Final report

for the CORE Organic Cofund funded project

"MIX-ENABLE: MIXEd livestock farming for improved sustaiNABiLity and robustnEss of organic livestock"

Period covered: 1 April 2018 - 31 September 2021

CORE Organic Cofund is an ERA-NET funded by the European Commission´s Horizon 2020 Framework Programme for Research and Innovation Contract No. 727495. Project period: December 2016 - May 2022

Index

1. General information

1.1 Project information

Project information			
Project acronym	MIX-ENABLE	Project ID	
Project title	MIXEd livestock farming for improved sustaiNABiLity and robustnEss of organic livestock		
Project website	https://projects.au.dk/coreorganiccofund/core-organic-cofund-projects/mix-enable/		
Details of the project coordinator			
Name	Martin	First name	Guillaume
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Institution	INRAE	Country	France
Start of project	1st of April 2018	End date of project	31st of March 2021
Duration in months	42	New end date in case of a project extension due to COVID-19	30th of September 2021

1.2 Consortium

Partner no.	Country	Institution/ organisation name	Type of institution/ organisation[1)]	Functions[2)]	Involved in WPs	Contact person[3)]
1	France	INRA – Institut National de la Recherche Agronomique	Public Research Centre	PC + WPL	1, 2, 3, 4, 5, 6	guillaume.martin@inra.fr
2	Switzerland	FiBL - Research Institute of Organic Agriculture	Public Research Centre	WPL	2, 3, 4, 6	steffen.werne@fibl.org
3	Italy	Tuscia University - Department of Science and Technology for Agriculture, Forestry, Nature and Energy	University	P	2, 3, 6	ronchi@unitus.it
4	France	IDELE - Institut de l'élevage	Other (association)	P	2, 6	pierre.mischler@idele.fr
5	Belgium	CRAW - Walloon Agricultural Research Centre	Public Research Centre	WPL	2, 3, 4, 6	m.moerman@cra.wallonie.be
6	Austria	BOKU - University of Natural Resources and Life Sciences, Vienna	University	P	2, 3, 5, 6	christoph.winckler@boku.ac.at
7	France	ITAB - Institut Technique de l'Agriculture Biologique	Other (association)	WPL	6	olivia.tavares@itab.asso.fr
8	Germany	Forschungsring e.V.	Private Research Centre	P	2, 3, 5, 6	brock@forschungsring.de
9	Sweden	SLU - Swedish University of Agricultural Sciences	University	WPL	2, 3, 5, 6	david.parsons@slu.se
10	Germany	TI-OL - Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Organic Farming	Public Research Centre	P	4, 6	kerstin.barth@thuenen.de

University, Public research centre, Private research centre, Company, Other
PC = Project coordinator, WPL = Work package leader, WPCL = Work package co-leader, P = Participant
inclusive e-mail address

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2. Summary

2.1 Final project summary suitable for web publication for a wider audience

Multi-species livestock farming consists of keeping two or more animal species – or more generally combining different animal production units – on the same farm. It was often proposed as a solution towards higher sustainability of livestock farms but in practice although the proof of evidence was limited. This is why in MIX-ENABLE, our objective was to develop the knowledge base on organic multi-species livestock farms. To do so, we combined several approaches:

We synthesized potential benefits and limitations of multi-species livestock farming for farm sustainability from existing literature. We showed that multi-species livestock farming has the potential to improve the five dimensions of farm sustainability reviewed: resource-use efficiency and conservation, animal health and welfare, productivity, profitability and human welfare; as long as locally relevant farming practices are used, especially an appropriate stocking rate during grazing.

We conducted a desktop analysis of specialized and multi-species organic livestock farms. We compared 3 farm samples from France over the period 2000-2016: farms specialized in one ruminant species (219 farms), farms with two ruminant species (44 farms) and farms with ruminants and monogastrics (17 farms). We showed that multi-species farms, especially those combining ruminants and monogastrics, tend to have a higher and more stable income (in the range 506-532 €/ha against 338-455 €/ha with a coefficient of variation in the range 43-49% against 59-80%) but create higher N surplus (in the range 32-77 kg N/ha against -3-3 kg N/ha). Overall it showed that the theoretical benefits of multi-species livestock farming often reported in the literature are not systematic.

We surveyed 127 farms to collect data on key aspects of farm structure, crop, pasture and livestock management, raw material inflows and outflows, economics and social data (satisfaction of the farmer, workload). Data on strengths and weaknesses, opportunities and threats perceived by farmers were also collected to identify the levers and barriers to the development of organic multi-species livestock farming. After cleaning and verification, data on 102 farms were organized in a database from which we showed among other things that 6 out of 86 farms that outperform their peers (based on four indicators) despite having the same resources and constraints. They have very different sizes and enterprise combinations but all have a strong autonomy for feed and strong interactions among farm activities. They also very often practice direct sales and have set up a satisfactory work organization, both intra-farm and with local networks.

Using experimental trials, we showed that: (i) when sequentially grazing young dual-purpose steers with lambs, next to the well-established effects on lambs, no benefits but also no disadvantages for steers were observed, neither in terms of parasite egg excretion nor in daily weight gains; (ii) when co-grazing beef cattle batches and sheep flocks, mixing species seem to be profitable for sheep with no effects on cattle: all the lambs could be finished at pasture before winter whereas 10% of the lambs from the solitaire sheep flock had to be finished indoor. Lambs and ewes in mixed flock also excreted less parasite eggs; and (iii) when rearing cattle and broilers on the same pasture, losses of broiler chickens due to predatory birds were reduced.

Farm simulation modelling were conducted over four French farms surveyed using Orfee, a bio-economic model that optimizes a function of net income under market and policy variability. Simulations showed that the risk associated with 70% reduction of grassland yield was by far the highest. Three of the four farms had significant risk of negative income for the baseline situation. The reduction of stocking rate reduced

variability of income in all cases, nonetheless it did not remove the probability to have very low income. The introduction of a pig enterprise and the replacement of beef with dairy did not much reduce the variability but increased income and consequently reduced farm vulnerability.

Various communication and dissemination items have been produced including an educational toolkit stimulate students' learning on organic multi-species livestock farming.

2.2 Process update of the whole project

The project achieved nearly all of its objectives, as can be seen from the below lists of milestones and deliverables. The main deviations occurred in WP5 and WP6 and were related to participatory and dissemination activities that were impossible during the second half of the project due to the Covid-19 related rules applying across all partner countries.

3. Outcomes of the project

3.1. Main results, discussion, conclusions and fulfilment of objectives

WP1	*Project coordination*

WP leader: Guillaume Martin (INRAE)
Responsible partners: INRAE

Overall summary of main results, discussion and conclusions of WP1
The coordinator has ensured that the project progressed in line with the work plan, with regard to milestones, deliverables, and planned resources. He has tried to optimize the organization e.g. for project meetings, notably during the time-period with Covid-19 constraints that did not allow physical meetings. He has steered the project to address all unexpected situations, be these scientific, technological, environmental, or political.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

This WP was for internal purpose to ensure that the project progressed in line with the work plan.
The kick-off and first annual meeting were organized as planned and were fruitful leading to key decisions for the project e.g. a distribution of farm data analysis in WP3. Unfortunately, all other meetings took place remotely.

Meeting	**Location**	**Dates**
Kick-off	Toulouse, France	April 2018
Annual meeting 1	Darmstadt, Germany	April 2019
Annual meeting 2	Webmeeting	April 2020
Annual meeting 3	Webmeeting	September 2020
Annual meeting 4	Webmeeting	March 2021
Final meeting	Webmeeting	September 2021

The steering committee meetings took place as expected. No critical points had to be tackled.
Whenever needed, decisions on important adjustments to the project plans were discussed collectively e.g. when we decided to change the way of registering and integrating the farm survey data by switching from Kobo to a solution based on Excel and R.

B- fulfilment of objectives:

Objectives of this WP fulfilled as expected with the achievement of all milestones (project meetings) in due time. Objectives of the project fulfilled as expected with the achievement of milestones and deliverables planned in all cases but two (cancelled due to impossibility to organize participatory and dissemination activities) and sometimes with some delay due to Covid-19 related constraints in most cases.

WP2	*Characterization of organic mixed livestock farms in Europe*

WP leader: Marie Moerman (CRAW)
Responsible partners: CRAW, BOKU, FIBL, Forschungsring, IDELE, INRA, SLU, Tuscia Uni.

