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Abstract

Growing demand for animal products has contributed to an increase in biogeochemical fluxes, leading particularly to gaseous ammonia, methane, and nitrous oxide emissions into the atmosphere. Developing accurate knowledge on the sources and magnitude of gas emissions from the livestock sector is essential to reducing emissions, while meeting other societal expectations, and to implementing effective regulations. To this end, a database called ELFE (ELevage et Facteurs d'Emission; i.e., Livestock and Emission Factors) was recently developed. It currently contains ~5200 gas emission measurements extracted from 345 publications of the international literature published from 1964 to 2018 from 37 countries. One of its innovative aspects is the structured and comprehensive description of both the livestock system and the measurement method associated with emission data. Ammonia emitted by livestock systems represents 40 to 80% of emission values and 45 to 81% of the values concern production systems with slurry, depending on the animal produced. This database will contribute to improved emission factors for national inventories by more thoroughly considering factors influencing emission levels and data quality. It highlights the need for shared and standardized reporting protocols for both the livestock system itself and the measurement conditions, to allow for thorough comparisons and to reduce uncertainty in unit conversions. The database is available online on the Institut national de la recherche agronomique (INRA) platform (https://data.inra.fr/dataset.xhtml?persistentId=doi:10.15454/MHJPYT) and will be updated annually with new gas emissions.

Core Ideas

- A new database includes about 5200 emission values from 345 publications.
- Of these emission values, 62% were related to NH_3, 41% to CH_4, 29% to N_2O, and 29% to CO_2.
- The database includes a detailed description of production systems and measurement methods.
- Complete data for system description and unit conversion increase potential uses.

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Gas emissions from livestock systems receive attention because of human health and environmental concerns. This sector is a major emitter of gaseous ammonia (NH_3), which leads to the formation of secondary fine particles and to eutrophication and acidification of ecosystems. It is also a significant contributor to emissions of greenhouse gases (GHGs) and thus to climate change. Furthermore, changes in food consumption and population growth have increased demand for animal products. To meet societal and environmental demands, it is essential to improve knowledge to guide livestock farmers and their research and industrial partners in the development of sustainable livestock systems. Published studies quantifying gas emissions from different livestock systems have accumulated in recent decades. Increasing amounts of data on NH_3 and GHG emissions from a wide variety of livestock systems have become available. Emission factors currently used for national inventories (CITEPA, 2017; IPCC, 2006) or for life cycle assessment (Wilfart et al., 2016) are not always detailed. Capitalizing on the collection and documentation of emission measurements would help to improve emission factors that are used for national inventories and environmental assessments of agricultural products. It would also help to identify and/or confirm the main factors influencing emission levels (animal type, climate, diet, manure type, etc.) to highlight specific farming practices that reduce emissions, and to avoid aggregating emission factors into categories that are too large to reveal the benefits of recent progress.

A consortium of French research organizations (Institut National de la Recherche Agronomique [INRA] and Institut national de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture [IRSTEA]) and agricultural technical institutes (Institut du porc [Ifip], Institut Technique de l'AVIculture [ITAVI], Institut de l'ELEvage [IDELE], Chambre Régionale d'Agriculture de Bretagne [CRAB]) was established

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Abbreviations: ELFE, ELevage et Facteurs d'Emission (Livestock and Emission Factors); GHG, greenhouse gas; LU, livestock unit (500 kg live weight); PM, particulate matter; VOC, volatile organic compound.

to provide expert assessment of and collate available data on gas emissions from livestock systems into a database called ELFE (ELevage et Facteurs d'Emission; i.e., Livestock and Emission Factors). Raw emission data are called "emission values" and are converted into emission factors after data extraction, transformation, and aggregation, as defined by USEPA (2018) and UNFCCC (2019). One innovative aspect of the database is the inclusion of structured and comprehensive data about production conditions and the methods used to acquire emission values.

This article (i) describes the ELFE database, (ii) provides an overview of the collected literature on gas emissions from livestock systems (i.e., year of publication, country, type of publication, type of animal production, and emission sources), and (iii) presents the contents of the ELFE database (i.e., livestock system and measurement methods) that would be of significant interest to potential users.

