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Abstract

Agricultural specialization is linked with negative environmental impact. The SYNERGY bio-economic model studies promising levers to limit these impacts: expand of legumes production and exchanges of crops and manure between farms. SYNERGY is a regional model that includes specialized farm types and models exchanges of crops (including legumes) and manure between them. To build this model, a large variety of data were collected. The aim of this paper is to present these data and specify their sources. The data implemented in SYNERGY were secondary data collected from a variety of sources or primary data generated thanks to different tools. It encompasses several domains (crop, livestock, feed, fertilization), and several scales, from national data (France), to local data (administrative regions). The data set presents three specific features. First, it includes data on feed costs that are differentiated according to their origin. Secondly, it includes detailed data on legumes, from their production to their use in feed. Thirdly, it includes data to calculate two environmental indicators on nitrogen efficiency and nitrogen losses. Thus, the data set of the SYNERGY model represents a valuable collection of agronomic, economic and environmental data to develop further research on the production of legumes, the different feeding strategies and their related environmental and economic impacts of agroecosystems.

Direct URL to data: https://doi.org/10.15454/YIBW7X

1. Introduction

Since the middle of the 20th century, a process of specialization in agriculture has taken place, with a dissociation of crop and animal production on different scales. Some farms and regions got specialized in crop production, while others got specialized in livestock production. This specialization was linked with negative impacts on agroecosystems (Naylor et al. 2005). An interesting way to benefit from the economic advantages of this specialization, while limiting its environmental impacts, is to develop a circular economy based on material flows between specialized farms in the same region (Martin et al. 2016; Leterme et al. 2019). In particular, livestock farms can export manure to crop farms deficient in nitrogen (N) for fertilization, while crop farms can produce legumes and sell them to feed animals on livestock farms. To study this lever, the bio economic model SYNERGY was built (Jouan et al. 2020a).

SYNERGY assesses economic, technical and environmental impacts of producing legumes (e.g., faba bean, pea, alfalfa) on farms as final or intermediate goods (i.e., in livestock feed). To do so, it represents specialized farm types (dairy, pig and crop) in a region and models exchanges of crops (including legumes) and manure between them. As a bio-economic model, SYNERGY relies on an objective function that maximizes farmers' expected profit at the regional scale under resource and production constraints and under the possibility to exchange crops and manure. It yields optimal values of variables, which are the areas, crop production, and livestock production of each farm type. SYNERGY was applied to a specific region, western France, which corresponds to two European Union (EU) territories, Brittany and Pays de la Loire. Modelling this region is interesting because Brittany is highly specialized in livestock production (68% of pigs and 38% of dairy cows produced in France come from this region), while the Pays de la Loire is more mixed, with a higher percentage of crop production (Draaf Bretagne 2019; Draaf Pays de la Loire 2019).