Overall summary of main results, discussion and conclusions WP2

In WP2, we aimed to characterize organic multi-species livestock farms in Europe. We implemented 3 different approaches towards this overall aim. 1) We synthesized potential benefits and limitations of multi-species livestock farming for farm sustainability from existing literature and listed research challenges related to it. We showed that multi-species livestock farming has the potential to improve the five dimensions of farm sustainability reviewed: resource-use efficiency and conservation, animal health and welfare, productivity, profitability and human welfare; as long as locally relevant farming practices are used, especially an appropriate stocking rate during grazing. We identified four research challenges. i) Characterize better the management of mixed-species livestock farms. ii) Explore further the complementarity of livestock species on multi-species livestock farms. iii) Assess better the sustainability of multi-species livestock farm scenarios. iv) Characterize conditions for success of and obstacles to multi-species livestock farming. 2) We conducted a desktop analysis of specialized and multi-species organic livestock farms to compare their respective benefits and drawbacks in terms of sustainability and robustness. From the data on livestock farms owned by Inosys Réseaux d'Elevage, we compared 3 farm samples over the period 2000-2016: farms specialized in one ruminant species (219 farms), farms with two ruminant species (44 farms) and farms with ruminants and monogastrics (17 farms). Conclusions show that multi-species farms, especially those combining ruminants and monogastrics, tend to have a higher and more stable income (in the range 506-532 €/ha against 338-455 €/ha with a coefficient of variation in the range 43-49% against 59-80%) but also a lower economic efficiency (in the range 31-35% against 35-45%) related to a higher dependency on feed inputs that create higher N surplus (in the range 32-77 kg N/ha against -3-3 kg N/ha). 3) Through several web meetings, we designed a survey guide to collect the data required for the calculation of 107 indicators and analysis of multi-species livestock farms in WP3. We surveyed 127 farms to collect data on key aspects of farm structure, crop, pasture and livestock management, raw material inflows and outflows, economics and social data (satisfaction of the farmer, workload). Data on strengths and weaknesses, opportunities and threats perceived by farmers were also collected to identify the levers and barriers to the development of organic multi-species livestock farming. After cleaning and verification, data on 102 farms were organized in a database publicly available at DOI:10.15454/AKEO5G.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

T2.1: We synthesized potential benefits and limitations of multi-species livestock farming for farm sustainability from existing literature and listed research challenges related to it (https://doi.org/10.1016/j.agsy.2020.102821). We showed that multi-species livestock farming has the potential to improve the five dimensions of farm sustainability reviewed: resource-use efficiency and conservation, animal health and welfare, productivity, profitability and human welfare; as long as locally relevant farming practices are used, especially an appropriate stocking rate during grazing. To further the spread of multi-species livestock farming, we identify four research challenges of interest to the scientific community. 1) Characterize better the management of mixed-species livestock farms from three perspectives: farming practices (i.e. co-management vs. segregated management), work organization (i.e. versatile vs. specialized workers across enterprises) and sales management (i.e. similar vs. segregated sales channels among enterprises). 2) Explore further the complementarity of livestock species on multi-species livestock farms. 3) Assess better the sustainability of multi-species livestock farm scenarios (current or alternative) according to the management practices used and production conditions, which requires adapting existing methods/models or developing new ones. 4) Characterize conditions for success of and obstacles to multi-species livestock farming along the value chain from production to consumption, considering chain actors' objectives, work habits and constraints.

T2.2: We conducted a desktop analysis of specialized and multi-species organic livestock farms to compare their respective benefits and drawbacks in terms of sustainability and robustness (https://orgprints.org/id/eprint/36705/). From the data on livestock farms owned by Inosys Réseaux d'Elevage, we compared 3 farm samples over the period 2000-2016: farms specialized in one ruminant species (219 farms), farms with two ruminant species (44 farms) and farms with ruminants and monogastrics (17 farms). In this network no data are available on farms specialized in monogastrics as the network focuses on ruminant livestock. To avoid any bias related to the importance of cropping activities in the farms, we further split each group according to land use i.e. pasture-based farms, farms having less than 15% of crops in the UAA, and farms having more than 15% of the UAA as crops. Conclusions show that multi-species farms, especially those combining ruminants and monogastrics, tend to have a higher and more stable income (in the range 506-532 €/ha against 338-455 €/ha with a coefficient of variation in the range 43-49% against 59-80%) but also a lower economic efficiency (in the range 31-35% against 35-45%) related to a higher dependency on feed inputs that create higher N surplus (in the range 32-77 kg N/ha against -3-3 kg N/ha). This was the very first large-scale comparison of multi-species livestock farms with specialized farms. Overall this report shows to scientists and practitioners that the theoretical benefits of multi-species livestock farming often reported in the literature are not systematic and that researchers should put more efforts into clarifying the conditions (especially regarding the management of crops, pastures and livestock) to achieve those benefits.

T2.3: Through several web meetings, we designed a survey guide to collect the data required for the calculation of indicators and analysis of multi-species livestock farms in WP3. We surveyed a sample of 128 European organic multi-species livestock farms located across seven countries – Austria, Belgium, France, Germany, Italy, Sweden and Switzerland – and covering a large range of livestock species combinations. We recorded 1574 variables as raw data out of which we calculated 107 indicators describing farm structure, management and several sustainability dimensions: resource use efficiency and conservation, animal, land and work productivities, animal and human welfare. After technical validation of the data, we withdrew 26 farms and the database covers 102 farms. This database is well suited to unveil relationships between various dimensions of organic multi-species livestock farm sustainability and their structure and management. It can help reveal sustainable strategies for organic multi-species livestock farming systems and understand levers or barriers to their development. It is publicly available at DOI:10.15454/AKEO5G and further details are available in a data paper (https://doi.org/10.3389/fsufs.2021.685778).

B- fulfilment of objectives:

WP2 had a four-fold objective:
- Review the literature (scientific, grey and technical) on multi-species livestock farms and on indicators to assess the sustainability and robustness of complex agricultural systems.
- Conduct a desktop analysis of specialized and multi-species organic livestock farms to compare their respective benefits and drawbacks in terms of sustainability and robustness.
- Survey organic multi-species livestock farms to collect technical, economic and social data.
- Integrate the collected data in a database shared by all project partners.

The literature review (D2.1) has been published in Agricultural Systems. The desktop analysis has been conducted and the results have been reported in D2.2. The farm surveys have been completed and the database (D2.3) has been published.

A few adjustments are to be noted however:

T2.2: Originally, we had planned a comparison of desktop data from specialized and multi-species farms across all Europe. All partners looked for data in their own countries but it came out that only in France there was sufficient data to conduct the comparison from a technical and economic perspective. In other countries, only data on farm structures was available. Thus we decided to focus on France to conduct the comparison.

T2.3: Originally, we had planned to survey for each country a limited number of livestock species combinations with at least a ruminant species on the farm, a secondary ruminant or monogastric species. Horses are considered only as a third species as most horses are not kept for food production.

Types of farms surveyed or experimented in each partner country (BC: beef cattle; DC: dairy cattle; S: sheep; G: goat, H: horse; P: pig, Po: poultry)

Partner Country	Types of farm surveyed or experimented
Austria	BC – DC / DC – Po
Belgium	BC – P / BC – Po / BC – DC / DC – P / DC – Po
France	BC – S / S – H – P / DC – P / DC – Po / BC – DC
Germany	DC – Po / DC – P
Italy	BC – S – G - H / BC - S
Sweden	BC – S / DC – S
Switzerland	BC – DC / BC - S

In practice, it proved hard to stick to these original plans for 3 reasons: the GDPR complexifies a lot the identification of farms to create a sample of candidate farms, there are not so many livestock farms that are both multi-species and organic, we aimed to reach a minimum number of farms (15) for each species combination to have quite balanced sub-samples in the statistical analysis.

For those reasons, we had to adjust the types of species combinations surveyed and ended up with the following highly diversified (21 livestock combinations) sample:

	Austria	**Belgium**	**France**	**Germany**	**Italy**	**Sweden**	**Switzerland**	**Total**
BC & DS	0	0	0	0	1	0	0	**1**
BC & DS & G	0	0	0	0	1	0	0	**1**
BC & MS	2	1	7	0	0	11	1	**22**
BC & MS & P	0	2	0	0	0	0	0	**2**
BC & P	2	1	7	1	0	0	3	**14**
BC & P & Po	1	0	0	4	0	0	0	**5**
BC & Po	2	1	6	5	0	0	1	**15**
DC & BC	1	0	2	0	1	0	1	**5**
DC & BC & H	0	0	0	0	0	0	1	**1**
DC & BC & P	0	1	0	0	0	0	0	**1**
DC & DS	1	0	0	0	0	0	0	**1**
DC & G	1	0	1	0	0	0	0	**2**
DC & MS	0	0	0	0	0	2	0	**2**
DC & MS & P	0	1	0	0	0	0	0	**1**

DC & MS & Po	2	0	0	0	0	0	0	**2**
DC & P	0	1	3	4	0	0	1	**9**
DC & P & Po	0	1	0	2	0	0	0	**3**
DC & Po	2	3	0	5	0	0	0	**10**
DS & G	0	0	0	0	4	0	0	**4**
MS & G	0	0	2	0	0	0	0	**2**
MS & P	0	0	1	0	0	0	0	**1**
Total	14	12	29	21	7	13	8	**104**

WP3	Integrated assessment of organic mixed livestock farms in Europe

WP leader: Marc Benoit (INRA)
Responsible partners: INRAE, BOKU, CRAW, FiBL, Forschungsring, SLU, Tuscia Uni.

