MARS 2021

TOWARDS A JUST TRANSITION OF FOOD SYSTEMS

Challenges and policy levers for France

Pierre-Marie Aubert, Baptiste Gardin (Iddri) & Christophe Alliot (BASIC)
With contributions from Élise Huber & Michele Schiavo (IDDRI), Théodore Fechner & Delphine McAdam (BASIC), Xavier Poux (AScA), Christian Couturier & Sylvain Doublet (Solagro)

Annexes

IDDRI

BASIC

Citation : Aubert, P.-M., Gardin, B., Aillot, C., (2021). Towards a just transition of food systems. Challenges and policy levers for France, Annexes, IDDRI.

For more information about this document, please contact : Pierre-Marie Aubert, pierremarie.aubert@iddri.org

Funded by:

GOUVERNEMENT

Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

La responsabilité des ministères ne saurait être engagée

OFB OFFICE FRANÇAIS DE LA BIODIVERSITÉ

Carasso Daniel & Nina
Fondation sous l'égide de la Fondation de France

Fondation Didier et Martine Primat

VALUMICS Food Systems Dynamics

The VALUMICS project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727243

Le projet VALUMICS a été financé par le programme de recherche et d'innovation Horizon 2020 de l'Union européenne dans le cadre de la convention de subvention n° 727243.

IFOAM ORGANICS EUROPE

Life

Cette publication a été co-financée par le programme LIFE+ de l'Union Européenne, sous la direction de l'Agence Exécutive pour les Petites et Moyennes Entreprises (EASME). La publication ne reflète que les positions des auteurs. EASME n'est pas responsable de l'information fournie dans cette publication, ni de son utilisation.

FONDATION TERRE SOLIDAIRE

Acknowledgements

While the authors take sole responsibility for any errors or omissions in this document, they would like to thank the members of the scientific committee for their advice and critical feedback:

Valentin Bellassen *(CESAER, INRAE) ;* ***Philippe Boulet*** *(Director of the Performance and Prospects Unit, CerFrance) ;* ***Pierre-Alain Jayet*** *(INRAe) ;* ***Christophe Perrot*** *(Institut de l'Elevage) ;* ***Jean-Louis Rastoin*** *(Montpellier Supagro) ;* ***Bernard Valluis*** *(Honorary President of European Flour Millers).*

This study has received financial support from the French government in the framework of the programme "Investissements d'avenir", managed by ANR (the French National Research Agency) under the reference ANR-10-LABX-01. Access to some confidential data, on which is based this work, has been made possible within a secure environment offered by *CASD* – Centre d'accès sécurisé aux données (Ref. 10.34724/*CASD*)

Graphic design: Ivan Pharabod.

ISSN 2258-7535

TOWARDS A JUST TRANSITION OF FOOD SYSTEMS
Challenges and policy levers for France

Annexes

Appendix 1.
Modelling the impacts of the transition at the farming system level with SP_calc

Appendix 2.
Using IAA_calc to understand the impact on employment and investment needs resulting from change in the agri-food industry

Introduction

This document is intended for members of the public who wish to extend their knowledge of the modelling tools presented in the report "Towards a just transition of food systems. Challenges and policy levers for France" (Aubert et al., 2021). It contains technical appendices that describe the structure of the models used to produce the results of the Dual France and Territorial Recompositions scenarios.

The document is structured in two parts. The first describes the method used to analyse the impact of the scenarios at the level of the farming system. Following a similar format, the second part looks at the impacts of the transformations on the agri-food industry sector. Both sections firstly present the data sources used, then provide the technical details of the models constructed for this study (SP_Calc and IAA_Calc). For simplicity, explanations of the methods used for the two sectors analysed (dairy and arable) were kept together as much as possible. However, when this was not possible, because the approaches used depend on the sector analysed, we separated the sections or focused on specific areas.

The modelling approach for the agricultural production and industry sectors differ in one key respect: we identified typical farming systems for the former, and imagined their technical and structural evolution by 2030. This was not possible for the industry sector. Given the absence of complete and statistically representative data on each processing company (like the FADN database for farms), we analysed the industry as a single block (not separating, for example, small and large companies). The heterogeneity of processing pathways within a single scenario are then only treated implicitly or by making aggregate averages. This is a limitation of the current method, which could be pursued and consolidated in future work.

2. Appendix 1. Modelling the impacts of the transition at the farming system level with SP_calc

2.1 *Structure of our farming system analysis*

Two main phases of work formed the basis of the analysis of the farm level socio-economic impacts:

1. The development of a typology of farming systems that is compatible with the transition envisaged in 2030, based on a typology of farming systems in 2015 and the analysis of their pathways of change.
2. A quantification or modelling phase for the construction of SP_calc, taking the biophysical quantities (livestock and land area) defined in the French National Low-Carbon Strategy (SNBC) 2030 scenario as a reference point. It was used to estimate:
   - the impacts on farm numbers and on the number of total agricultural workers per sector, based on the extrapolation of job numbers in each farming system;
   - the conditions (in terms of prices and subsidies) under which the envisaged developments can simultaneously remunerate the workforce and amortize the investments necessary for the transition.

The analysis framework is based on a detailed understanding of the production sectors studied (dairy sector and the cereals, oilseed and protein crops sector). Although the overall approach remains the same, the development of farming system typologies and model calibration are specific to each production sector. The specificities of the calibrations in relation to the two sectors are explained in subsidiary appendices at each analysis level (2015 typology, pathways, 2030 typology, calibration of system populations). The sections below firstly present a discussion of the data sources used for the different analysis phases, followed by an analysis of the work of qualifying the 2015 farming systems and their evolutionary pathway towards a set of 2030 farming systems. Finally, we describe the structure of the SP_calc model and the different calculation modules.

2.2 *Data sources*

The data required to calibrate the model's baseline is derived from several sources.

Numerous data sources were used to define the 2015 and 2030 farming system types for both sectors.

The FADN database is the reference database for SP_Calc. This EU statistical database focuses on large and medium-sized farms with a standard output (SO) of over €25,000. For France, the sample includes 7,284 farms, extrapolated to 296,800.[1] Although this only represents about 70% of the total number of farms

Table 1. Data sources for farming systems analysis

	Source
Qualitative definition of farming systems (typology)	Agreste, Idele, Arvalis, AGPM/AGPB, French Chambres of agriculture, expert advice, etc.
Quantitative definition of farming systems (livestock number, area, etc.)	FADN, expert advice
Employment intensity of farming system	FADN, expert advice
Capital intensity (tangible assets)	FADN, expert advice
Average producer income	FADN
Average conventional and organic prices (milk, cereals)	Producer price surveys (FranceAgriMer), Monthly milk survey (FranceAgriMer)

(450,000 in 2013), large and medium-sized farms are statistically significant. Indeed, they account for 95% of production potential and 90% of land area. The FADN analysis here relates to 2015, which was chosen as the reference year for scenarios. It should be noted that the 2015 data are based on a particular economic situation. Thus, 2015 was rather favourable for crop production and more difficult for pig and dairy farming. However, for the purposes of this study we considered such cyclical variations to be negligible, given the overall structural determinants taken into account. A chronological comparison could "smooth" the FADN data over time.

2.3 First phase of work: development of a typology of farming systems compatible with the transition envisaged in the SNBC

There are three main stages to the characterization of farming systems that are compatible with the transition envisaged in 2030.

Development of a typology of current farming systems (2015)

The starting point of the analysis was to describe the current main types of farming systems for each sector. To this end, extensive research was carried out to establish system categories that are both statistically consistent and relevant to the ultimate objective: to provide a basis for considering the development of farming systems in France up to 2030 in accordance with the SNBC's GHG emissions reduction targets. Given that the move towards a more sustainable agricultural model has consequences for both agricultural techniques (crop type, herd size, yield, combination of production units, etc.) and socio-economic structures (employee numbers, fixed capital, farm concentration, etc.), the agronomic aspects and socio-economic determinants were thus jointly addressed, from the perspective of French-style comparative agriculture (Cochet and Devienne 2006) (Cochet 2011).

Firstly, statistical investigations were performed to categorize farming systems into groups with common characteristics. Climatic conditions, soil characteristics and gradient determine the framework in which agricultural production takes place; thus, a territorial categorization on the basis of soil microclimate was first implemented to illustrate the territorial division of the different types of production, which was followed by a review of the major production in each territory. The principal component analysis method was also tested on the basis of soil microclimate, agronomic and socio-economic criteria. However, this exclusively statistical method was not ultimately utilized, because it did not enable the identification of sufficiently homogeneous groups of systems and, above all, it was less relevant for the discussion of results with stakeholders.