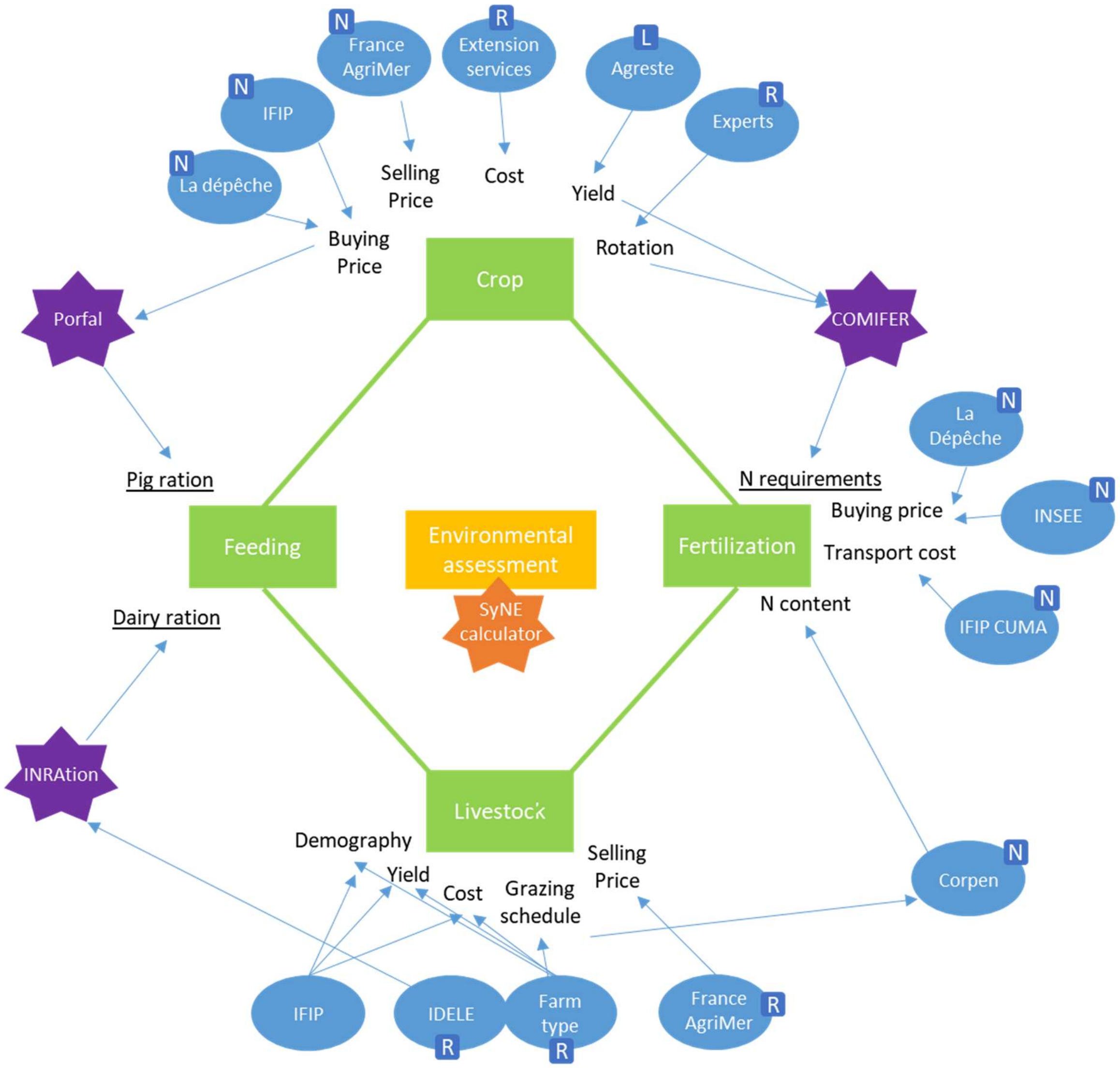
To configure the SYNERGY model, many parameters, called technical coefficients, had to be collected from a wide variety of data: they represent the quantity of inputs needed to produce outputs (e.g., the quantity of N needed per ha to produce wheat). The data are either used directly in SYNERGY's optimization step as inputs or used in a second step, to compute environmental indicators from the solution obtained in the optimization step. This paper aims to present these data, their sources and how they were connected to be used in the model.

2. Materials and Methods

Data included in SYNERGY were used in two different ways. First, some data were used as inputs to solve the optimization model: they are related to crop systems (e.g., crop rotation, N fertilization) and livestock systems (e.g., herd demography, feed ration). Secondly, other data were used as inputs to calculate environmental indicators related to N-use efficiency and N balance (SyNE and SyNB, respectively; Godinot et al. (2014)), once the model had reached an optimal solution.

The data introduced in SYNERGY were determined in two different ways (Figure 1). First, most of the data were directly collected from a variety of sources (worksheet "references" in the dataset): they are secondary data that have not undergone any special process. Secondly, other data were created by us: they are primary data. Among these primary data, some data were calculated by means of secondary data, this is the case for costs and prices that were calculated from 5-year means and for yields calculated from 5-year "Olympic mean". In addition, other primary data were generated specifically for the study using various tools: it is the case for the dairy rations created by using INRAtion (INRA 2003) and for pig rations created by using Porfal © (IFIP 2018). Regarding fertilization needs, they were based on crop N requirements estimated by the French method COMIFER (COMIFER 2011). Finally, data can also be differentiated by their scale: when possible, local data (i.e., administrative department) were collected to represent characteristics of the territory as accurately as possible. Otherwise, data were regional or national. The collection and generation of data represented ca. 1 year of work due to the research for data sources, as well as the diversity of crops and livestock studied: for example, each set of crop data (e.g., mean yield) was collected for 11 crops.