Materials and Methods

Collection of Publications from the Literature

Literature published from 1964 to 2018 was reviewed to identify publications that focused on gas emissions from livestock systems, primarily peer-reviewed articles, proceedings, technical reports, and theses, regardless of geographical location or the protocol used (laboratory, experimental system, commercial system, etc.). The Web of Science (http://apps.webofknowledge.com/) was used with a specific keyword series for each type of animal production and emission source. To ensure a thorough review, the list of publications was later compared with those of some major international reviews on gas emissions from livestock systems (Giner-Santonja et al., 2017; Griffing et al., 2007; Hafner et al., 2018; Hassouna et al., 2015a; Hristov et al., 2011; Jayasundara et al., 2016; Meda et al., 2011; Niu et al., 2018; Owen and Silver, 2015; Peyraud et al., 2012; Philippe et al., 2011; Philippe and Nicks, 2015; Sintermann et al., 2012; Webb et al., 2010), which covered different periods from 1981 to 2017.

Description of the Database

The database, developed in Microsoft Excel 2016, consists of five Excel files: Files 1, 2, and 3 for animal housing (cattle, pig and poultry), and Files 4 and 5 for manure storage and manure spreading, respectively (for all types of animal production combined) (Fig. 1).

Specific "Animal housing" files were created for each type of animal production (cattle, pig, and poultry) to capture specific production characteristics. Each "Manure storage" and "Manure spreading" file contains all types of animal production because emissions during manure storage and spreading are related to manure type and composition, which depend more on manure management and possible treatments during storage. Unlike the ALFAM (ammonia losses from field-applied animal manure) database of NH_3 emissions from field application of manure (Hafner et al., 2018; Søgaard et al., 2002), the ELFE database also includes emissions of GHGs, NO_x, hydrogen sulfide (H_2S), volatile organic compounds (VOCs), particulate matter (PM), and odors from field application of several types of manure, especially slurry and farmyard manure. Each file in the database has three tabs: "data entry," "list of items," and "glossary." The "data entry" tab contains the data input from the literature (1 column = 1 variable). To facilitate and standardize data entry, drop-down lists were created for most variables. The "list of items" tab contains the items for each drop-down list. Finally, the "glossary" tab defines each variable in the file to define database terms explicitly. Definitions are given in English (ELFE's default language) and French in the current version. Each row of the "data entry" tab contains one emission value and its associated variables describing geographical location, weather conditions, livestock system features, and metrology. Thus, in each file, the variables are organized into thematic groups (Weather during measurement period, Manure management, Farming system characteristics, Measurement protocol, etc.) (Fig. 1). Some thematic groups are common to all emission sources, whereas others are specific to animal housing, manure storage, or manure spreading. Each thematic group contains variables in three main categories:

- System description (Animal category, Manure type, Ventilation type, etc.)
- Study results (Emission value, Manure dry matter, etc.)
- Measurement details (Sampling method, Airflow rate, etc.)

Each category contains variables (temperature, manure emptying system, etc.) known to influence emission values.

The Animal housing, Manure storage, and Manure spreading files have 676, 265, and 295 columns, respectively, of which about 500, 150, and 200, respectively, contain quantitative and qualitative variables (the remaining columns contain the units of quantitative variables). In the thematic groups related to metrology and common to all files, the database covers all measurement processes from air sampling to analysis of gas pollutant concentrations and emissions. A wide range of methods for sampling, analyzing pollutant concentration, and measuring airflow and emissions is described by Hassouna et al. (2015b).

Data Collection

Data collection consists of identifying relevant data from each publication identified and adding them to the database. The main rule is to enter raw data without any calculation or conversion. The ELFE database was created to facilitate data entry. Thus, a color code is used to indicate whether a column is formatted for manual input, an item from a modifiable or nonmodifiable drop-down list, or automatic input determined by another variable (e.g., choosing "Pig" for [Animal category] automatically fills in "Pig" for [Species]). If the publication lacks the information needed to fill a given cell, the item "nd" ("not documented") can be chosen. If the publication lacks a piece of information because it is unrelated to the study (e.g., milk yield, if not studying dairy cows), the item "na" ("not applicable") is automatically entered. These input codes are important for characterizing the degree of data completeness (see the section "Evaluating Completeness of Emission Values" below). If the same emission value is expressed in different units, (e.g., mg N_2O-N m^{-2}, g N_2O-N ha^{-1}, % N applied, etc.) in a publication, up to four units can be entered on a single row.