Overall summary of main results, discussion and conclusions of WP1

In WP3, we aimed at assessing the levels of integration and sustainability of organic multi-species livestock farms. We developed an indicator system to assess the level of integration between farm enterprises within multi-species livestock farms considering integration over space and time and from three perspectives: farming practices, work organization, and sales. We also developed an indicator system to assess the sustainability of multi-species livestock farms considering the main sustainability issues regarding organic livestock farms and organic farming principles: resource use efficiency, resource conservation, self-reliance, productivity, profitability, human welfare, animal welfare, and resilience against adverse environmental and economic events. Not all these indicators could be calculated in all surveyed farms due to lack of data in some instances but this indicator system could be used in future studies on diversified farming systems. Nevertheless, we showed the following: 1) We highlighted 6 out of 86 farms that outperform their peers (based on four indicators) despite having the same resources and constraints. They have very different sizes and enterprise combinations but all have a strong autonomy for feed and strong interactions among farm activities. They also very often practice direct sales and have set up a satisfactory work organization, both intra-farm and with local networks. 2) We highlighted the indirect role of monogastrics in the overall efficiency of the farm livestock enterprises, according to their relative importance, in particular in relation to higher availability of organic fertilizers allowed by higher feed inputs for monogastrics.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

T3.1: We have developed an indicator system to assess the level of integration between crops, pastures and livestock and more broadly between farm enterprises within multi-species livestock farms. Integration refers to the management of interactions over space and time between these enterprises. We addressed integration from three different perspectives: (i) farming practices: crop – livestock (e.g. crop area in rotation with sown pastures) and pasture-livestock (e.g. proportion of animals fed full grazing the whole year) interactions, interactions among livestock enterprises (e.g. duration of simultaneous grazing) and interactions among all enterprises (e.g. number of flows of by-products between enterprises); (ii) work organization (e.g. the versatility of workers across enterprises); (iii) sales management: integration of farm products through processing (e.g. number of products for human consumption whose ingredients come from at least 2 enterprises within the farm) and integration of sales channels (e.g. share of long channel clients for at least two enterprises within the farm). This indicator system on integration is the first that goes beyond farming practices and that is suited to farming systems including multiple livestock productions. It can inform future scientific studies aiming at unravelling complex relations among management practices and performances in agricultural systems.

T3.2: We have developed an indicator system (https://orgprints.org/id/eprint/37939/) to assess the sustainability of multi-species livestock farms considering the following main sustainability issues regarding organic livestock farms and organic farming principles:

- resource use efficiency: organic livestock farms are confronted with high input prices and are expected by consumers to limit environmental pollution. This implies efficient input use;
- resource conservation: organic livestock farms are expected by consumers to preserve the natural resources: soils, water, air and biodiversity;
- self-reliance: self-reliance is key to limit the exposure of organic livestock farms to adverse environmental events and above all economic hazards;
- productivity: organic livestock farms are criticized for their lower productivity compared to conventional farms and they need to address this challenge in order to remain competitive and to maintain their environmental performance (e.g. GHG emissions);
- profitability: profitability is key to maintain organic livestock farms on the long run. Not only does it allow a decent income to the farmers, it also keeps organic farming attractive;
- human welfare: the increase in farm size observed in Europe for several decades has led to severe issues of welfare for farmers. Organic livestock farms need to address this issue to remain over the long run;
- animal welfare: in an era where livestock farming is highly criticized, consumers perceive organic livestock farming as a premium way of farming which implies to avoid issues of animal welfare;
- resilience: organic livestock farms are criticized for being possibly more sensitive to adverse environmental events than conventional ones. This questions farm resilience to hazards.

Then, we identified indicators (e.g. productivity of N inputs for resource use efficiency, debt to capital ratio for self-reliance, income per worker for profitability) corresponding to these dimensions by picking up indicators from existing assessment methods and creating additional ones when needed. The indicator system can be re-used in future studies on diversified farming.

T3.3: We have identified European organic multi-species livestock farms that outperform their peers despite having the same resources and constraints, and characterized their distinctive management principles. We used 86 farms from the initial project sample that had complete data. These farms included 19 different combinations of large ruminants, small ruminants, large and small ruminants, and large ruminants and monogastrics. We implemented a positive deviance approach based on four indicators: land productivity, nitrogen input dependence, nitrogen balance and satisfaction regarding income. Six structurally diverse positive deviant farms were identified with multiple types of livestock combinations represented, and farmland area ranging from 25.3 to 199.3 ha, herd size from 26 to 126.3 livestock units and total workforce size from 2 to 5 annual worker units. Most of these farms had high overall autonomy for feed (85-97% against a mean of 75% for the whole sample) by fostering diversity of pastures, crops and livestock and promoting interactions among farm activities in ways (e.g. matter flows, co-grazing, crop rotations including pastures, etc.) that benefited the whole system. Diversity of production activities allowed four out of the six farmers to develop direct selling which was well suited to support their farming strategies oriented towards high autonomy for feed. Diversity was also found besides agricultural production through e.g. agritourism. Some farmers, especially in farms with co-farmers, had found organizational models suited to control their workload and to take free days throughout the year by efficiently planning, distributing, and sharing tasks. This strategy allowed them to save time for networking with other farmers to access to information, support, and equipment. These principles will inform farmers running multi-species livestock farms or transitioning to this model.

B- fulfilment of objectives:

WP3 had a three-fold objective:

• Adapt and apply a method to describe and assess the level of integration between farm components in surveyed organic multi-species livestock farms.
• Develop a science-based and easy-to-use indicator system for integrated assessment of the sustainability and robustness of organic multi-species livestock farms.
• Apply this indicator system to assess the sustainability and robustness of surveyed organic multi-species livestock farms and connect it to the level of integration between farm components.

The indicator system to assess the level of integration between farm components has been rejected by Agricultural Systems with an invitation to re-submit and is currently under revisions. The indicator system to assess the sustainability of organic multi-species livestock farms has been published as a report with a protocol (D3.2). The positive deviance analysis connecting integration and sustainability assessment is under revision after major revisions have been requested by Agricultural Systems. These revisions do not compromise the above conclusions.

WP4	*Farm-level experiments in organic mixed livestock systems*

WP leader: Steffen Werne (FiBL)
Responsible partners: FiBL, CRAW, INRA, TI-OL

Overall summary of main results, discussion and conclusions of WP1

In WP 4, the involved partners aimed at a further exploration of potential benefits of mixed livestock grazing. The partners focused on cattle/sheep systems with different priorities and on a cattle/broiler system in experimental studies.

In a cattle/sheep system, we could show that mixed grazed sheep consumed less concentrates and needed less anthelmintic treatments compared to control groups. Beyond this, the mixed lambs showed an improved growth rate. Using a rustic sheep breed additionally to mixed grazing allowed to finish all lambs quicker and pasture based. In the mixed system, the higher sheep performance and the lower concentrate input led to lower GHG emissions and energy use for sheep compared to controls. In a cattle/sheep system, the results suggest that there would be no benefit for young cattle in terms of performance and parasites. However, despite cross infections of a potentially harmful nematode from sheep to cattle occurred, we could not observe any negative effects on the cattle either. In the mixed cattle/broiler system, broiler losses due to predation were lower in all 7 replications over a 3 year period. We could not reveal any effects on the performance or parasite load of broilers or cattle.
In conclusion, the exact trials in WP4 suggest, that using cattle/sheep and cattle/broiler combinations will be of advantage for at least one involved species. No adverse effects on any involved species could be shown, proposing the use of the studied livestock combinations under practical conditions.

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

T.4.1: In most studies on mixed or sequential grazing with cattle and sheep, cattle performance remained unaffected. However, the treatment regime of the sheep in these studies was very intense and may have limited cross-transmission of nematodes from sheep to cattle. We conducted a sequential-grazing study with first season grazing steers and ewe lambs. We stratified 20 organically reared steers to 10 couples according to their origin, nematode egg excretion per gram faeces (EPG), metabolic weight and previous weight gain record. Thirty naturally infected ewe lambs were stratified to 5 groups according to metabolic live weight and EPG. Five pairs of the steers were sequentially grazed with the 5 groups of lambs, whereas another five pairs of steers served as control. Grazing duration was 70 days with a subsequent indoor period of additional 35 days for the steers. The sequentially grazed steer groups did not differ from the control group with regard to EPG, live weight and daily weight gain. However, the sequentially grazed steers showed elevated pepsinogen levels compared to the control steers (e.g. 3.34 ± 1.05 units tyrosine and 1.29 ± 0.50 units tyrosine after 70 days of grazing, respectively). We conclude that short term sequential grazing of first season grazing steers with lambs excreting mainly eggs of Haemonchus spp. did not adversely affect steer performance despite increased pepsinogen values. However, the trial took place under hot and dry conditions, which may have had a suppressive effect on larval development, migration and finally uptake by the steers.

