% organic.

However, the challenges are also strikingly technical. Indeed, sustainable agriculture in a more holistic fashion challenges conventional ways of doing and technical reference points. For instance, in Mirecourt, the principle of autonomy (rather than the principle of maximising dairy yield thanks to the use of external inputs) requires considerable management of chaff stock. This variable stock, depending on fluctuating annual weather conditions, must be made to correlate to the relative inertia of herd size. This, in turn, re-questions usual technical norms relating to, for example, calf feeding length, cow weight and crop rotation.

[54] http://www.agriculture-durable.org/

This exploratory mode of innovating in relation to a more integrated farming design, in turn, stresses a need for participatory governance between the different stakeholders involved in the project. Accordingly, in Mirecourt, numerous team meetings in which, the technician's point of view matters just as much as that of the scientists allows for capacity building.

4.4.3. Impacts

4.4.3.1. Economics

In terms of economics, in comparison with the conventional dairy system previously implemented in Mirecourt, the revenues are much the same. The inferior volume of milk production is compensated for by the higher market price of organic milk. However, beyond raw yield, it is worth mentioning that, for each sub-system, the gross operating profit (GOP) represents around 50% of the turnover although for conventional farming the reference in France is around 30% (Coquil, Béguin, and Dedieu 2014).

This impressive surplus is due to the limitation of using external inputs, which, in turn, induces particularly low operating costs. As the agro-economist in charge at Mirecourt puts it, this economic performance illustrates the potential capacity of farmers to tackle the issue of profitability via the reduction of costs rather than the question of selling prices over which they have little control. Furthermore, on the basis of these operational results and also according to French wage policy, each sub-system allows on average for three decent salaries.

Table 11: **Mirecourt annual financial Results (on average from 2005 to 2013) in Euros**

		Livestock-grazing sub-system	Multi-crop livestock sub-system	Whole system
Operating revenues		126,700	277,963	404,663
Expenses	Operating	13,937 11%	47,253 17%	61,190 15%
	Overheads	49,413 39%	105625 38%	155,038 38%
Gross operating profit		63,350 50%	125,083 45%	188,433 47%
Labour	Workload	1 F-T eq. (*)	2 F-T eq.	
	Wages (**)	3 persons	3.5 persons	

Legend: (*)Full-time equivalent, (**), On the basis of 1,600 Euros net (charges included), percentages of the operating revenues

Source: Own summary based on the filmed atelier on Mirecourt economic impacts

4.4.3.2. Environment

In considering the relations between the farm and its ecosystem, land use has been defined as a catalyst for environmental diversity. For instance, hedgerows, wooded strips and seven hectares of forest have been maintained or replanted. In order to evaluate the environmental impacts of such a system on biodiversity, the population of birds and carabids present on the site are qualitatively and quantitatively monitored. For instance, 110 species of carabids have been identified since 2007. These predatory beetles are used for pest and weed management.

4.5. Elements of success of organic farming research initiatives

These initiatives at farm level feature five elements: (i) the willingness of bottom-up coordination; and thereby, (ii) the implication of farmers and other stakeholders; (iii) the progression from technical 'business-as-usual' solutions to an integrated approach to farming systems rooted in sustainability concerns; (iv) the openness for sharing through diffusion; (v) the adaptation of innovative processes to the context.

Table 12: Main dimensions of micro-level initiatives

	Frankenhausen	Mirecourt
Coordination	Participatory approach for farmers and researchers	Inclusive making decision process between management, technicians, scientists
Actors	Farmers, experimental technicians, researchers and project leaders	Meta-research project involving 9 commercial farms;
Sustainability	Sustainable and efficient production in agreement with nature conservation, innovation of energy concepts	Coupling economic performance and socio-environmental impacts (innovation in terms of indicators)
Diffusion	Intense exchange with farms in the region	800 to 1,000 diverse visitors a year (horizontally) and vertical diffusion to INRA
Adaptation	A centre for teaching, experiments and transfer for organic farming and sustainable development of the region	A leitmotiv in Mirecourt for gaining autonomy from external inputs

CONCLUSIONS

The general findings of this report on the research into organic farming are paradoxical.

On the one hand, investment in organic research compared to biotechnological research both at the European level and at the National level considering the four countries studied remains marginal.

On the other, scientific evidence shows the potential of organic farming as an alternative to conventional farming. This is particularly relevant in a context in which the productivity of the latter is reaching a limit and this, despite huge investment in research and the intensive use of fossil energy and non-renewable inputs. Further, given the structural constraints of European farming, it appears promising for European farms to establish themselves as leaders in biological and social diversity with pioneering farming systems based on organic and agroecological principles. In addition, the participatory vision of research at work in organic farm systems generating a collective assessment of problems and a co-design of solutions appears to be a promising means to tackle contemporary agro-food challenges.

Organic farming is thereby relevant and profitable at both the farm level and for society as a whole as a driver for socio-technical innovations and a field of opportunities.

Therefore, increased investment in research into organic farming will help to provide some answers to many of the environmental and social issues in our farming systems.