Data Quality Management

Data quality assurance is the end user's responsibility. To limit erroneous data entry as far as possible, only well-trained experts of the ELFE project can input data into the

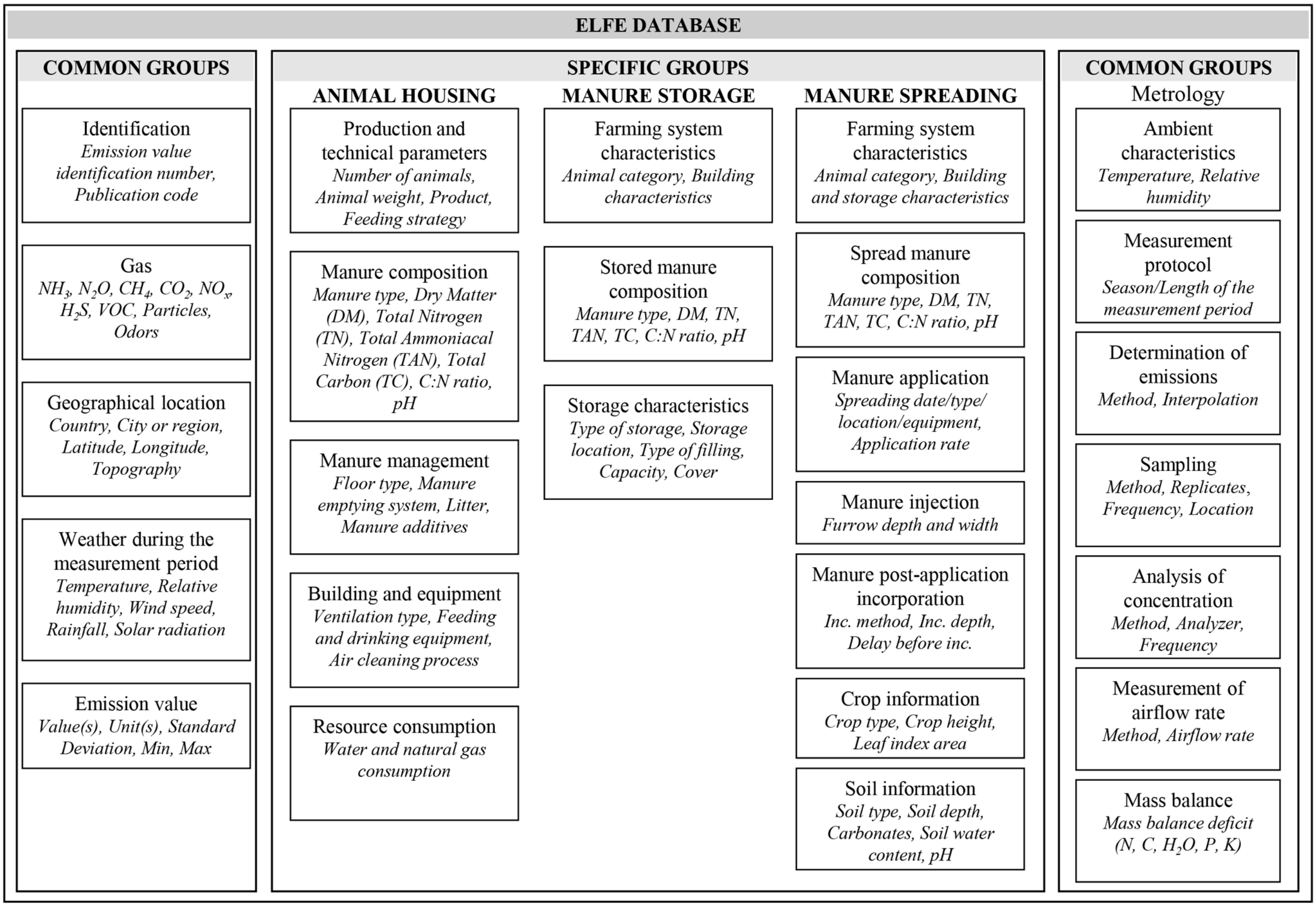

Fig. 1. Organization of thematic groups in the five files of the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database: Common groups (Files 1–5), Animal housing (Files 1–3), Manure storage (File 4), and Manure spreading (File 5). VOC, volatile organic compound.

database. Guidelines define how to enter new data to ensure that emission values as well as their associated metadata are entered in a standard manner (https://data.inra.fr/dataset.xhtml?persistentId=doi:10.15454/MHJPYT). If other persons propose data from peer-reviewed articles for inclusion, ELFE members will check these new data before addition to the database. The ELFE members meet every 6 to 12 mo to review proposals and to input those that meet the data quality requirements. To limit erroneous emission factor estimates deduced from ELFE data, the end user should select only the relevant data and plot average, minimum, maximum, and standard deviation as box plots for all selected data. If the number of data is small (e.g., <10), all values must be checked before publishing emission factor results. If number of data is high, it is assumed that most values of the database are correct, and only outliers (e.g., detected by the interquartile range method, as described by Niu et al., 2018) that will significantly change the average and other emission factor statistics must be extracted for control before publishing results.