T.4.2: We hypothesized that the performances of grassland-based systems, aiming at producing grass-fed meat from permanent pastures, may be improved by associating beef cattle and sheep, via a better valorization of forages and a lower parasitism level in sheep. Three systems (beef cattle (CAT), sheep (SH), mixed beef cattle-sheep (MIX)) were put to the test for 5 years into separate farmlets in INRAE Herbipole experimental farm (1000-1300 m asl). In order to favour the production of grass-fed meat with young animals, we crossbred hardy breeds (Limousine ewes, Salers cows) with early maturing breeds (Suffolk rams, Angus bulls). Calving and lambing periods occurred at the end of winter-beginning of spring to optimize grazing. Young cattle grazed with their dams on pasture until weaning in October; they were fattened indoors with hay and haylage then slaughtered at 12-15 months. MIX sheep took advantage of the association, with a lower use of concentrates and anthelmintics and a better lamb growth rate than SH sheep, enabling all lambs to be exclusively pasture-fattened. Despite a satisfactory degree of fatness, the carcass of young cattle were considered too light by the industry (230-280 kg), with poor price. The need for conserved forages for beef fattening, coupled with drought, generated additional costs (purchase of hay). In the MIX system, the higher sheep performance and the lower concentrate input led to lower GHG emissions and energy use for sheep, compared to SH (-13% EqCO2.KgLW-1 and -17%MJ.KgLW-1); it also resulted in a 15% higher income per sheep LU in MIX vs SH.

T.4.3: We have conducted an experiment over seven experimental rounds (2018 – 2021) comparing two rotational grazing systems: the mixed system had 10 young dairy heifers and 54 – 60 broilers on the same pasture paddocks and the separated system both species on separate pastures. The mixed system showed fewer losses in broilers (median: 1) due to predatory birds compared to the separated system (median: 4) in all seven experimental rounds. Goshawks were found to be the main avian predators. In terms of ranging behavior generally the differences between the groups started small, became wide in the second to fifth week but in the last week became small again. We assume that due to the rapid weight gain, the broilers became less active towards the end. The fewer losses in the mixed system corresponded to a higher percentage of the broilers ranging: 24% in the mixed system over 19% broilers outside where there were no cattle on the pasture. The assumption that the parasite burden in cattle is lowered by chicken scratching in dung pats could not be verified or proven wrong as no broilers were recorded scratching on the surface of cattle feces or use it in any other way as feed source. The fecal egg count in the young cattle did not differ between the treatments. No statistically significant differences in weight gain or final weight in both broilers and cattle were found. There was a tendency towards higher end weight in the broiler groups mixed with cattle (3138 ± 169 g) compared to the control group (2990 ± 250 g; p=0,106). Swab samples were taken from pasture before slaughter of the broilers and tested for salmonella. Results were constantly negative.

T.4.4: Unpublished data from a trial conducted in Libramont (Belgium) for 4 years from 2004 to 2007 was re-analyzed to assess the benefits on animal health and performance as well as nitrogen balance of co-grazing cattle and sheep vs. single grazing for different grazing management strategies. Five grazing schemes were compared: cattle (Belgian Blue Heifers) in a rotational (1) or in a continuous grazing systems (2); sheep (Swifter ewes with lambs) in a continuous system (3); cattle and sheep managed in a simultaneous rotational or continuous grazing systems (4) and a leader-follower rotational grazing system (5). For the leader-follower scheme, heifers were the leader herd. According to the year, total stocking rate varied from 3.0 Livestock Units (LU)/ha (2004) to 3.7 LU/ha (2005 – 2007). From 2005 to 2007, heifers stocking rates were similar between grazing systems, ewes and lambs were added. Increasing the stocking rate with sheep (systems 4 and 5) did not modify heifers' growth which ranged between 0.657 and 0.705 kg/day for all tested modalities. We observed a significant effect of the year on the growth of suckling lamb (ADG = 371; 229; and 184 g/day in 2004, 2005 and 2006). The parasite infestation was assessed by analysis of serum pepsinogen and parasite eggs in feces. In summer 2004, pepsinogen were lowest for heifers in the simultaneous grazing systems (system 3) and parasite eggs in feces were highest for heifers in rotational grazing (system 1). In mixed conditions, sheep "cleaned" pastures from cattle parasites. In summer 2005 and 2006, with a higher total stocking rate (3.6 LU/ha), opposite results were obtained notably because heifers grazed shorter, with accordingly higher infestation with gastro-intestinal parasites. To assess the environmental pressure, soil nitrate (NNO3) was determined. We observed a great variability between paddocks. On average over 3 years, soil residual nitrogen was highest (50 kg NNO3/ha) for heifers (system 2) in continuous grazing and lowest for sheep (system 3; 7 kg NNO3/ha) while mixed grazing had little impact on this indicator.

B- fulfilment of objectives:

WP 4 had a fourfold objective:

- Deliver new information obtained by experimentation into WP5, to improve the data basis for modelling.
- Analyse the mutual and environmental benefit of mixing dairy calves and lambs as well as dairy calves and broilers.
- Analyze the opportunity to further improve the benefits of mixed livestock grazing by making use of traditional breeds.
- Deliver clear and comprehensible solutions for farmers to be implemented on organic farms.

We consider that the above mentioned objectives were met by the results of WP4 as i) data was made available for the modelling work (https://orgprints.org/id/eprint/40228/), ii) the benefits of mixed grazing on dairy calves* (T4.1) and dairy calves and broilers (T4.3) could be analysed, iii) the potential of the use of rustic, traditional breeds in a mixed grazing situation could be shown.

WP 4 could also deliver clear and comprehensible recommendations for farmers, in brief:

Combining pasture and broiler outrun is likely to reduce losses of broilers due to avian predators without detrimental effect on performance of both used species and with low risk of Salmonella transmission.

Sheep and young cattle may be sequentially grazed with low risk, even if H. contortus is the predominant genus and if anthelmintic intervention is low.

The combination of mixed grazing and traditional breeds leads to lower anthelmintic interventions, quicker finishing of lambs fully pasture based and overall lower GHG emissions.

*Deviation from originally promised approach:

In Task 4.1. it was originally planned to reveal <u>mutual</u> benefits of co-grazing sheep and young cattle using a latin square design with a total of 9 groups. However, statistical power analysis has shown that a significant statistical output would be difficult to obtain from this design. Therefore we decided to adapt the approach and look only at possible cattle effects if sequentially grazed with lambs. Instead of the originally 9 animal groups we used 10 steer and 5 lamb groups to assure a sound statistical output.

WP5	*Modelling and co-design of more integrated organic mixed livestock farms*

WP leader: David Parsons (SLU)
Responsible partners: SLU, BOKU, Forschungsring, INRAE

Overall summary of main results, discussion and conclusions of WP5

In WP5, partners aimed to develop and apply a modelling framework to co-design more integrated mixed livestock farms. The bioeconomic model Orfee was chosen and used for the desktop simulations of the project. This model was improved by adding more activities to be able to simulate a larger range of farming systems. The transferability of the model was improved by translating most model inputs and outputs in English. A framework was developed to simulate ex-ante and ex-post adaptations to risks. Four French farms surveyed in 2017 (see WP2) were interviewed in 2021 to understand how farmers felt exposed to risks and managed them and which alternative strategies appeared relevant for them. Simulations were made to assess the sensitivity and vulnerability of current and alternative systems to risks. Climate risk appeared to be the most serious risk for the farmers interviewed, followed by market risks. The reduction of stocking rate and the modification of the enterprise mix with either the addition of a pig enterprise or the replacement of beef cattle by dairy cattle appeared relevant strategies to be tested. The simulation showed that the risk associated with 70% reduction of grassland yield was by far the highest. Three of the four farms had significant risk of negative income for the baseline situation. The reduction of stocking rate reduced variability of income in all cases, nonetheless it did not remove the probability to have very low income. The introduction of a pig enterprise and the replacement of beef with dairy did not much reduce the variability but increased income and consequently farm vulnerability.

Workshops were held in spring 2021 in Germany, Austria and Sweden with farmers, advisors and experts. The workshop concept was developed together with the project partners and with the help of consultation with external experts. The basic assumption was that farms are individual in their conditions and their way of doing business, and therefore jointly developed development strategies and solutions must also be so. Due to delays in developing the bioeconomic model, workshops discussed sustainability and robustness, project results, and data analysis (including SWOT analysis).