Finally, a national-scale typology of current farming systems was constructed using a combination of expert advice and statistical analyses. A literature review of existing typologies (particularly the Gesebov prospective studies (Gac et al., 2016) for the dairy sector and *Culturibles* for arable crops) along with interviews enabled major systems to be defined in a qualitative manner, which were then translated into statistical groups within the FADN. The starting point of the typology is the specialization of farms defined according to the Type of farming (TF),[2] however it partially moves away from it, so that in certain cases the diversity of production units present on each farm can be taken into account. The mixed crop livestock farming category, for example, includes cattle farming systems with less than two thirds of the UAA in fodder or with more than 40ha of crops (definition developed during the CASDAR REDSPYCE research project conducted by Idele (Perrot 2017)). A complementary document, the farming systems catalogue, presents the details of the statistical processing procedures and practical choices used to define each farming system.

Analysis of transition pathways to 2030

To move away from current frameworks for the analysis of agriculture, in the context of a scenario that proposes major reconfigurations to production, the decision was made to avoid reasoning on the basis of a constant farming system. The 2030 time frame was chosen because it is both far enough away to envisage major transformations in the farming system structure, but also close enough to be tangible/perceivable to actors (within a time frame of about 3 investment cycles). This highlights the fact that the strategic decisions that will allow the agro-ecological transition to be achieved, must be envisaged/implemented now. The scenario thus defines the 2030 horizon as compatible with being on track for carbon neutrality on a global scale by 2050, as envisaged by the SNBC.

The analysis of farming system evolution in 2030 in the framework of the SNBC takes as a starting point the 2015 farming systems typology, and the retrospective analysis of recent changes presented in the first part. The retrospective analysis thus enables the description of current farming systems to be refined and for their possible developments to be put into perspective. Two indicators in particular are highlighted as structural for the evolution of the systems: the levels of concentration (farm size) and specialization. Based on these two indicators, an evolution matrix was developed that combines 4 possible development strategies (**Figure 1**).

The four strategies considered do not determine the ultimate configuration of the farming system, but rather the pathway taken. The final configuration thus depends on the combination of three parameters:

1. the strategy adopted by the farmer (for which we propose 4 options above);
2. the need to adopt the practices/techniques identified by the SNBC to reduce emissions (see *Assumptions regarding changes to production techniques in the SNBC scenario*);
3. the initial situation, knowing that not all strategies are applicable in all initial situations and for all sectors.

The set of possible combinations of the 4 development strategies and the 2015 types is first considered, then in a second step the types are recombined (grouping of close or similar types) in order to keep the number of 2030 systems similar to the number of systems present in 2015, so as not to complicate the analysis. The example of dairy cattle is presented in **Figure 2**.

The definition of the 2030 systems was also enriched by existing prospective work detailing transformation strategies for French farms (CerFrance 2019). Thus, qualitative aspects concerning the strategic options followed by farmers and the drivers of the system's transformation made it possible to complete the definition of the 2030 farming systems (**Table 1**).

This original prospective methodology for describing types of farming systems in 2030 according to development strategies thus aims to break away from the current frameworks for analysing the agricultural situation, within the framework of a scenario that proposes profound reconfigurations of production and therefore of farming system structures.

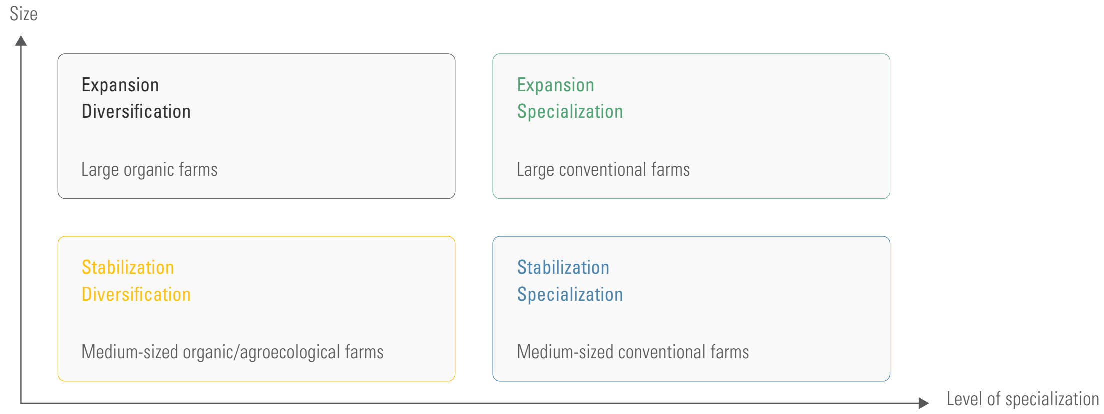
Socio-economic characterization of farming system types in 2030

We have seen that the construction of the 2030 types is based on the simultaneous analysis of: (i) recent farming system dynamics, (ii) possible strategies that a farmer may pursue, and (iii) agri-environmental constraints imposed by the SNBC (e.g. share of livestock fed with additive, decrease in pesticide use and increase in efficiency of nitrogen use, etc.).

Structural assumptions are also needed to describe the farming systems by 2030 (crop area, livestock number, labour productivity, etc.). For these quantitative assumptions, the values are estimated on the basis of the trends currently observed in the FADN, adjusted in line with expert advice (technical institutes in particular) and on the basis of current examples of farms representative of the dynamics examined in the study. The different assumptions used are detailed in an appendix: the catalogue of 2030 farming systems. The seven 2030 dairy cattle systems and the eight 2030 arable crop systems constitute a simplified and necessarily reductive set. The real situation is and will remain diverse and contrasting, with both continuities and ruptures between the 2030 systems defined in the study.

For the parameterization of the finer characteristics of the 2030 systems, we started from the assumption that these systems are already present in the 2015 FADN, but in limited numbers. For this reason, we use the characteristics of the innovative farms present in the 2015 FADN that are closest to the 2030 systems in order to use their specific characteristics to be able to carry out a detailed analysis at the farm income

Figure 1. Strategies for the development of 2015 farming systems



Source: IDDRI inspired by (Cerfrance, 2019)

Figure 2. Diagram of the construction of 2030 dairy cattle farming systems based on the 2015 typology and the matrix of development strategies

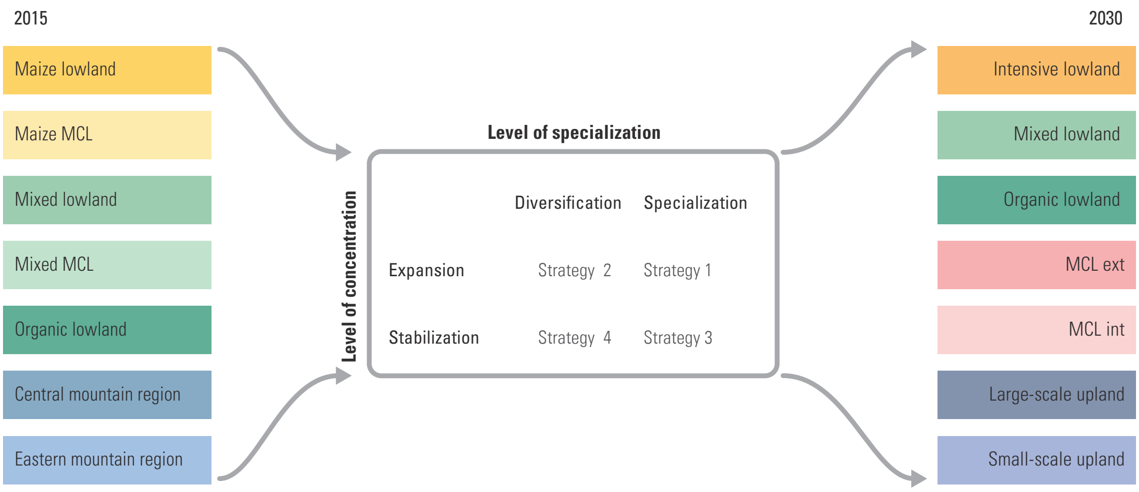


Table 2. The 2030 development strategy (source: les cahiers CerFrance 2019, accompanying the transformation of French farms)

	Competitiveness	Contractual	System
The 3 main development strategies	A strategy to develop volumes in highly competitive standard channels	A strategy of segmentation and contractualization of all or part of the production	A strategy of conversion and inclusion in a differentiated chain dynamic with the possibility of direct sales
Levers for change	Organize work with application of new technologies Produce volumes at lower costs Finance development and transmission, particularly by opening up farm capital	Comply with specifications Manage traceability for different product ranges Change practices without affecting economic performance	Carry out technical changes linked to changes in practices Promote complementarity between different types of production Join production chains that combine labels and locality

Table 3. Description of a 2030 intensive mixed crop dairy farming system

Intensive mixed crop dairy farming system 2030
Description: Large mixed crop dairy farm with independent production activities to simplify farm management. A favourable compromise between crops and livestock is sought to optimize farm profitability, the objective being to ensure a high level of milk and crop production.
Competitive advantage: the farmer chooses to participate in the concentration of volume by aiming for economies of scale.
Emergence modalities: this type of farming system is developing in areas with good production potential, with the possibility of using livestock production to valorize farmland with less potential.