Figure 1. Overview of the main types of data and their sources used to study technical complementarities of crop and livestock production with the bio-economic model SYNERGY



Green boxes: modules of the SYNERGY model that use input data; yellow box: module performing post-optimization environmental assessment using the encoded SyNE and SyNB indicators (Godinot et al. 2014; Carof and Godinot 2018); blue circles: source of secondary data; purple stars: biotechnical simulators or calculation methods to generate primary data; primary data are underlines; L: local data (i.e., at the scale of administrative departments); R: regional data; N: national data.

3. Major Characteristics of the Dataset

3.1. General description of the dataset

Our dataset enables (i) to represent specialized farm in the bio-economic model SYNERGY and (ii) calculate economic and environmental indicators. In particular, it includes data about various elements:

- 3 farm types: dairy farm, pig farm, and crop farm
- 11 crops: barley, faba bean, dehydrated alfalfa, forage maize, grain maize, permanent grassland, temporary grassland, pea, rapeseed, sunflower and wheat
- 5 animals: dairy cow, heifer, calve, sow and pig
- 3 concentrates for feed: soybean meal, rapeseed meal, bran and sunflower meal
- 6 types of fertilizer: (solid) manure from dairy cow, slurry (liquid manure) from dairy cow, manure from grazing cow, slurry (liquid manure) from sow, slurry (liquid manure) from pig and synthetic N fertilizer.
- 5 types of forages from grassland: pastured grass from permanent grassland, pastured grass from temporary grassland, hay from permanent grassland, hay from temporary grassland, and silage grass from temporary grassland

It also contains data about 22 rations and 58 rotations.

The dataset contains 52 technical coefficient that are related to one or several of these elements. For example, the technical coefficient "chop_a" represents the production costs of animal and depends on the animal and ration. A detailed description of the technical coefficient is available in Appendix.

The dataset is available in a Microsoft® Excel workbook (dataset_synergy.xlsx), which contains several worksheets. The first worksheet "index_T.Coefficient" is an index that presents all the technical indicators included in the dataset, as well as their references. The second worksheet "index_set" presents the elements and their abbreviations. The third worksheet "references" details the technical indicators' references. These references are detailed in the worksheet "references". The 52 other worksheets constitute the data on the technical coefficients.

3.2. Feed cost differentiated by feed origin

One essential part of data collection was to differentiate feed cost by feed origin, produced on farm, exchanged locally or on world markets. For on-farm feed (i.e., cash crops and forage produced on livestock farms and fed directly to livestock), feed cost corresponds to production costs. For feed bought on the global market (e.g., cash crops, meals), feed cost corresponds to purchase costs. Since public databases only provide selling price of crops, purchase costs of feed were collected from livestock technical institutes (IDELE 2016; IFIP 2017). Even though these data are not collected by public institutions, they are still widely used by extension services and feed industries. Finally, feed produced on crop farms and sold to livestock farms in the same region costs 10% less than feed bought on the global market, to represent lower transport costs. This difference in cost was defined using data from La Dépêche - Le Petit Meunier (2018). Due to the journal's privacy policy, data from this journal cannot be detailed in this article.

3.3. Inclusion of legume data

Since SYNERGY focuses on legumes produced and exchanged between farms, it was important to represent the combined role of these crops in providing N-rich feed and N-fertilization of subsequent crop. A set of rotations, with and without legumes, was thus defined. Defining each crop within each rotation made it possible to differentiate expected yields and N requirements using a simplification of the COMIFER method (COMIFER 2011), a French method to estimate crop N fertilization. In total, 26 of the 53 rotations defined contained legumes. N-rich crops were introduced as livestock feed in legume-based rations, which were built from standard rations using two tools: Porfal for pig rations (IFIP 2018) and INRAtion for dairy cow rations (INRA 2003). Porfal generated standard and legume-based pig rations that fulfil nutritional requirements at the lowest cost. In comparison, standard dairy cow rations were based on IDELE rations: these rations corresponded to average practices observed in a network of typical dairy farms and differed in the main forage ingredient (i.e., forage maize, forage grass or both), depending on whether the farm systems were more or less grass-based. Alternative legume-based dairy rations were then generated by replacing the soybean meal of standard ration with legumes (here, pea, faba bean, dehydrated alfalfa) using INRAtion®. If legumes could not replace all soybean meal due to nutritional constraints, some rapeseed meal was added. In total, 15 of the 20 rations for dairy cows and 1 of the 2 rations for pigs used in the model were legume-based.