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

T5.1. Adapting models. Few farm models target organic systems and offer the possibility to simulate different livestock species and none of them provide enough flexibility to explore the variety of management options in an organic mixed livestock farm under risks. The IAT farm model (Lisson *et al.* 2010) and the Orfee farm model (Mosnier et al. 2017) that have interesting characteristics were compared. Orfee is an optimisation model developed on the GAMS platform by Inrae in France, previously used to analyze the performance of mixed livestock or crop livestock farms in France. IAT was developed in Excel by CSIRO in Australia, and initially used in participatory workshops with smallholders farming systems with cattle in Indonesia. Orfee is a model that represents in each simulation the production process for one year while the IAT typically simulates a 10-year period. Both models provide outputs regarding farm production, income, methane emissions, distribution of workload over the year. Orfee can optimize ex-ante adaptation to economic risks but does not simulate sequential decisions. In IAT, a fixed strategy is tested in different scenarios which could include various hazards. The project team decided early in the project to focus efforts on developing and applying the Orfee model because IAT was in a period of transition toward the CLEM model which was not currently designed for European farming systems. Both models required further development to add new livestock categories or species, which would be a large undertaking if it were to be done for two models and the developer of the Orfee model is a project participant. More categories of heifers, lambs and low productive natural grassland were added to the Orfee model in order to be able to simulate the farm case studies selected. It was accepted that it would be too complicated to introduce sequential decision making within the core of the Orfee code. Instead, we decided to test different strategies by fixing exogenously long term decisions such as herd size, main crop allocation or maximum-security stocks and to optimize short term decisions such as feed purchases or sales, end-use of crop and animal production, storage or removal of security hay stock according to annual conditions. Several simulations can be made to simulate various perturbations and to assess the overall sensitivity, vulnerability and sustainability of each farming strategy. We improved the transferability of the model by translating the interface and most model outputs in English to characterize farm functioning and farm sustainability.

T5.2. Simulation of alternative management strategies in response to climatic and economic variability

Based on farm surveys, seven types of risks were aggregated: spring grassland yield, fall grassland yield, cereal yield, cereal price, beef price, input price and agricultural policy. The distribution of yields and output prices were based on subjective farmers' probability estimations, while input prices and agricultural policy were based on national data over the period 2010-2018. The short-term adaptations such as feed purchase, feed stock, modification of grassland and forage end-use, intercropping and the type of animal produced and sold were optimized by the model for each combination of risk within the range of possibilities specified by farmers. Two alternative scenarios were simulated and compared to the 2017 farm structure baseline: 1) reduction of stocking rate either by a decrease in the size of the herd or by an increase of the area of permanent grasslands and 2) reduction of stocking rate associated with a change in the animal enterprise mix either by the addition of a pig enterprise or the replacement of beef enterprise by a dairy cow enterprise. Vulnerability corresponds to the risk of falling below a threshold. It depends on the probability of a set of disturbance and farm sensitivity to these disturbances. Sensitivity was measured as the elasticity of income to a change of the value of a variable. Sensitivity was highest to changes in producer prices, particularly for pork and milk prices, followed by subsidies, then spring pasture yield and then grain yield. Variations in spring yield, up to -70% 2 years out of 10 for three of the farms, proved to be the strongest risk. Farms that had more flexibility to adapt to hazards were somewhat less sensitive. Farms were also quite exposed to risks affecting grain yields, especially for a farm that sells all of its grain. The reduction of stocking rate, reduced these sensitivities (except for cereal yield) by reducing farm exposure. The introduction of pigs or dairy also reduced the sensitivity by increasing average income. Three of the four farms were found to be vulnerable for the baseline situation since they had significant risk of low and even negative incomes. Farms that had already low income because of low technical performance or high fixed costs in a normal year, or that had a higher probability of low grassland or crop yields had higher probability to fall below critical levels. The reduction of stocking rate reduced variability and standard deviation in all cases, nonetheless it was not sufficient to bring some farms out of vulnerability. The introduction of a pig enterprise and the replacement of beef with dairy and cheese making did not reduce the standard deviation much due to significant risks associated with these enterprises, but increased income; consequently, the farm vulnerability was reduced. Nonetheless, the range of profitability for pig or dairy is rather narrow. A poor technical mastery or a less good valorization of the products on the market can call into question the profitability of these activities. Similarly, technical improvements could be made on these farms where farmers sometimes admit to neglecting certain activities in order to concentrate on others.

T5.3. Organization of participatory modelling workshops

Participatory modelling workshops could not be organized due to the limitations imposed by Covid, and the changing nature of restrictions in different countries. Workshops could only be conducted online, and as a result, the participatory concept suffered greatly. Certain methods, such as the World Café, could not be implemented. However different actions were made in order to involve stakeholders.

Additional surveys were conducted for four French farmers in order to use their farms as case studies and to develop scenarios which fit with their subjective assessment of risks and were consistent with the adaptations they considered as potentially relevant. Climate risk appeared to be the most serious risk for farmers, followed by market risks. They considered that bad yields tend to become normal. Short term adaptations such as grassland end-use, animal production or forage security stock varied between farmers but they all frequently purchased supplementary feeding. All farmers planned to maintain diversified systems with several animal enterprises, and in particular they considered sheep more profitable and more adapted to climate change, although sensitive to certain diseases. Some farmers were thinking of adding a monogastric enterprise or replacing beef cattle with dairy cattle. All farmers had already reduced their stocking rate or planned to do so.

In Germany, the workshops took place online on 2 days in June 2021 as an after-work event. In the run-up to the workshops, the project team had identified certain challenges of the farms from the individual farm evaluations and invited input from external experts to develop solution concepts. Despite intensive advertising, the farmers did not accept the offer of a joint exchange in the workshop, which was probably also due to the timing (hay season) and the form of the workshop (an online event). Additionally in Germany, an individual farm evaluation for all farms with the respective consultant in charge was organized. The results of the individual farms were presented in comparison to the reference group, and a discussion took place in which the weaknesses and strengths of the farm were worked out together and the advisors were able to specifically support "their farm" with the weak points and point out ways to improve. The farmers reported that the farm-specific feedback on the project results increased the benefits of the project for the participating farms.

In Sweden, an online meeting was held to present project results and discuss various questions, such as the current situation in relation to sustainability and robustness, what factors may challenge the *status quo*, and what could be done by farms in response. Specific scenarios and farmer response were identified, for use in scenario analysis with the bioeconomic model.

A webinar in German took place on the 30th of November 2021. In addition to the presentation of results, the advantages and disadvantages of mixed animal husbandry were also discussed. The 23 participants from Germany, Switzerland and Austria mentioned that the webinar had been very informative. They also enjoyed the interesting stories from other participants regarding their own experience with multi-species livestock farming.

B- fulfilment of objectives:

Three objectives were assigned to this WP :

- Adapt the IAT and ORFEE models to simulate farmer behaviour when confronted with adverse climatic and economic events and thus examine a larger range of organic mixed livestock farms.
- Analyze benefits and drawbacks of livestock diversity in organic farms under different contexts.

• Co-design with farmers sustainable and robust alternatives to European mixed livestock farms. This involves adapting and developing participatory design methods relevant to organic mixed livestock farming. 1. Two models were initially targeted to be improved (IAT and Orfee). Both models required further developments and the PhD student who was initially responsible for working with IAT resigned from the project. The development then focused on the Orfee model. Additional activities were added and a framework was developed to simulate farmer behaviour under adverse climatic and economic events and to assess farmer sensitivity and vulnerability. However, the framework and the model remain complex and not yet easily transferable to the different partners. The Orfee model utilized default prices, subsidies, yields and practices for France that were not adequate for other European contexts. This required a lot of effort to adapt the model to other countries, and with limited success. Ultimately, Orfee was developed to be able to simulate mixed organic livestock farms in France, and partially in Sweden, but not other countries. From this perspective the objective was mostly fulfilled. 2. A report is completed that analyzes farm performance under different scenarios in France. This will be summarized in the form of a scientific article, but after the project has officially finished. The work to adapt the model to Swedish conditions is still underway. Thus the objective was partially fulfilled. 3. In France, some farmer interviews were done to design simulations. However, we were not able to organize workshops where farmers and advisers could interact together, discuss results and simulation assumptions, to help develop the model and scenarios for the farms under different contexts. The process was also partially followed in Sweden. A co-design process was not achieved in Germany, due to the Covid situation. Because of the lack of results arising from participatory processes, the deliverable D5.3 was not able to be achieved.