	Qualitative assumptions	Quantitative assumptions
PS size	Significant increase in herd size and UAA to reach the size of today's largest farms.	**DC:** approx 100 DC **UAA:** 250 ha 50 ha Grassland
Productivity	Significant increase in dairy cow productivity and milk production.	**Productivity:** 8,500 l/DC **Milk production:** 850 t
Labour mobilization	Optimization of labour mobilization as a competitive factor. Labour productivity > 200,000l/AWU Farms organized as companies	**AWU:** approx 3 AWU **Share of AWU employed:** 25% **Labour productivity:** 280 t milk/AWU/year
Capital intensity	Major need for investment. Importance of new technologies and mechanization (robots, innovative buildings, etc.) Possible mobilization of external capital.	**Fixed capital:** €1,600,000
Technical innovations SNBC	Covering of slurry pits and biogas flares, or anaerobic digestion to reduce emissions from livestock effluent Adaptation of rations to limit enteric fermentation	
Selection criteria in the 2015 FADN	TF milk meat cattle and mixed and MCL, MFA/UAA < 60%, DC between 80 and 120, yield > 7,000l/DC	81 FADN farms

(source: IDDRI)

statement level (the criteria for selecting groups of innovative farms in the 2015 FADN as well as their characteristics are detailed in the 2030 farming systems catalogue). Thus, the analysis is based on the current farming systems that are most compatible with the scenario's objectives in order to analyse the conditions for their generalization in a prospective manner. Each 2030 farming system is described according to a set of qualitative (description, competitive advantage, emergence modality) and quantitative (size, productivity, labour, capital intensity) criteria, see the example below (**Table 3**).

Adjustments were required for the emerging farming systems of 2030, which are not represented, or only marginally so, in the 2015 FADN. Thus, a specific method was developed to define the two types of organic arable crop farming systems in 2030, based on an ad hoc group of experts composed of technicians from the French Chambers of Agriculture and technical institutes. Ultimately, the Specialized Intensive Dairy Cattle 2030 system was developed by adjusting the innovative 2015 farming system that was selected using a coefficient to obtain a system of sufficient size.

2.4 *Second phase of work: evaluation using the SP_Calc model*

SP_calc is a model that uses biophysical values (livestock and land area) defined in the SNBC 2030 scenario to calculate two indicators:

- impacts on farm numbers and on the number of agricultural workers per sector;
- conditions (in terms of prices and subsidies) under which the planned developments will simultaneously enable the remuneration of the workforce and the amortization of the investments necessary for the transition.

The model is based on the definition of the 2030 farming systems described in the previous section. It is structured in 3 modules:

1. Module for constructing 2030 farming system populations based on:
   - biophysical limitations posed by the SNBC;
   - general assumptions linked to the different development scenarios envisaged (average size, specialization level, regionalization, demography, etc.).
2. Module for analysing impacts on employment and farm numbers.

3. Module for analysing the price and subsidy conditions under which this population of farms can generate sufficient income or even increase it.

Module 1: construction of 2030 farming system populations

The first module aims to construct populations of 2030 farming systems that are compatible with the biophysical limitations set by the SNBC.

In this module, SP_Calc calculates the number of farming systems in 2030 of each type that are compatible, firstly, with the SNBC's biophysical framework (number of dairy cows for dairy production or area cultivated for arable production), and secondly with a set of scenario construction assumptions taken at the overall level (e.g. average size, specialization level, demographic framework, regionalization criteria).

The precise number of each system is then calculated by means of a solver that makes it possible to find the solution that respects all proposed assumptions.

The assumptions of the biophysical framework and scenarios are detailed for each sector in the following appendices:

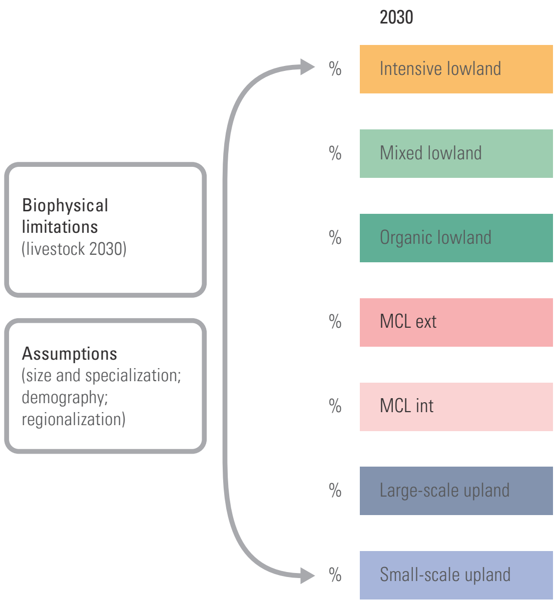
- Focus: module 1 Dairy cattle
- Focus module 1 Arable crops

Module 2: employment impact

Once the 2030 farming system population has been determined in Module 1, Module 2 allows the number of jobs in the farming systems to be calculated from the employment intensity levels of each farming system. The following formula presents the calculation:

$$E = \Sigma\ (FS30_i \times AWUFS30_i)$$

Figure 3. Diagram of the method for constructing the 2030 farming system populations for the Dairy Cattle sector



Where E: total number of jobs

FS_{30i} : number of type i 2030 farming systems

$AWUFS30_{30i}$: number of jobs in the type i 2030 farming system in AWU

Module 3: income impact

In our study, income is considered globally as the difference between all farm outgoings and revenue. Income includes both the amount used to pay for the workforce, and the available amounts to make the necessary investments, based on the notion of "depreciation" (**Figure 4**). Calculations of income levels

Figure 4. : Diagram of the disposable income estimation method for income and depreciation in FADN (IDDRI)

are indeed approximated from farm income statements that record investments not at their total fixed asset value, but at their depreciated book value for the given year.

In other words, calculation of the level of remuneration for labour and depreciation is as follows:

$$R_i = (PrFS30_i + SubFS30_i) - (CiFS30_i + ChFS30_i)$$

R : level of labour remuneration and depreciation for the 2030 FS i

$PrFS_{30i}$: revenue from type i 2030 FS activities (production x purchase price)

$SubFS_{30i}$: subsidies received by the type i 2030 FS

$CiFS_{30i}$: intermediate consumption of type i 2030 FS

$ChFS_{30i}$: other type i 2030 FS expenses (rent, insurance…)

Then, a set of possible configurations are examined that could lead to acceptable income and investment levels for the producer. For this purpose, different configurations of the amount of subsidies, of the premium allocated to production, and of income level are considered within a combinatorial matrix (**Figure 5**).

The matrix can be read as follows: for a given level of income (constant or + or - 10%), it presents the combinations of the amount of subsidies and the price of milk within which farmers will be able to cover a reasonable level of depreciation. The matrix thus translates the levers necessary for farmers to be able to address an investment need to ensure the transformation of their farm in the framework of the scenario.

Depreciation is a key indicator, as it represents the amount dedicated to the return on capital investments in the farm's operating income. Nevertheless, the handling of this indicator requires great care and poses many challenges due to its "dynamic" and "constructed" dimensions.

- Firstly, the temporal dimension is fundamental, as depreciation refers to the distribution of the acquisition cost of the asset over the period during which it will be used by the company. Future investments, to be made between now and 2030 as part of a strategy to develop a farming system, will not all be made at once. Thus, the amount of depreciation is not the amount of additional fixed capital divided by the number of years, but will vary with the rate at which the farm manager invests in this new capital. Similarly, ongoing investments were made at different dates and therefore depreciate over different periods, and as a result, the depreciation allowance in the 2015 income statement is reduced at a rate that is impossible to know. Furthermore, depreciation is a key indicator for calculating farm accounting results, which is also used as a basis for calculating social security contributions and taxes. As a result, it can have a "constructed" dimension insofar as it is the result of various tax optimization strategies. For example, the additional depreciation measure, the "Macron Law", has enabled all companies, between April 2015 and April 2017, to apply additional depreciation of 140% of the purchase value of the assets acquired, which mechanically reduces the tax liability base (Piet L and al. 2020). On this second point, the FADN recalculates depreciation on a straight-line basis to avoid biasing comparisons with tax considerations.