3.4. Calculation of the SyNE and SyNB environmental indicators

SYNERGY calculated two environmental indicators, SyNE and SyNB (Godinot et al. 2014). SyNE estimates N-use efficiency of a farming system (i.e., the extent to which N inputs of a farming system are converted into N outputs). In comparison, SyNB estimates potential N losses from a farming system (i.e., the sum of N inputs, N losses during production and transport of inputs, and change in soil N, minus N outputs). We encoded equations to calculate SyNE and SyNB in SYNERGY and collected data for them. Most of the data (e.g., indirect loss of N) came from Godinot et al. (2014) and the SyNE calculator (Carof and Godinot 2018). However, additional work was performed by collecting all data needed to calculate SyNE and SyNB for two products which were not included in the SynE calculator yet: faba bean and pigs.

4. Discussion & Conclusion

This dataset paper presents data on crop, livestock, feed, fertilization, and N indicators at the farm scale. These data are available at https://doi.org/10.15454/YIBW7X. These data are secondary data collected from many sources, including official statistics, and professional journals, and primary data created by us by using various tools. The main strength of the dataset is the integration of both environmental and economic data (e.g., prices), which allows developing interdisciplinary studies that assess both the economic and environmental impact of technical changes related to legumes. However, the data presented here have also some drawbacks. In particular, rations and N fertilization were created from numerous hypothesis needed to use dedicated tools or methods. Besides, the rations are very optimized which can lead a gap with real commercial farms, the yields are specific to the region studied which limits the scope of the study and the calculation of fertilization needs relies on hypothesis on soil mineralization, which can vary also a lot depending on the soil and climate conditions. Regarding economic data, we tried to smooth the high variability of prices of crops and feed through 5-year means but these data stayed very specific to the time period studied (i.e., 2013-2017).

The dataset was originally used to run the bio-economic model SYNERGY. This work led to the publication of two studies in peer-reviewed journals. In Jouan et al. (2020a), authors showed that increasing legume production at 10% of the agricultural area of the studied region did not improve environmental results because they are not sufficiently used in feed. In Jouan et al. (2020b), authors showed that implementing a GMO-free certification for animal products is efficient to increase the use of legumes in feed, but the extend of livestock production in the region limits the improvement of crop-livestock complementarities.

In addition to these original uses, the dataset presented here can be reused in studies requiring data on legumes, in particular on their use in animal feed since these data are at the scale of France. Indeed, on the main interesting features of this data set is to include a large variety of feed which are differentiated by origin. The collection of data on feed, as well as other input data such as N fertilizers, represents a work that is rarely done due to the difficulty to access such data.. In particular, it would be interesting to assess different feeding strategies, and their economic and environmental impacts, in different types of French livestock farms. In addition, the inclusion of legumes related data in a livestock region such as western France represents an interesting basis for developing further research into the production of legumes for feed, which is usually less studied than legumes as cash-crops (Jouan et al. 2019).

More generally, this dataset can be reused in studies evaluating the environmental impacts of crop diversification through the development of legumes. Indeed, numerous rotations with legumes are available in the dataset and the legumes' pre-crop effects are integrated to highlight their benefits in the management of N fertilization. Thus, this dataset represents a valuable tool to demonstrate the interest of legumes in agroecosystems, which represents one of the pillars of sustainable agriculture.