WP6	*Stakeholder engagement, compilation and dissemination of results*
WP leader: Catherine Experton (ITAB) then Fabienne Launay (IDELE) **Responsible partners:** IDELE, BOKU, CRAW, FIBL, Forschungsring, INRAE, SLU, TI-OL, Tuscia Uni.	
Overall summary of main results, discussion and conclusions of WP6 WP6 aimed at compiling, disseminating and communicating the project results. However, the Covid-19 context has constrained the achievement of our initial objectives for this WP6. A dissemination plan was developed and validated by all project partners. It aimed at identifying the target audiences for the different project outputs and establishing a dissemination map. This dissemination plan also allowed to plan the different steps and communication and dissemination items of the project according to each audience, such as leaflets that had to be translated into different languages, a press release for the media, scientific articles to explain and disseminate the project results to peers, as well as technical articles published in specialized magazines for organic farmers and technical advisors. At the end of the project, two additional deliverables have been developed compared to our initial plans: a practice abstract (requested by Core Organic) which synthesizes the benefits of multi-species livestock farming and an educational toolkit composed of 3 independent and complementary tools to sensitize students on multi-species livestock farming. Over the project duration, communication was mainly ensured via online medias because of the Covid-19 context: Facebook posts on the dedicated project page, a webpage on the institutional site of Core Organic, upload of all the publications on the Organic Eprints platform, virtual participation in conferences (IFOAM and IFSA symposiums and EAAP conferences). The organization of a final webinar allowed presenting and communicating the results of the project to a large audience.	

Report on the results obtained (A), and fulfilment of objectives (B) comparing to the original project proposal

A- results obtained and structured in relation to the user groups they are relevant for:

Our target groups for stakeholder engagement were agricultural consultants (from farmers' associations,

chambers of agriculture etc.) and farmers. In addition to agricultural consultants and farmers, students at agricultural colleges and universities were the targets for dissemination of the project results. Written deliverables have been made available for all target groups.

The constraints imposed by the Covid-19 pandemic have not allowed to reach all expected results for Tasks 6.1 and 6.3. The pandemic has had a strong impact on stakeholder's participation to the project as well as on the dissemination of the outputs.

T6.1 allowed the mapping of targeted stakeholders but no further opportunity was offered to enrich this mapping thanks to organized dissemination events or informal contacts made during conferences, etc.

T6.2 consisted in defining and implementing a dissemination plan. This plan was developed and agreed upon among all partners at the beginning of the project. It was revised in 2021 as due to the Covid-19 context, it became clear that not all activities planned could be conducted by the end of the project. After all, we managed to produce a diversity of communication and dissemination items: leaflets translated into different languages, a press release for the media, scientific articles to explain and disseminate the project results to peers, technical articles published in magazines for organic farmers and technical advisors, Facebook posts, a webpage on the institutional site of Core Organic, several talks at international conferences (IFOAM and IFSA symposiums and EAAP conferences), a final webinar, a practice abstract and an educational toolkit.

T6.3 aimed at conducting a systematic assessment of the project outcomes, i.e. changes beyond the walls of research partners in terms of values, attitudes and behavior. We had planned to do so by using deliberative evaluation forms filled during participatory and dissemination actions (e.g. farmer field days). The form was developed at a very early stage of the project and distributed to all partners. Unfortunately, as we could not organize participatory and dissemination actions, we decided, in agreement with the Core Organic Secretariat, to withdraw this task. Hopefully it can be re-used for future projects.

B- fulfilment of objectives:

WP6 had a four-fold objective:

• Engaging agricultural consultants and farmers in the implementation of the project.
• Compiling the project outputs.
• Disseminating the project outputs.
• Communicating the project outcomes

We mapped agricultural consultants and farmers as much as we could considering the GDPR constraints. As explained above, due to the Covid-19 pandemic, we could not further engage these stakeholders in the implementation of the project beyond farm surveys and very punctual interactions (see activities in WP5).

We defined a dissemination plan and compiled all project outputs in Organic Eprints and tried to synthesize these outputs in the form of an educational toolkit that encapsulates the knowledge base generated to stimulate students' learning on organic multi-species livestock farming.

All the communication and dissemination medias we had planned to use have been implemented. We disseminated the project outputs through: a total of 21 scientific articles, 21 technical articles (3 per country), Facebook posts (reaching up to 700 views against a total of 100 followers), articles in the Core Organic newsletter, a final webinar (instead of the physical event planned) that gathered 43 attendees from various fields (farmers, students, etc.) and countries (Pakistan, Malaysia, Ethiopia). Unfortunately, due to the Covid-19 pandemic, organizing physical events proved very hard.

This WP aimed at making a cross-cutting analysis of the project's findings across the different methods used: review of the literature, desktop data analysis, farm surveys, system trials, simulation modelling, co-design workshops. This analysis proved more difficult than expected. We found a single source of data for the desktop data analysis and the database did not include detailed data on the monogastric enterprise of farms. Detailed data was available only for farms mixing cattle and sheep. Only three livestock species combinations could be tested in the system trials. The same limitation applied to simulation modelling. Against these limited scopes, we surveyed 21 different livestock species combinations in commercial farms. And on top of diversity in species combinations, farms also had different non-livestock activities: cropping, agritourism, energy production, on-farm processing, etc. Thus, we had a very large diversity of farms and a limited number of farms for each livestock species combination. Therefore it was hard to reach robust conclusions for each livestock species combination to be confronted with the results obtained with other methods. Due to these reasons, the cross-cutting analysis of the project's findings was below our initial expectations.

3.2 Deliverables and milestones status

Deliverable No.	Deliverable name	Link to the document[2)]	Planned delivery month[1)]	Actual delivery month[1)]	Reasons for changes/delay and explanation of consequences in case of delay, if any
D6.1	Map of agricultural consultants active in organic mixed farming	https://orgprints.org/36525/	May-18	Jun-18	Data collection took slightly longer than expected
D6.2	Dissemination plan	https://orgprints.org/id/eprint/36773/ and https://orgprints.org/id/eprint/42415/	Jul-18	Jul-18	Updated in 2021 to take into account the Covid-19 related constraints
D2.1	Literature review on mixed livestock farms in Europe	https://orgprints.org/id/eprint/37782/	Apr-19	Jul-19	Collective writing took slightly longer than expected
D2.2	Comparison of specialized and mixed livestock farms in Europe	https://orgprints.org/id/eprint/36705/	Apr-19	Sep-19	Data collection and analysis took longer than expected
D4.1	First year data obtained in experiments in 4.1	https://orgprints.org/id/eprint/40228/	Jun-19	Jul-21	Data analysis took longer than expected

	and 4.2 for modelling				
D4.2	Innovative strategies to increase multi-performance of livestock systems	https://orgprints.org/id/eprint/42976/	Jun-19	Jul-21	In agreement with the Core Organic representative, it was decided to wait for another year of data
D1.1	Mid-term project report	Available upon request	Oct-19	Nov-19	As requested by Core Organic
D2.3	Database on mixed livestock farms in Europe	https://orgprints.org/id/eprint/42955/	Oct-19	Oct-19	/
D5.1	Development of the IAT and ORFEE models for simulating mixed livestock farms	https://orgprints.org/id/eprint/42336/	Oct-19	Sep-21	Delayed as the PhD student who was expected to work on this task quitted her position
D3.1	Patterns of integration in organic mixed livestock farms	https://orgprints.org/id/eprint/40154/	Oct-19	Apr-21	Delayed due to the time needed to clean the survey data
D3.2	A toolkit to assess the sustainability and robustness of mixed livestock farms	https://orgprints.org/id/eprint/37939/	Dec-19	Apr-20	
D5.2	Assessing mixed livestock farming strategies in response to adverse events	https://orgprints.org/id/eprint/42975/	April-20	Dec-21	Due to delay taken in model development
D3.3	Sustainability and robustness of mixed livestock farms in Europe	https://orgprints.org/id/eprint/40164/ and https://orgprints.org/id/eprint/40160/	Oct-20	Sep-21	Delay due to the time needed to clean the farm data
D4.3	Mutual benefits of co-grazing dairy calves and lambs growth	https://orgprints.org/id/eprint/40229/	Jan-21	Jul-21	Submitted July 2021
D.4.4	Effects on health, welfare and performance of mixed grazing of dairy young stock and broilers	https://orgprints.org/id/eprint/43011/	Mar-21	Dec-21	Additional round of experiments was conducted, delayed data analysis

D1.2	Final project report	Will be made available in Organic Eprints	Mar-21	Dec-21	Due to extension of project duration
D5.3	Farmer-developed innovative options for organic mixed livestock farming in Europe	/	Mar-21	NA	Cancelled due to impossibility to organize participatory workshops
D6.3	Technical articles (at least one per country per year)	All articles are available at: https://orgprints.org/view/projects/Mix-Enable.html	Mar-21	Sep-21	Due to extension of project duration
D6.4	Project outcomes	/	Mar-21	NA	Cancelled due to impossibility to organize dissemination events

Measured in months from the project start date (month 1)