To be able to analyse the evolution of the amount of depreciation in the profit and loss accounts of farms, we propose to account for the dynamic dimension of depreciation according to several assumptions detailed below:

- We positioned ourselves at a pathway milestone, 2025, at which point we considered that:
  - half of the investments made before 2015 will be fully depreciated, which means that the depreciation charge remaining to be paid is equal to half of that of 2015
  - all investments needed by 2030 will have been made;
  - these new investments will have a 10-year depreciation period;
  - half of these investments are made by purchasing new assets and the other half by acquiring assets at half their value (acquisition of assets from other farms that cease activities).
- Depreciation requirement for 2025 = half of 2015 depreciation + additional capital to be invested, divided by 10 (depreciation period) with half purchased new and half purchased at half its value (see equation below).

- The depreciation requirement can then be included in the expenses to identify the conditions for economic viability.

Calculation of the amount of depreciation in 2030 based on the differential levels of fixed assets between 2015 and 2030:

$$Dp_{30} = \frac{Dp_{15}}{2} + 0{,}1 \times (\frac{(AcFS_{30} - AcFS_{15})}{2} + \frac{(AcFS_{30} - AcFS_{15})}{2} \times 0{,}5)$$

Dp_{30} : depreciation of 2030 Farming system
Dp_{15} : depreciation of 2015 Farming system
Ac SP_{30i} : fixed assets of 2030 Farming system
Ac SP_{15i} : fixed assets of 2015 Farming system

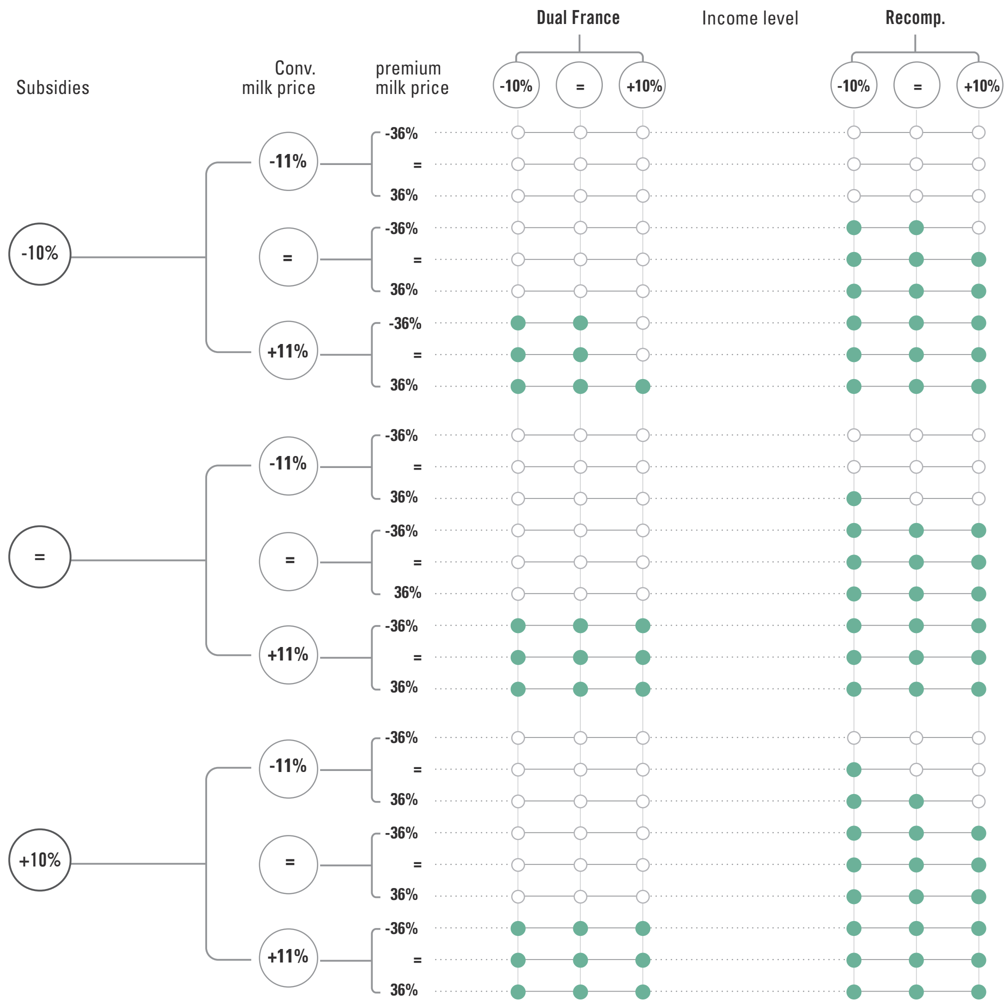
Thus, the calculation of the level of depreciation is fundamentally dynamic, and lies in the comparison between an initial asset level in 2015 versus a final asset level in 2030. Therefore, the determination of the investment level involves the characterization of each individual transition strategy from the 2015 situations to the 2030 situations.

Thus, each individual strategy is characterized, as shown in the **Figure 6** example of dairy cattle farming systems in the Dual France scenario.

Therefore, the aggregate analysis at the sector level combines all individual pathways into an aggregate profit and loss account. For example, for the dairy

Figure 5. Combinatorial matrix showing the combinations of income, subsidies and prices for which the Dairy farming systems can cover a reasonable amount of depreciation (green box)

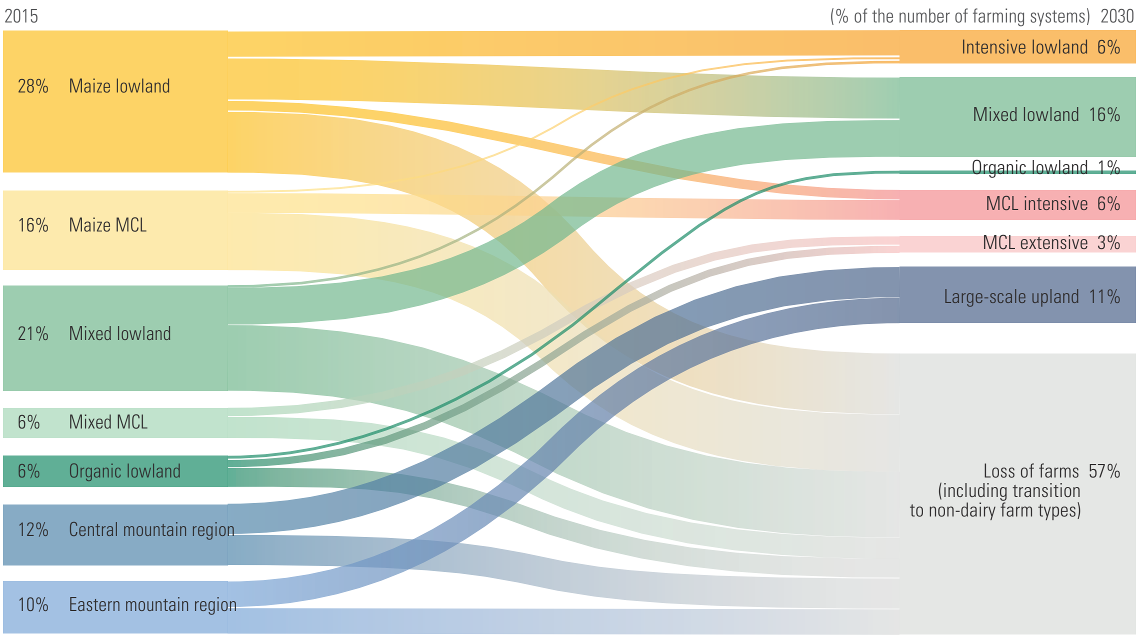
Key: Each box represents a combination of milk price, subsidy level and wage target.
A green box means that the combination generates a surplus that is sufficient to cover the investment costs of the transition.



Source: authors, based on RICA data

sector, this represents the French dairy farm as an aggregation of all dairy farms. Even if this graph does not really make sense from an economic point of view, because it combines the management strategies of heterogeneous individual farms, it nevertheless shows the major trends at work for each item of expenditure and income, in an aggregated manner (**Figure 7**).