Evaluating the Completeness of Emission Values

Since emission values entered into the database come from many publications, their degree of description varies greatly. The degree of completeness is characterized by the availability of information about selected key variables (Fig. 2). Most key variables that come from high-quality information are fully complete. They depend on the emission source and the type of animal production and are organized into two categories: livestock system (30–47 variables) and metrology (19–24 variables). These key variables represent 11 to 24% ("Animal housing–Cattle" and "Spreading," respectively) of all database variables.

To compare the completeness of emission values, each key variable automatically receives a score of 1 (information available) or a score of 0 (missing information). The degree of completeness is then calculated by summing the scores of each key variable. Averages per category (livestock system and metrology) allow the degree of completeness of groups of emission values to be compared.

Major Characteristics of the Database

Publications Included in the Database

For each type of animal production, an initial set of 1098 publications from 1964 to 2018 related to emission sources and gases was identified. From this list, 71 publications reported emission values that could not be included in the database (e.g., only a range of emissions, data in a graph but no numbers specified in the text), and 345 are currently included in the database. Among those in the database, 22% describe multiple types of animal production and/or emission sources (e.g., housing and storage), of which 47% describe different types of animal production for a single emission source, 39% describe a single type of animal production for different emission sources, and 14% describe different types of animal production and emission sources. Most of

Category 1: Livestock system			Category 2: Metrology
Animal housing	Manure storage	Manure spreading	
Geographical location Country ***Weather during the measurement period*** Temperature, Relative humidity ***Production and technical parameters*** Species†, Physiological stage Number of animals, Animal density‡ Housing system† Initial and Final or Average animal weight Breeding duration‡ Average daily gain§, Feed consumption ratio‡ Meat or milk¶ or egg# production Feeding strategy, Number of feeding phases‡ Diet¶, Pasture access, Age for pasture access# Type of feed‡, Feed characteristics, Crude feed ingested#, Feed dry matter†, Energy††, Crude protein content, Feed Phosphorus, Potassium# ***Manure composition*** Manure type††,Excreted nitrogen, Excreted carbon†† Dry Matter, Total Nitrogen, Total Ammoniacal Nitrogen, Total Carbon†† Phosphorus, Potassium#, pH†† Sampling frequency and times‡ ***Manure management*** Floor type, Floor area§, Slat material§ Nature of litter, Litter composition‡, Litter management†† Amount of litter, Frequency of changing litter†† Pit area, Pit depth or volume†† Manure emptying system, Frequency emptying† Dropping dehydrator# ***Building and equipment*** Housing type†, Ventilation type Extraction system‡, Air inlet and outlet system§ Heating system, Heating duration# Heat exchanger, Cooling system# Number of pigs per pen§ Feeding equipment§, Drinking equipment‡ ***Resource consumption*** Water consumption#	***Geographical location*** Country ***Weather during the measurement period*** Temperature Wind speed Rainfall ***Farming system characteristics*** Animal category Species Physiological stage Building characteristics ***Stored manure composition*** Manure type Age of manure Dry Matter, Total Nitrogen, Total Ammoniacal Nitrogen, Uric acid, Total Carbon, Organic carbon, C:N ratio, pH ***Storage characteristics*** Type of storage Storage location Shape of storage location Underground storage (yes/no) Type of filling Frequency of filling the storage unit Capacity Volume stored Surface area of stored slurry Height of manure stored Cover Type of cover Stirring during the storage period Frequency of stirring Manure temperature Depth of temperature measurement in manure	***Geographical location*** Country ***Weather during the measurement period*** Temperature Wind speed Rainfall ***Farming system characteristics*** Animal category Species Physiological stage ***Spread manure composition*** Manure type Dry Matter, Organic matter, Total Nitrogen, Total Ammoniacal Nitrogen, Uric acid, Total Carbon, Organic carbon, C:N ratio, pH ***Manure application*** Spreading type Spreading location Spreading equipment Application rate ***Manure post-application incorporation*** Incorporation method Incorporation depth ***Crop information*** Crop type Crop height ***Soil information*** Soil type Soil water content pH	***Ambient characteristics*** Temperature and humidity measurement locations‡‡ Temperature, Relative humidity ***Measurement protocol*** Season of the measurement period Length of the measurement period Heating during measurement period§§ Cooling during measurement period§§ Number of batches§§ ***Determination of emissions*** Method for determining emissions ***Sampling*** Sampling method Frequency of sampling Measurement scale Area measured Sampling location Heating of sampling tubes§§ Number of samples Number of replicates of the measurement device ***Analysis of concentration*** Method for analyzing gas concentrations Analyzer type, Analyzer trend Time between sampling and analysis Conservation of sample until analysis Measurement duration Measurement frequency ***Measurement of airflow rate*** Method for measuring airflow rate Airflow rate (or exchange coefficient) ¶¶ Air speed on the surface of the manure¶¶ ***Mass balance*** Mass balance deficit (nitrogen, carbon, water, phosphorus, potassium) ***Emission value*** Value(s), Standard deviation Minimum emission value Maximum emission value Emission dynamics