E.g. documents as orgprints.org/33121 or other types of deliverable (e.g. APPs or devices)

Milestone No.	**Milestone name**	**Planned delivery month[3)]**	**Actual delivery month[3)]**	**Reasons for changes/delay and explanation of consequences, if any.**
M1.1	Start-up meeting	Apr-18	Apr-18	/
M6.2.1	Agreement on the dissemination plan	Apr-18	Jun-18	Slight delay to get the feedbacks from all partners
M4.1	Exact trials defined, start of experiments	Jul-18	Jul-18	/
M2.1	Literature review: shared library of scientific articles	Aug-18	Aug-18	/
M2.2	Database on specialized and mixed livestock farms based on desktop data	Sep-18	Sep-18	/
M5.1	Decision on plan for integrated model development	Sep-18	Sep-19	The decision was made to focus on ORFEE
M6.1	Agreements made for stakeholder engagement	Sep-18	Oct-19	Large delay to get the feedback from all partners and stakeholders (need for a letter of agreement from each stakeholder listed)
M6.3	Deliberative forms for outcomes evaluation	Sep-18	Sep-18	/
M3.1.1	Adaptation of the method to assess the level of integration between components in mixed livestock farms	Nov-18	Sep-18	/

M2.3.1	Definition of a guide to sample and survey mixed livestock farms in Europe	Dec-18	Oct-18	/
M1.2	Annual meeting 1	May-19	Apr-19	/
M4.2	Data obtained from first year exact trial feed in WP5	Jun-19	Jul-20	Data from the different tasks were not available as early as planned
M2.3.2	Farm surveys across partner countries	Jul-19	Aug-19	Slight delay to finalize the surveys as it was hard to find farms
M3.1.2	Implementation of the method on surveyed farms	Aug-19	Jan-21	
M3.2	Definition of an indicator system for integrated assessment of the sustainability and robustness of mixed livestock farms	Oct-19	Oct-18	Finally this list was fully defined at the beginning of the project to allow for a single round of surveys
M5.2	Definition of simulation experiments	Dec-19	Dec-20	Due to delay taken in model development
M3.3	Combination of the toolkit and the farm database to assess the sustainability and robustness of mixed livestock farms	Jan-20	Sep-20	Delay due to the time needed to clean the farm data
M6.2.2	Communication tools	Apr-20	Apr-20	
M1.3	Annual meeting 2	May-20	Apr-20	
M5.3	Design and organization of participatory workshops	Jul-20	Oct-20	Due to the Covid context that required postponing participatory workshops
M4.3	Completion of experiments	Jan-21	Jun-21	Due to extension of project duration
M1.4	Final meeting	Apr-21	Sep-21	Due to extension of project duration

Measured in months from the project start date (month 1)

4. Publications and dissemination activities

4.1 List extracted from Organic Eprints

Number of items at this level: 62.

Journal paper

Bam, Joken; Thüer, Susann; Holinger, Mirjam; Oberhänsli, Thomas; Leubin, Markus; Leiber, Florian and Werne, Steffen (2021) Performance and parasitological parameters of steers sequentially grazed with lambs infected with Haemonchus spp. Veterinary Parasitology, -, ---. [Submitted] (Submitted for peer-review but not yet accepted)

Hübner, Severin; Schanz, Lisa; Barth, Kerstin and Winkler, Christoph (2022) Effects of mixing broilers with cattle on broiler losses and behaviour. *Poultry Science*, NA, NA-NA. [draft]

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This list was generated on Sun Dec 19 13:14:59 2021 CET.

4.2 Stakeholders oriented articles in the CORE Organic newsletter

Six articles were published via the Core organic newsletter to address different stakeholder groups:

1) Farmers and agricultural advisers active in the organic sector:

- CORE Organic Newsletter, November 2018: Alternating grazing to control parasites in young cattle
- Group of agricultural advisers, researchers, students at agricultural colleges and universities:
- CORE Organic Newsletter, October 2019: Farmers' management practices determine sustainability patterns of French organic multi-species livestock farms
- CORE Organic Newsletter, May 2020: Animal diversity in organic farms: the performances are still being questioned
- CORE Organic Newsletter, December 2020: Productivity of multi-species organic farms in Europe: initial insights toward sustainable livestock systems

2) All stakeholders (farmers, agricultural advisers, researchers and students):

- CORE Organic Newsletter, December 2020: Between high workload and high satisfaction: The wellbeing of farmers running a mixed farm
- CORE Organic Newsletter, December 2020: Webinar 28 Sep. 2021 at 10am: Main results of the MIX-ENABLE project

4.3. Practice abstracts

Multi-species livestock farming: https://orgprints.org/id/eprint/42677/

4.4 Other dissemination activities and material

Final public webinar, 28th of September 10-12 am, the presentations have been uploaded on Organic Eprints but are not online yet.
Public webinar (in German), 30th of November 2021 19-20.30
Educational Toolkit: to be published in December 2021. Its realization and publication have been delayed because the tests with teachers and students could not be realized as it was initially planned due to the Covid-19 related constraints that did not allow for physical classes with sufficiently large groups of students.
Articles on the project Facebook page. Over all the project, we have made 52 posts and reached a total of 100 followers in September2021.

4.5 Future dissemination actions

List publication/deliverables/activities arising from your project that you are planning for the future:

With the resurgence of the pandemic and the arrival of the Omicron variant, it remains very hard to plan dissemination activities. Nevertheless, a webinar presenting the project key findings was organized in Germany and in Austria in November, another one is planned in March and several partners took engagement for future dissemination events that farmers attend. In France, a session on the project outcomes is planned on the 21st of September 2022 at the big farmer-oriented event La Terre est Notre Métier. In Switzerland, a similar session is planned during the next Bétail Bio event. Depending on opportunities offered by the local context, additional dissemination actions will take place in all countries.

In the meantime, the safest source of communication is the publication of scientific papers and of technical articles for end-users. Over the project, we have produced the following list with various status:

WP3 Ecological network analysis to link interactions between system components and performances in multispecies livestock farms; lead author: INRAE; published in Agronomy for Sustainable Development https://dx.doi.org/10.1007/s13593-021-00696-x

WP3 Positive deviant strategies implemented by organic multi-species livestock farms in Europe; lead author: INRAE; major revisions requested in Agricultural Systems

WP3 A new analytical framework to assess integration among multi-species livestock farm enterprises; lead author: INRAE; rejected by Agricultural Systems and under revision

WP3 The use of concentrates at the heart of the productive efficiency of multi-species livestock systems in organic agriculture; lead author: INRAE; to be submitted to Animal

WP3 High work satisfaction despite high workload among European organic mixed livestock farmers; lead authors: FiBL and BOKU; submitted to Agronomy for Sustainable Development

WP3 a paper on animal welfare; lead author: BOKU; to be submitted summer 2022

WP3 Multi-species organic livestock systems in Europe: which farm characteristics are useful for estimating productivity?; lead author: SLU; submitted to Renewable Agriculture and Food Systems

WP3 Sustainability of multi-species organic livestock farms explained by farm structures and management practices; lead author: INRAE; to be submitted spring 2022

WP4 Performance and parasitological parameters of steers sequentially grazed with lambs infected with Haemonchus spp.; Lead author: FiBL; moderate revisions needed for Veterinary Parasitology. https://orgprints.org/id/eprint/40229/

WP4 3 papers planned French experiment: on the sheep system, on the beef system and on a comparison of specialized and diversified systems; lead author: INRAE; to be submitted spring 2022

WP4 2 papers planned on the German experiment; lead author: Thuenen Institute and BOKU; to be submitted spring 2022

WP5 Assessing and reducing the vulnerability of mixed organic cattle-sheep farms; lead author: INRAE; to be submitted winter 2022

2 PhD theses to be defended in 2022 by Lisa Schanz (BOKU) and Severin Hübner (TI-OL) in addition to the one by Lucille Steinmetz (INRAE) defended in June 2021

List publications/deliverables arising from your project that more specifically Funding Bodies could disseminate in the respective national contexts publications/deliverables that could be useful to translate:

The slides of the final webinar can easily be distributed and translated. So does the educational toolkit especially as students' knowledge of organic multi-species livestock farming appears to be very limited and could benefit from using this game as a first approach.

4.6 Specific questions regarding dissemination and publications

Is your CORE Organic Cofund project website up-to-date : The Mix-Enable project information is up-to-date on the CORE Organic Cofund website. Only the last deliverable "educational toolkit" will be added in December 2021

List the categories of end users relevant to the research results and how they have been addressed or will be addressed by dissemination activities (Please order them according to the user groups).

Research and education institutes have been more easily addressed via scientific publications, a final webinar in English and the development of the educational toolkit. It was harder to address other categories of end-users (non-governmental organizations in the food and farming sector including organic farmers associations, consultants and farmers) in the absence of physical dissemination activities. Still we published a number of technical articles, Facebook posts and videos that may have reached these other end-users.