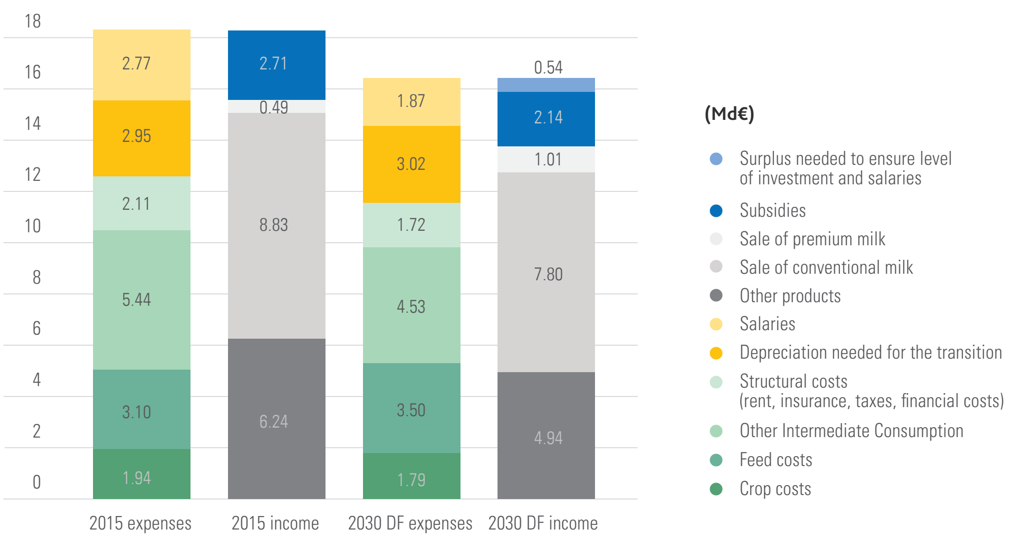
Figure 6. Diagram of the evolution of the Dairy Cattle FS in the Dual France scenario



MCL: mixed crop-livestock farming. Note: the definition of the farming systems considered changes during the period 2015 - 2030

Source: IDDRI

Figure 7. Aggregate profit and loss account for all dairy cattle farms in 2015 and in the Dual France 2030 scenario (€ billion)



Source: FADN and IDDRI

2.5 *Focus on key sectoral assumptions and technical developments*

Key assumptions for dairy sector

The physical constraints of the SNBC

Both scenarios are in line with a dairy herd reduction dynamic, defined in the biophysical framework of the SNBC.

Table 4. Evolution of the number of dairy cows in the national low-carbon strategy scenario

	2000	2015	2030
DC numbers (million)	4.3	3.6	3.2

Source: SNBC

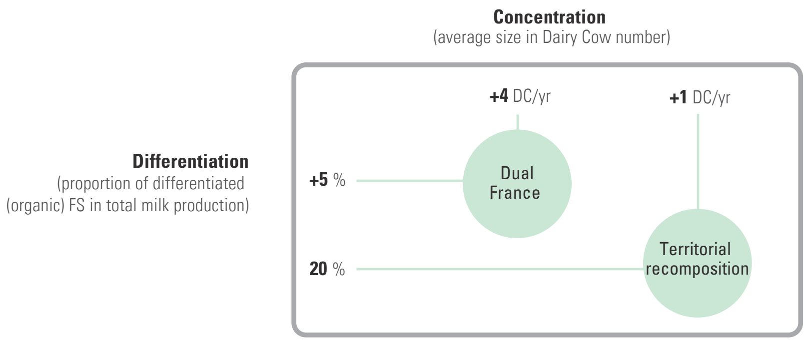
How the systems are combined in the two contrasting scenarios

Two criteria are used to frame the development of the two farming system populations: the concentration and specialization levels. The threshold values used are based on the retrospective analysis.

Table 5. Level of concentration and specialization of dairy farms in the scenarios

	2000	2015	Dual France 2030	Recompositions 2030
Concentration (average size in DC number)	38	60 (+1.5 DC/yr)	115 (+4 DC/yr)	75(+1 DC/yr)
Specialization (proportion of organic in total production)		3.50 %	8 %	25 %

Figure 8. Development criteria for the two contrasting scenarios for the dairy sector



Regionalization criteria and proportion of grassland systems

The SNBC-A places considerable importance on maintaining grassland in general. Depending on the regions where these grasslands are maintained or reclaimed - in particular for biodiversity reasons - the structure of FS populations will differ. **Table 2** presents two ways of approaching these regional dynamics.

Table 6. Regionalization criteria and proportion of grassland systems (in number of DC per Farming System group)

	Regional criteria (lowland, upland, MCL)			Proportion of grassland systems		
	Share of specialized lowland FS	Share of upland FS	Share of MCL FS	Share of organic FS in lowland specialized FS group	Share of FS ext in MCL FS	Share of FS ext in upland FS
2015	57 %	18 %	25 %	9 %	26 %	70 %
Dual France narrative Duale France quantitative translation	Concentration of production in specialized areas, plains (west) and uplands			No specific objectives		
	65 %	20 %	15 %			
Territorial recomposition	Increase in the share of mixed farming and de-concentration in upland and lowland (west) areas			Major development of organic FS in lowlands	Share of MCL ext greater than or equal to 2015	Share of upland ext at least equal to 2015
		15 %	40 %	25 %	>=26 %	>=70 %

Demographic framework

The number of farms in 2030 is strongly constrained by demographic dynamics, taking into account both the current age pyramid in the sector and the low influx of new entrants.

Table 7. Evolution of the number of dairy farms

2030 Trend (Idele)	Assumption of retirement of the oldest farmers with maintenance of the current installation rate	35,000 farms
Dual France	Decline in current installation rate	between 25,000 and 35,000 farms
Recomposition	Increase in current installation rate	between 35,000 and 43,000 farms

Key assumptions for the arable crops sector

Physical limitations of the SNBC

In the case of arable crops, the biophysical framework is based on a number of assumptions.

Table 8. 2030 SNBC cropland and assumptions regarding proportion of each crop cultivated in 2030 arable crop farming systems

	Cropland in 2015 (kha)	Cropland in SNBC 2030 (kha)	Proportion of crop in AC FS (FADN 2015)	Targeted SNBC area in AC FS 2030 (kha)
Con. Cereal	9 370	7 025	67%	4 702
Con. oilseed	2 475	1 886	80%	1 500
Con. protein crops	325	429	79%	340
Organic cereals	177	2 212	60%	1 327
Organic oilseed	47	504	60%	303
Organic protein crops	67	627	60%	376
Temporary pasture	3 198	2 263	25%	566

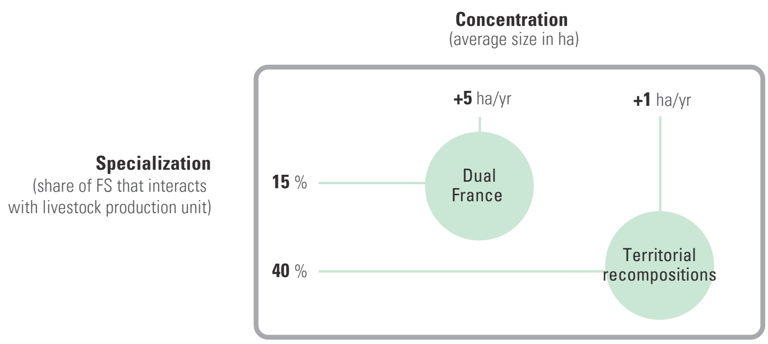
How the systems are combined in the two contrasting scenarios

Overall criteria: concentration and specialization levels

Tableau 9. Niveau de concentration et de spécialisation des exploitations Grandes Cultures dans les scénarios

	2000	2015	Dual France	Territorial recompositions
Concentration (average size in ha)	90	130 (+2.7 ha/yr)	205 (+5 ha/yr)	145 (+1 ha/yr)
Specialization (share of FS that interacts with livestock production unit)		20 %	15 %	40 %

Figure 9. Development criteria for the two contrasting scenarios for the arable crop sector



Demographic framework

The number of farms in 2030 in the scenarios is put into perspective with the current flows of retirements and installations. The analysis is based on figures from the FADN database and therefore does not take into account small farms with an SO of less than €25,000.