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Annex

Investment in organic farming research and agricultural biotechnology research - Methodology

a. Agricultural research and innovation in the European Union

4.5.1.1. Framework Program 5

The available database (cordisfp5complete.xls) contains 16.038 projects, of which the large majority (10.469) ends after 2002. The available entries for funding by the EU sum up to 12.267 Mio€, i.e. almost 90% of the official budget (13.700 Mio€). CORDIS lists 999 projects for the subject agriculture within FP5. In the corresponding Excel-file, ~one third are not classified according to subjects, thus, several keywords were used searching the title and objectives of the projects to filter projects dealing with agricultural issues:

agricultur/farm/crop/livestock/ aquaculture/horticult/ vegetable/agro/animal/plant/genetic/

Titles and objectives were manually scanned afterwards to avoid classification errors. Of the resulting list, those were excluded without dates or financial contributions available. As a result, 1.332 projects were found for agriculture in total. Of these, those ending before 2003 were excluded, resulting in 928 projects. It was then noticed that several projects lasted for extremely long time (e.g. until 2086!). The maximum funding period for FP6 and FP7 is 7 years, thus, all projects within FP5 with longer lasting funding were checked at: http://www.ist-world.org/default.aspx and dates corrected in ALL CASES!!!!!! (thus, there may be more mistakes…). Eighteen projects ending before 2003 were further excluded, resulting in the final list of 909 projects.

4.5.1.2. Framework Program 6

The database as downloaded from http://open-data.europa.eu/en/data, file fp6proj201504.xlsx, contains 10101 projects. When searching for FP6 projects on the CORDIS website (http://cordis.europa.eu/search/advanced_en?projects), one receives however a list for 28 867 projects, of which only 260 should be considered as agricultural research. Thus, a substantial part of the projects might be missing from the provided excel-file!

Filtering the subject for AGR led to only 73 projects concerning agriculture, but more than half of all projects (6496 out of 10101) were not classified according to subjects. These were searched for the keywords in title or objectives as for FP5 and titles and objectives manually scanned afterwards, resulting in 353 projects for agriculture in total.

4.5.1.3. Framework Program 7

The file fp7proj201504.xlsx contains 25610 projects, while CORDIS lists 24029 on their web site (with 293 for agriculture). The list first looks quite complete. However, when summing up the budget for all projects (48 projects are without costs), a total of 29.743 Mio€ results, i.e. only 60% of the official budget. It seems therefore that a large part of projects is not registered in any of the databases.

Projects in the excel file were filtered for the subject containing AGR or ABI. Of the 25610 projects listed, more than half did not contain a subject for classification. As above, these were searched for the corresponding keywords in title or objectives and titles and objectives manually scanned afterwards. Further, all projects starting only in 2014 or later were excluded, resulting in a final list of 367 projects.

4.5.1.4. Identification of biotech or organic projects

To search and classify projects on agricultural biotechnology, the projects were first filtered for 'biotechnology' (FP5), 'BIO' (FP6) or 'ABI' and 'BIO' (FP7) in the subject. Further, titles and objectives were filtered for the following keywords: biotechnol, GMO, genetic, genome, transgen, molecular, vaccine, marker, DNA, In vitro, metabol, microbi.

To filter for organic projects, titles and objectives were searched for: organic, low input.

The resulting projects were cross-checked with http://www.organic-research.net/transnational-projects/european-projects.html and reports published by the EU:

A decade of EU-funded low-input and organic Agriculture Research and A decade of EU-funded GMO research (2001 - 2010)

4.5.1.5. Calculation of yearly budget

The allocated funding by the EU was divided onto 'annual budget' by the number of years a project was running. Regardless whether a project started or ended in January or December of a given year, that year was counted. This annual budget was then spread over the according years a project was running and summed up for all projects to give a – maybe rather – imaginary sum that the EU spent per year. This method is very systematic and does therefore not consider that maybe projects received the entire budget in the first year or any other possible partitioning. For FP7, where a large part of the projects continue after 2013 when the study ends, this leads to a budget of over 400 Mio€ (39%), which is – according to our calculations – spent after 2014 and therefore not included in the table and figure.

b. Fisaonline-catalogue, Germany

Fisaonline.de lists the different projects in several excel-tables, ready for download. All tables dealing explicitly with agriculture (excluding fisheries and aquaculture, forestry, nutritional science, food technology) were examined and combined. This resulted in 15,728 projects. Of those, 7196 included monetary values (46%). They were filtered for the projects funded between 2003 and 2013 (6,417 projects). Then 2,800 duplicates were eliminated (searching for all criteria being the same but discipline).

This resulted in a final list of 3,617 projects, summing up to 1.484.673.597 €. They were then classified into biotechnological projects via the discipline "Biotechnology/genetic resources/plant breeding", and via titles containing:

geneti, genom, gentechn, molekul, mikrobi, GMO, transgen, Marker, DNA, In vitro, Metabol, zücht, klon, virus, viral;

Titles were manually checked for errors.

To classify for organic projects, the discipline "Ökologischer Landbau" was considered and titles were searched for "ökolog".