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Appendix

Description of the data (technical coefficient) available in the dataset

Name of technical coefficients (TC)	Description	Unit	Primary data	Secondary data
chop_a	Production costs of animal: vet + breeding service + other miscellaneous costs	€ / animal	X	
chop_c	Production costs of crops: seeds and pesticides	€ / ha	X	
coeff_biomass_air	Coefficient aerial biomass: share of non-exported aerial biomass of crop determined from its yield	unitless		X
coeff_biomass_root	Coefficient root biomass: share of non-exported root biomass of crop determined from its yield	unitless		X
content_dryM_c	Content of dry matter in harvested crop: (1- moisture content) / total weight	%		X
content_dryM_co	Content of dry matter in concentrate: (1- moisture content) / total weight	%		X
content_dryM_seed	Content of dry matter in seed crop: (1- moisture content) / total weight	%		X
density_seed	Sowing density: amount of seeds sown per hectare	kg seed / ha		X
indloss_N_a	Indirect loss of nitrogen (N) in animals: N loss due to the production and transport of animals	kg N /t living weight (Tlw)		X
indloss_N_c	Indirect loss of N in crops: N loss due to the production and transport of crops	kg N / t dry matter (Tdm)		X
indloss_N_co	Indirect loss of N in concentrates: N loss due to the production and transport of concentrates	kgN / Tdm		X
indloss_N_seed	Indirect loss of N in seeds: N loss due to the production and transport of seed	kgN / Tdm seed		X
keq_ma	Effective synthetic fertilizer equivalence coefficient: ration between N supplied by a mineral fertilizer and N supplied by the organic fertilizer that allows the same N absorption	kg / T or Tdm		X
mat_c	Crude protein of crops: protein content calculated as the quantity of mineral N multiplied by 6.25	kg / T or Tdm		X
mat_co	Crude protein of concentrate: protein content calculated as the quantity of mineral N multiplied by 6.25	kg / T or Tdm		X
mat_gr	Crude protein of fodder: protein content calculated as the quantity of mineral N multiplied by 6.25	kg / Tdm		X
max_ma	Maximum manure fertilization: maximum share of N fertilization from manure	%	X	
nb_rot	Share of crop inside a crop rotation: cultivation time divided by total rotation time (in years)	-		X
need_c	Animals' need in crop: quantity of crop in the animal's ration for 1 year	kg dry matter (KGdm) /animal	X	
need_co	Animals' need in concentrate: quantity of concentrate in the animal's ration for 1 year	KGdm / animal	X	
need_gra	Animals' need in fodder: quantity of fodder in the animal's ration for 1 year	KGdm / animal	X	
pwb_a	Price of animal bought: price of animal bought by the farm (on the world market)	€ / animal	X	
pwb_c	Price of crop bought: price of crop bought by the farm (on the world market)	€ / T	X	

pwb_co	Price of concentrate bought: price of concentrate bought by the farm (on the world market)	€ / T	X	
pwb_fe	Price of fertilizer bought: price of fertilizer bought by the farm (on the world market)	€ / T	X	
pws_a	Price of animal sold: price of animal sold by the farm (on the world market)	€/ kg living weight (KGwl)	X	
pws_c	Price of crop sold: price of crop sold by the farm (on the world market)	€ / T	X	
pws_milk	Price of milk sold: price of milk sold by the farm (on the world market)	€ / L	X	
rate_clay	Rate of clay: rate of clay in the soil	g / kg		X
rate_CN_fe	C/N rate: ratio of Carbone(C) /N in organic and mineral fertilizers	kg C / T		X
rate_Corg	Rate of C: rate of organic C in the soil	g / kg		X
rate_cull	Cull rate: cull rate of animals	%		X
rate_N_a	Rate of N in animal: kilogram of N in animals per ton of live weight of the animal	kg N / Tlw		X
rate_N_c	Rate of N in crop: kilogram of N in crop per ton of (dry matter of) crop	kgN / T or Tdm		X
rate_N_co	Rate of N in concentrate: kilogram of N in concentrate per ton of concentrate	kgN / T		X
rate_N_fe	Rate of N in fertilizer: kilogram of N in fertilizer per ton of fertilizer	kgN / T		X
rate_N_seed	Rate of N in seed: kilogram of N in seed per ton of (dry matter of) seed	kgN / T or Tdm		X
rate_prolif	Prolificacy rate: number of young animal produced per mother per year	%		X
rate_purchase	Purchase rate: number of sow purchased per sow present on the farm	%		X
rate_renew	Renew rate: number of young kept for reproduction per number of young produced	%		X
rate_sale	Sale rate: number of animal sold per number on animal (of the same type) present on the farm	%		X
su_c	Coupled support: direct support for legumes under CAP's pillar I	€ / ha		X
symb_Nfix	N fixed: quantity of atmospheric N fixed by legumes through symbiosis with soil bacteria	kgN / Tdm		X
tb_milk	Fat rate: fat rate in milk	g / kg		X
time_c	Cultivation time: number of years the crop is cultivated	year		X
tmoy	Mean temperature: mean temperature of the department where the farm is located (5 years mean)	°C		X
tp_milk	Protein rate; protein rate in milk	g / hg		X
y_c	Yield of crop: "Olympic average" of crop's yield	T or Tdm / ha	X	
y_milk	Yield of milk: yield of milk produced per cow, which depends on the type of dairy farm	L / cow	X	
y_N	Yield of manure: quantity of manure produced per animal	kgN / animal	X	
weight_a	Weight: Live weight of animal	KGwl	X	
xxa	Fertilization needs: Crops' needs in fertilization	kgN / ha	X	