Table 10. Evolution of the number of arable farms

2015	Number of medium and large farms (source: FADN)	86K farms
Current trend 2030	Assumption of farm manager retirement at over 50 years (60%) with maintenance of the current installation rate (2,100/year)	66K farms
Dual France 2030	Decline in current installation rate	54K farms
Recompo 2030	Augmentation du taux d'installation actuel	90k exploitations

Assumptions regarding changes to production techniques in the SNBC scenario

Table 11. Technical developments in livestock systems according to SNBC assumptions (Source: SNBC)

Livestock farming	2015	2035	2050
Reduction of protein intake	65 % of animals concerned	80 % of animals concerned	100 % of animals concerned
Reduction of enteric fermentation	0 % of animals concerned	30 % of animals concerned	90 % of animals concerned
Increase lifespan of temporary grasslands to 5 years	10 % of grassland concerned	50% of grassland concerned	85% of grassland concerned
Covering of slurry pits and installing flares	0 % of undigested effluent	46% of undigested effluent	80 % of undigested effluent
Reduce age at first calving - dairy cows	33.1 months	29 months	28.2 months
Reduce age at first calving - suckler cows	36 months	33 months	32 months
Decrease average calf mortality rate	17 %	10 %	10 %
Increase the proportion of dairy herds on grass	Proportion of dairy cows: - mostly grass-fed: 16% - mostly maize-fed: 58%	Proportion of dairy cows: - mostly grass-fed: 29% - mostly maize-fed: 54%	Proportion of dairy cows: - mostly grass-fed: 45% - mostly maize-fed: 44%

Table 12. Technical changes in cropping systems under SNBC assumptions (Source: SNBC)

Crops	2015	2035	2050
Organic arable crop (AC) area	2% of land area under AC	38% of land area under AC	44% of land area under AC
Energy consumption (compared to 2015): large reduction		-23 %	-44 %
Nitrogen fertilization: improving the efficiency of nitrogen supply to the plant: decision support tools, equipment, delaying the first application, burying and targeting, optimizing grassland fertilization, optimizing use of livestock effluents.	surplus of 46 kg of nitrogen per ha of AC UAA (in addition to losses through volatilization)	surplus of 21 kg of nitrogen per ha of UAA (in addition to losses through volatilization)	surplus of 7 kg of nitrogen per ha of UAA (in addition to losses through volatilisation)
Forms of mineral nitrogen: preference given to ammonium nitrate	36 % of ammonium nitrate	50 % of ammonium nitrate	75 % of ammonium nitrate
Proportion of no-till AC	2 %	10 %	30 %
Proportion of AC under occasional ploughing every 5 years	2 %	15 %	30 %

3. Appendix 2. Using IAA_calc to understand the impact on employment and investment needs resulting from change in the agri-food industry

In this section, we describe the structure of IAA_Calc, the model we used to assess the impact of Dual France and Territorial Recompositions scenarios on the French agri-food sector.

Without intending to assess the consequences of the scenarios on the prices of processed products, on salaries, on the profits of companies, or to optimize the behaviour of economic agents, IAA_Calc helps us to estimate the effects of variations in the volumes of raw agricultural products on employment and on tangible investments needed in the agri-food industries. IAA_Calc starts from the agricultural production resulting from the SNBC's 2030 scenarios, transforms it based on a product mix defined by the modeller, and then calculates the variation in employment and tangible assets in each productive sector using labour and capital intensities that can vary according to the hypotheses of the scenarios. The transfers of raw materials in several processing stages are taken into account (e.g. flour that becomes bread, biscuits or pastry) through the use of coefficients. Similarly, at the end of the modelling, the production volumes at each production stage are compared to the current uses, and to the uses in 2030 of the two scenarios. In this way, it is possible to assess the impact of Dual France and Territorial Recompositions on the trade balance (export-import) at constant consumption or by imagining changes in consumer preferences.

As a result of the specificities of the two production sectors studied, IAA_Calc differs slightly depending on whether the dairy sector or the COP sector (cereals, oilseed and protein crops) is analysed. Despite the specificities of each sector, the dairy and the COP module share the same data sources and the same rationale. In the following sections, firstly, we discuss the data sources needed to calibrate the two modules. Then, the structures of the dairy and of the COP module are analysed in more detail.

3.1 Data sources

The data used to calibrate the model's baseline (reference year of 2015) comes from several sources. They are summarized in the following table.

As seen in the table, while agricultural production data sources for COP and milk collection are limited due to the relative simplicity of the information sought, more in-depth research and consistency work was needed for the product mix parameterization. We relied on

Table 13. Data sources for the agri-food industry analysis

	Source
Agricultural production and milk collection	FAOSTAT, Idele
Product mix	EUROSTAT – PRODCOM survey, Passion Céréales, Agreste, FranceAgriMer, Terres Univia, Idele, expert advice
Employment intensity	INSEE, EUROSTAT – PRODCOM survey, articles, internet publications, expert advice
Capital intensity (tangible assets)	INSEE, EUROSTAT – PRODCOM survey, articles, internet publications, expert advice
Usage and trade balance	EUROSTAT – PRODCOM survey, FAOSTAT, Terres Univia, Idele

several data sources to identify the outlets for agricultural production. Then, we aggregated the different outlets according to the APE/NAF categories at the sub-class level (5-character NAF code) characterizing the activities carried out by companies in France. When the APE/NAF category was absent (e.g. manufacture of foodstuffs from protein crops for human consumption) or did not represent the sector well (e.g. durum semolina milling), we recreated a category to enable agricultural production to be directed towards these sectors that lack information.

Faced with missing data in the Eurostat-PRODCOM survey for the reference year 2015, due to a lack of information or statistical secrecy, we used "reconstructed" data by applying the following method. If, for a given product, less than 4 years are available for the entire 2008-2018 period, while all other years are either absent or under statistical secrecy, then we eliminated the product because it is probably irrelevant (and therefore likely to have an outlier effect as it is produced by a very limited number of companies). On the other hand, if at least 4 years of data are available for the 2008-2018 period, and the reference year is missing, we attributed the value of the closest available year to 2015.

For the parameterization of labour and capital intensities, we used the employment data collected by INSEE that are part of the ESANE (Elaboration of Annual Statistics of Companies) scheme, which were matched to the volumes of processed products from the Eurostat PRODCOM survey. Firstly, we associated each PRODCOM product with its reference APE/NAF category. Secondly, we converted the volumes of each PRODCOM commodity into a volume of equivalent raw material to be able to compare the labour and capital intensities of productive sectors belonging to different stages of industrial processing. At this stage, it is important to underline that the data concerning the number of employees and the tangible fixed assets used are based on the APE/NAF codes at the sub-class level and were collected by INSEE at the company level. This means that the workforce of a production facility has been repatriated to the APE/NAF code of the main activity of the facility in question. This approach certainly induces margins of error for facilities that operate in several productive sectors (e.g. butter and milk powder manufacture), but we felt it was the most appropriate method given the employment data available. When production sectors were not present in the APE/NAF codes of the INSEE surveys that were part of the ESANE scheme (e.g. industrial processing of protein crops for human consumption), we recalculated the intensities using information from expert statements, newspaper articles or internet publications.

Data on product use and trade balances were retrieved from FAOSTAT for gross agricultural production. For processed products, we used the Eurostat PRODCOM survey for the vast majority of cereal products. For oilseed and protein crops, we made estimates from FAOSTAT and Terres Univia data. For dairy products, we used the data contained on the Idele website as it provides more detailed information on product usage compared to the PRODCOM survey.

3.2 *Dairy module*

In modelling the dairy sector, IAA_Calc combines two categories of analysis: one at the product level (milk, cream, butter, yoghurt, cheese, milk powder and other products) and one at the APE/NAF code level (manufacture of liquid milk and fresh products, manufacture of butter, manufacture of cheese and manufacture of other dairy products). These two categories of analysis

Table 14. APE/NAF code and associated dairy industry products

APE/NAF CODE	Dairy industry product
10.51A - Manufacture of liquid milk and fresh dairy products	Milk, cream, yoghurt
10.51B - Manufacture of butter	Butter
10.51C - Manufacture of cheese	Cheese
10.51D - Manufacture of other dairy products	Milk powder, casein, whey

are complementary for the simulation of the dairy sector carried out by IAA_Calc. The product approach allowed us to define a product mix based on the volumes collected that is consistent with the rationales of companies in the sector. Thus, we allocated the volumes of milk collected to the various processed products. Then, in the absence of specific data on employment and capital intensity for each processed product, we aggregated the volumes from the product mix to the most appropriate APE/NAF code (**Table 14**) for which we have data on the number of employees and the value of tangible assets.

In the first step, IAA_Calc starts from the volume of milk collected and then uses it to produce the various processed products (1).

(1) $V_i = C * \alpha_i$

Where

V = volume of milk used to produce the processed product

i = processed products (milk, cream, butter, yoghurt, cheese, milk powder)

C = milk collection volume

α = coefficient that determines the share of milk that goes into each processed product

We calibrated the value of the coefficient α for the reference year on the basis of estimates from Idele (Idele, 2019) regarding the distribution of the fat from milk according to the different processed products. With this choice, we adopted the assumption that the 6 products considered are the main products and are the recipients of the fat from the milk resource. Based on the manufacture of these 6 main products, IAA_Calc estimates the share of milk used for the manufacture of co-products: skimmed milk and lactoserum (2).