5. Project impact

Across Europe, farms converting to organic agriculture tend to be specialized in production of one animal species. Yet, in the context of organic agriculture, animal diversity within farms offers several theoretical advantages (enhanced animal health, improved use of pastures, etc.) pointed out in the review article published in the framework of MIX-ENABLE. Thus the project aimed at providing the organic sector with key insights about the conditions for the sustainability and robustness of multi-species livestock farms, innovative layouts of such farms and pathways from specialized towards multi-species livestock farms. The project has produced nearly all expected achievements on the science side. However, on the impact side, initial plans have been severely affected by the Covid-19 pandemic. Physical dissemination activities that were planned in most cases during the second half of the project all had to be cancelled. Participatory activities included in several tasks e.g. co-design workshops, also had to be cancelled. As a result, activities aimed at generating impact were limited to webinars, Facebook posts and technical articles which is quite unsatisfactory with regards to our initial ambition. We expect these constraints will have limited the spread of the project key findings throughout networks of organic farmers.

Beyond the project timeframe, we may still have impact through several ways. First, we developed an educational toolkit to sensitize students about multi-species livestock farming (further details available in the description of WP6). Second, additional dissemination activities are planned notably during farmer field days (see 4.5 above) if such events can take place in 2022. These field days will aim at presenting experiments where they have continued after the project ended (e.g. the Salamix experiment mixing cattle and sheep in France) and overall the main findings of these experiments. These field days gather multiple types of visitors such as farmers, advisors at cooperatives, chambers of agriculture. Communication on these field days will use multiple channels: local newspapers, social medias, personal invitations, invitations via farm advisors.

Beyond findings of interest for science, practice and policy-making, running a project during the Covid-19 pandemic also brought a few insights for the development of future projects. Our initial organization was very ambitious and relied on multiple collaborative activities, e.g. the implementation of the same survey across all 7 countries. Such collaborative activities involve the development of a shared interdisciplinary culture within the project consortium. Unfortunately, the lack of physical meetings limited the interactions to short and timely online meetings. This probably contributed to not allowing us to reach our initial ambitions. A more flexible approach allowing each partner to focus on their own area of expertise would have probably been better suited in this context.

6. Added value of the transnational cooperation in relation to the subject

The added value of carrying out the project on a transnational basis had several dimensions:

Organic mixed livestock farms are poorly documented in both the scientific and grey literatures. A transnational project has enabled the rapid collection of information on the current status of organic multi-species livestock farms, and conditions for their sustainability and robustness across a range of soil, climatic and farming conditions. This collection is gathered in the review article published in Agricultural Systems.

In addition to climates (from boreal to Mediterranean, through Atlantic), soil types (clayey to sandy, acidic to calcareous soils) and farming practices, the project has covered a broad range of combinations of animal species. This diversity would have been impossible to find in a single country, and due to this diversity of conditions, widely applicable methods and tools (for farm integration and sustainability assessment, etc.) have been developed and more general findings have been produced.

The consortium was very interdisciplinary and included agronomists, animal scientists, veterinary scientists and economists, to tackle the complexity of organic multi-species livestock farming into account. It would have been difficult to identify such a range of expertise in any single partner country of our Consortium.

It should be noted however that the transnational project was also a weakness at a time of Covid-19. Where national meetings would have been possible, transnational ones were not.

7. Suggestions for future research

From a knowledge production perspective:

Very few research had already tried to study commercial organic multi-species livestock farms. Most research came from experimental trials. MIX-ENABLE has revealed the very large diversity of these farms in which farming practices are interlinked with sales practices and work organization is highly complex. Unfortunately, addressing both biophysical and socio-economic aspects with the same level of details would have proven too hard. We remained quite frustrated by the socio-economic data we managed to gather. A future project focused on this issue and connected ones (e.g. that of farm management complexity) would be of great relevance, especially as our preliminary results tend to indicate that surveyed farmers were highly satisfied, a feedback seldom observed in the farmer community nowadays.

From a methodological perspective:

Comparing such a diversified sample of farms proved really challenging, much more than comparing multiple wheat fields across countries. Disentangling the effects of livestock species combinations and those of sales practices proved impossible as we actually had very few individuals for each combination x sales model. At the beginning of the project, we had predefined a limited number of livestock species combinations we wanted to focus on to avoid that issue. Shortly after, the RGPD was implemented and farmer associations no longer accepted to share farmer contacts. We surveyed the farmers we were able to find without structured sampling strategy. Designing well-balanced samples of non-documented farm types in the RGPD era is a new methodological challenge.

Annex 1: Project budget and balance overview for the full implementation period of 42months (in EUR)

Partner no.	Total person months budgeted	Total person months spent	Total coordination budget*	Total coordination budget*costs	Total project budget	Total project budget costs
P1	56.5	106.6	79,000	79,000	125,350	96,696
P2	9.2	15.9			147,000	268,935
P3	44	44			0	0
P4	4.97	5.40			30,678	50,694
P5	33	33			233,000	201,851
P6	24	27			140,200	150,467
P7	3	0.7			28,100	9,648
P8	11.8	12.4			122,344	128,326
P9	46.5	47.25			365,302	394,313
P10	25.2	35.8			140,700	194,024
TOTAL	254.2	328.05			1,318,196	1,473,909

P1: Personal costs of permanent workers were covered based on internal resources. Thus, most of the budget was planned for travelling and field activities. Due to Covid-19, most travels and some field activities had to be cancelled resulting in underspending.

P2: Overspending resulted from the extension of project duration due to Covid-19 and unexpected costs on the trial due to drought. To cover for these extra costs, additional funding was provided by the national organic organisation (12,000 CHF), a foundation (30,000 CHF) and the selling of experimental animals (11,000 CHF).

P4: Following ITAB's (P7) withdrawal from the project, IDELE has coordinated Action WP6 since the 1st of October 2019 in agreement with the national funding body. Nearly all (14,477€) the budget left (18,452€) by P7 was transferred to P4 under the supervision of the national funding body. The rest was funded based on internal resources.

P5: The project budget was defined using a mean personal cost. Involved researchers all had a cost below this mean which resulted in underspending.

P6: The project duration was extended due to Covid-19 and thus the contract with the PhD student was extended too leading to overspending. Overspending was financed based on internal resources. No additional money was provided by the national funding body.

P7: Due to the withdrawal of P7, it was agreed with the funding body that the budget left (18,452€) would be transferred to P4 as IDELE took over ITAB's activities in the project.

P8: Extension of project due to Covid-19, provision of final dataset and therefore also data analysis was delayed

P 8: Because the project was extended due to Covid-19, and because several activities (farm surveys, preparation and evaluation of the data) took more time than initially planned, extra budget was demanded and provided by the national funding body. This also explains why the budget was lower at the time of the mid-term report.

P9: The reason for hiring a postdoc was that the PhD student decided not to continue, and there was not enough time or money in the project to hire another 4-year PhD student. This change was not discussed with national funding body as it still used the allocated money to employ people to do the work. Overspending (due to postdocs having slightly higher salaries compared to PhD students at SLU) was financed based on internal resources. No additional money was provided by the national funding body.

P10: Extra costs related to various factors: (i) after a first experiment in 2018 experimental conditions were changed and another round of experimentation was deemed necessary in 2021, (ii) the extension of scope of work, and (iii) the extension of the project duration due to Covid-19 increasing personnel costs. These extra costs were accepted and funded by the national funding body.

Annex 2: Overview of coordination budget and activities for the full implementation period of 42 months (in EUR)

No.	Item in the coordination budget	Total cost spent
1	Travel	4765
2	PM	64838
3	Overhead (fixed at 25% of the total coordination costs)	Used as PM
4	Catering	3608
5	Other items	5789
	TOTAL	79000

The following items are envisaged in the table:

- Travels for participation in CORE Organic Cofund research seminars and travels to partners for problem solving (travels for project meetings are to be requested from the national funds);
- Person months to cover the coordination work and reporting to CORE Organic Cofund, also for permanent staff;
- Overhead (fixed at 25% of the total coordination costs);
- Catering in connection to project meetings,
- Other costs (must be specified and please include additional budget lines if needed).

With the Covid-19 context, the role of the project coordinator was modified. Accordingly, travel and catering budget was re-allocated to lengthening the contract of a project assistant who supported the coordinator in all coordination tasks.

Annex 3: Recommendations to the CORE Organic consortium in relation to the launching of future transnational calls and monitoring of the transnational research projects

Support provided by the representative of the CO Secretariat was extremely useful throughout the project. This is an excellent idea to be kept for future calls.

Mid-term evaluation was a bit frustrating due to the very few questions asked. Would it be possible to leave more time for discussion?