(2) $Z_c = V_j * \beta_{jc}$

Where

Z = volume of milk for the production of co-products (skimmed milk and lactoserum)

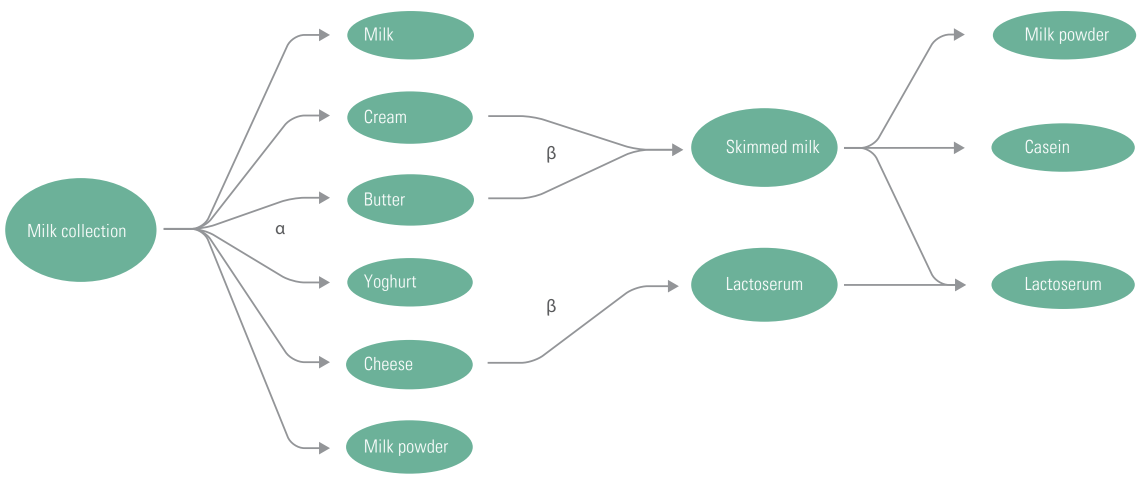
j ∈ i = processed products that give rise to co-products (cream, butter, cheese)

c = co-products (skimmed milk and lactoserum)

β = coefficient determining the share of milk that is not "retained" in the main product and that is intended for the manufacture of co-products

We set the β coefficient on the basis of Barbier et al, 2016. We also adopted the simplifying assumption that all skimmed milk is destined for the production of products falling under the APE/NAF category "Other dairy products" (milk powder, casein, lactoserum). **Figure 10** summarizes the reasoning adopted for the definition of the product mix. Following the definition of the product mix, for the calculation of the trade balance, we compared the volumes obtained with Idele data that estimate the quantities of milk equivalent in

Figure 10. Distribution of milk collection in IAA_Calc



fat consumed by French people in 2017 (Idele, 2019). As indicated at the beginning of the "Dairy module" section, following the definition of the product mix, IAA_Calc assigns the volumes produced in milk equivalent of processed products and co-products to each associated APE/NAF category. In this way, we obtain volumes of raw materials that transit through the factories, which are necessary to estimate the labour and capital intensities of each sector (3.1, 3.2).

(3.1) $H_k = E_k/(V_k+Z_k)$

(3.2) $G_k = R_k/(V_k+Z_k)$

Where:

k= productive sectors identified by APE/NAF codes

H = employment intensity

E = number of employees in FTE

G = capital intensity

R = tangible fixed assets in €M

From the employment and capital intensities, IAA_Calc calculates the number of employees and the value of tangible assets for each scenario (4.1, 4.2).

(4.1) $E_{ks} = (V_{ks} + Z_{ks})*H_{ks}$

(4.2) $R_{ks} = (V_{ks} + Z_{ks})*G_{ks}$

Where

s = scenario (baseline, Dual France, Territorial recompositions)

3.3 COP module

We decided to structure the section regarding IAA_Calc COP module in two parts: the first one addresses the definition of the product mix of the cereal and protein crop processing sub-sector for human food, while the second is dedicated to animal feed. In both cases, the model's main input variable is again the raw agricultural production derived from the reference year for the baseline and from the Dual France and Territorial Recompositions scenarios for 2030. For reasons of scenario design, we separated the COP into three categories: cereals, oilseed and protein crops (including soya). The method of calculating the number of employees and the value of fixed assets is common to both sub-sectors and is based on the same principle as that indicated in equations (4.1) and (4.2) (volumes * labour intensity; volumes * capital intensity).

COP processing for human food

For methodological reasons, we chose to only consider cereals and protein crops as COPs that contribute to human food (considering oil produced from oilseed and soy as an intermediate stage in animal feed production).

Unlike the dairy sector, where we modelled a single production stage, in the case of COP for human consumption, we structured the industrial chain on the basis of three processing stages. For cereals, the first stage consists of processing the raw material into flour, starch products, malt or other products. The four sectors correspond to the APE/NAF categories: "Flour milling", "Manufacture of starches and starch products", "Manufacture of malt", "Other manufacture of grain mill products". We allocated agricultural production to the four chains on the basis of equation (5).

(5) $F1_i = (F0_o - X_o + aM_o - A_o - U_o)* \varepsilon_i$

Where:

F1 = volume of cereals for processed products (1° processing)

o = all modelled COP sector products

i ∈ o = processed COP sector products (1° processing)

F0 = agricultural production of cereals

X = production wasted, exported, used for biofuel or alcohol manufacture

U = production for animal feed

M = imported agricultural production of cereals

a = share of imports used for human consumption

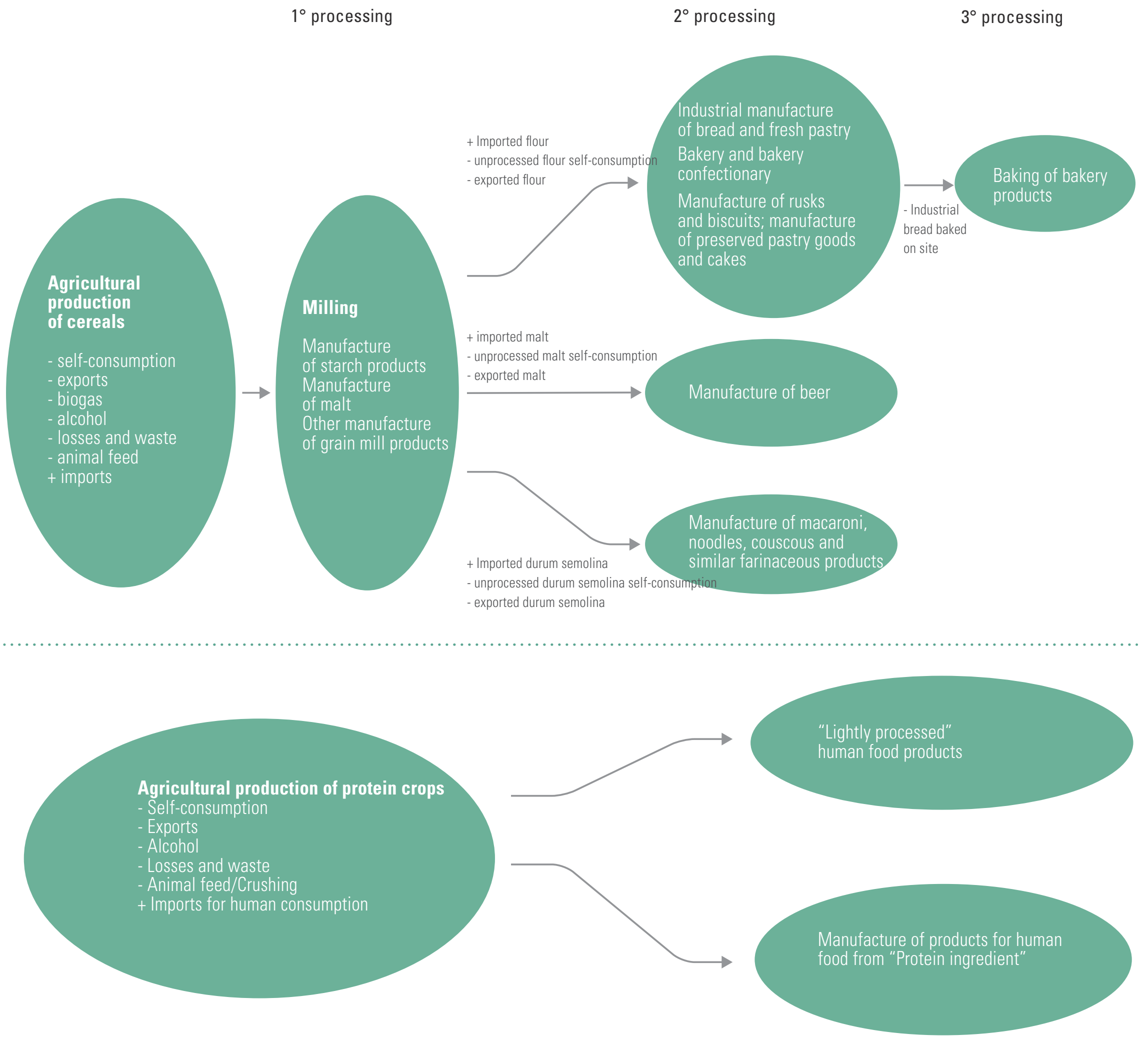
A = share of product used as it is

ε = coefficient that determines the share of cereals that goes into each processed product (1° processing)

For protein crops for human consumption, we adopted a similar procedure. Given the absence of an APE/NAF code specific to the processing of protein crops for human consumption, we created two processing categories: the first dedicated to the processing of "lightly processed" protein crops (e.g. shelled seeds to be consumed as they are, flours), the second concerns the manufacturing of "ultra-processed" products, that integrate protein as an ingredient.

We modelled the secondary processing of cereals for human consumption according to three outlets. The first is the processing of flour into industrial bread and pastry, artisanal bread and pastry, and preserved bis-

Figure 11 - 12. Distribution of agricultural production of COP for human consumption in IAA_Calc



cuits and pastry. For the definition of these outlets, we based ourselves on the following APE/NAF categories: "Industrial manufacture of bread and fresh pastry", "Bakery and bakery confectionary", and "Manufacture of rusks and biscuits; manufacture of preserved pastry goods and cakes". The second outlet is the processing of durum wheat durum semolina into pasta and couscous-type products (APE/NAF category "Manufacture of macaroni, noodles, couscous and similar farinaceous products"). Due to the absence of a specific APE/NAF code for durum semolina milling in primary processing, we calibrated a coefficient based on the actual volumes of durum semolina used, which applies to the APE/NAF category "Other manufacture of grain mill products". The third outlet is the processing of malt produced in the primary processing of beer (APE/NAF category "Manufacture of beer") (6).

(6) $F2_y = (F1_i - X_o + aM_o - A_o) * \eta_y$

Where:

F2 = volume of cereals for processed products (2° processing)

$y \in i$ = processed COP sector products (2° processing)

η = coefficient to determine proportion of processed product (1° processing) that goes into each processed product (2° processing)

Following secondary processing of cereal products, we introduced a third processing stage, "Baking of bakery products", which applies to the volumes of the APE/NAF "Industrial manufacture of bread and fresh pastry" sector. The definition of the volumes of the chain was calculated on the basis of the same principle adopted in equation (6).

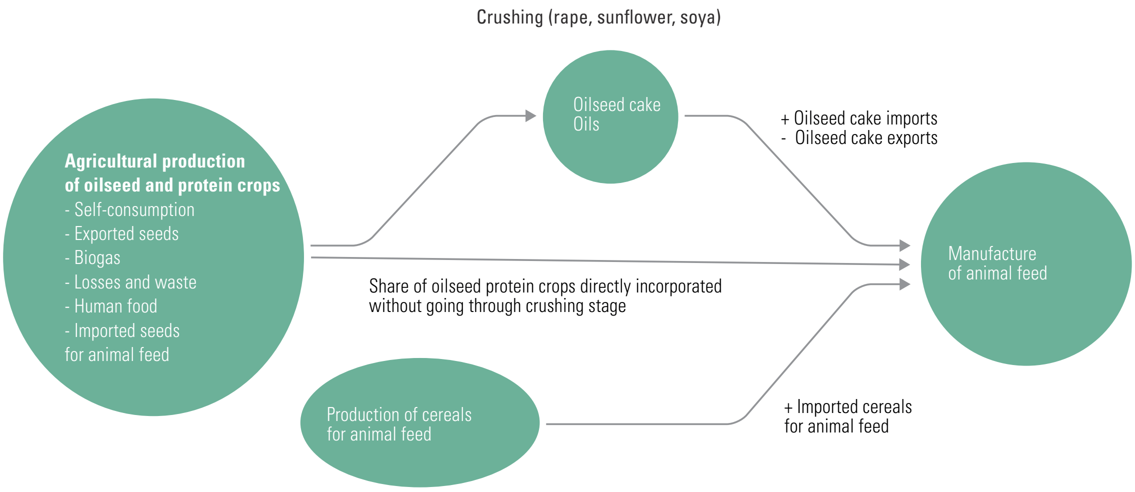
COP processing for animal feed

The animal feed sector in IAA_Calc includes all COP: cereals, oilseed and protein crops. Similarly to equation (5), for oilseed and protein crops we deducted from the raw agricultural production the unprocessed on-farm consumption, the exports, the stocks and waste. Then we added the imports of raw agricultural materials intended for animal feed. From the remaining oilseed and protein crop volumes, we distinguished between volumes going directly into animal feed production and those requiring an intermediate crushing stage.

The volumes destined for the industrial animal feed sector were thus estimated by taking into account: the production of cereals intended for animal feed, the oilseed cakes produced by the industrial crushing process, the oilseed and protein crops incorporated directly into animal feed and the imports of oilseed cakes, cereals and protein crops for animal feed. From this volume, we deducted the volumes of exported oilseed cake.

The volumes entering the crushing plants were matched to the APE/NAF category "Manufacture of crude oils and fat". The volumes intended for the industrial feed sector were matched to the APE/NAF code "Manufacture of prepared animal feeds".

Figure 13. Répartition de la production agricole des COP pour l'alimentation animale dans IAA_Calc



REFERENCES

- Aubert, Pierre-Marie, Christophe Alliot, Baptiste Gardin (2021). "Towards a just transition of food systems. Challenges and policy levers for France"
- Carine Barbier, Christian Couturier, Jean-Michel Cayla, Prabodh Pourouchottamin, Marie Sylvestre, Gilles Billen, Florence Toilier, et al. « Contenu énergétique et carbone de l'alimentation des ménages en France ». Projet CECAM, Rapport Intermédiaire, 2016.
- CerFrance (2019). "Stratégie 2030: comment rester dans la course". *Cahiers CerFrance*.
- Cochet, Hubert (2011). "Origine et actualité du 'Système Agraire': retour sur un concept". *Revue Tiers Monde* n°207 (3): 97-114.
- Cochet, Hubert, and Sophie Devienne (2006). "Fonctionnement et performances économiques des systèmes de production agricole : une démarche à l'échelle régionale". *Cahiers Agricultures*, January.
- Forget, V, J-N Depeyrot, M Mahé, E Midler, M Hugonnet, R Beaujeu, A Grandjean, and B Hérault (2019). Actif'Agri. Transformations des emplois et des activités en agriculture. Centre d'études et de prospective, Ministère de l'agriculture et de l'alimentation, La Documentation française, Paris.
- Gac, Armelle, Christophe Perrot, Claire Mosnier, Hélène Chambaut, Aline Lorilloux, and Jean Baptiste Dollé (2016). "GESEBOV. Emissions de gaz à effet de serre et consommations d'énergie de la fermebovine française: Bilan 1990, 2010 et perspectives 2035 – Rapport final". ADEME, 139.
- Perrot, Christophe (2017). "Économies de gammes *versus* économies d'échelle et d'agglomération en production laitière". Paper for the conference "Les polycultures-élevages: valoriser leurs atouts pour la transition agro-écologique". RMT Spyce, Dijon, October 2017.

Notes

1 Each individual farm is assigned an extrapolation coefficient based on the characteristics of the farm and the number of similar farms (in terms of specialization and economic size) in the FADN region. This is made possible by comparing the FADN sample with exhaustive surveys of all farms that are carried out every three years, the Farm Structure Survey (FSS).

2 Technical-economic orientation (TSE) is calculated from the Standard Output (SO) which describes the production potential of farms. A holding is considered specialized in a type of production when its main production accounts for more than two thirds of the holding's SO. The farm is then designated as one of the 64 technical-economic orientations of the detailed nomenclature.

IDDRI

The Institute for Sustainable Development and International Relations (IDDRI) is an independent think tank that facilitates the transition towards sustainable development. It was founded in 2001. To achieve this, IDDRI identifies the conditions and proposes the tools for integrating sustainable development into policies. It takes action at different levels, from international cooperation to that of national and sub-national governments and private companies, with each level informing the other. As a research institute and a dialogue platform, IDDRI creates the conditions for a shared analysis and expertise between stakeholders. It connects them in a transparent, collaborative manner, based on leading interdisciplinary research. IDDRI then makes its analyses and proposals available to all. Four issues are central to the institute's activities: climate, biodiversity and ecosystems, oceans, and sustainable development governance. To learn more about IDDRI's activities and publications, visit *www.iddri.org*

@IDDRI_ThinkTank