† Cattle and Poultry; ‡ Pig and Poultry; § Pig; ¶ Cattle; # Poultry; †† Cattle and Pig; ‡‡ Manure storage and spreading; §§ Animal housing – Pig and Poultry; ¶¶ Manure storage.

Fig. 2. Key variables identified for calculating the degree of completeness of emission values.

the literature identified was composed of peer-reviewed articles (78%), followed by proceedings (17%), technical reports (3%), and theses (2%). Most peer-reviewed articles in the database were published after 1998, especially for GHGs (N_2O, CH_4, and CO_2) (Fig. 3a). This pattern may be related to the influence of the United Nations Kyoto Protocol, signed in 1997 to reduce GHG emissions, and of the Gothenburg Protocol, signed in 1999 to reduce pollutant emissions, including NH_3. Peer-reviewed articles included in the database involved 37 countries (based on the country of the first author's institution), but only 20 countries contributed more than five articles (Fig. 3b). The United States, Canada, Denmark, the United Kingdom, the Netherlands, and France contributed 87% of the peer-reviewed articles. Countries contributing five or fewer articles included Argentina, Brazil, Cameroon, Colombia, Cuba, the Czech Republic, Finland, India, Lithuania, Mexico, Norway, Poland, the Slovak Republic, Slovenia, South Africa, Sri Lanka, and Vietnam.

Pigs, animal housing, and NH_3 are the most common animal production, emission source, and gas, respectively, studied in the publications represented in the database (Table 1). Likewise, Gac et al. (2005) reported that NH_3 was the gas most frequently studied in publications, related to the major contribution of animal farming to NH_3 emissions (Gothenburg Protocol). Moreover, pig production is more standardized than other types of animal production, with mechanical ventilation systems in buildings that make NH_3 emissions easier to quantify (by directly applying quantification methods from the industrial sector). For cattle production, however, buildings with natural ventilation and diffuse emission sources make quantifying NH_3 emissions more difficult.

Emission Values Collected in the Database

Summary of the Data Collected

The database contains ~5200 emission values among the types of animal production and emission sources (Table 2). Of the emission sources, NH_3 has the largest number of emission values, followed by CH_4 (particularly for manure storage), N_2O, and CO_2 (Fig. 4). The sources NO_x, H_2S, VOCs, PM, and odors together represent only 4, 10, and 2% of emission values collected for animal housing, manure storage, and manure spreading, respectively (the literature review has not yet focused on these emissions). One publication provided 24 emission values without indicating the animal(s) that produced the manure (Table 2), illustrating that some publications lack the information necessary to make emission values useful.

The cattle production system with the most emission values is dairy production (80%), of which 70% have slurry systems (Fig. 5). Thus, solid manure management has been studied less often, even though it represents more farms and animals in France. Housing systems with slurry stored outside the building are the most common in the literature included in the database. The pig production system with the most emission values is fattening pigs (79%), of which 56% have fully slatted floors. For slurry systems from fattening pigs, the most common manure management system is a vacuum system. Among types of manure storage in cattle and pig production, slurry is the manure type

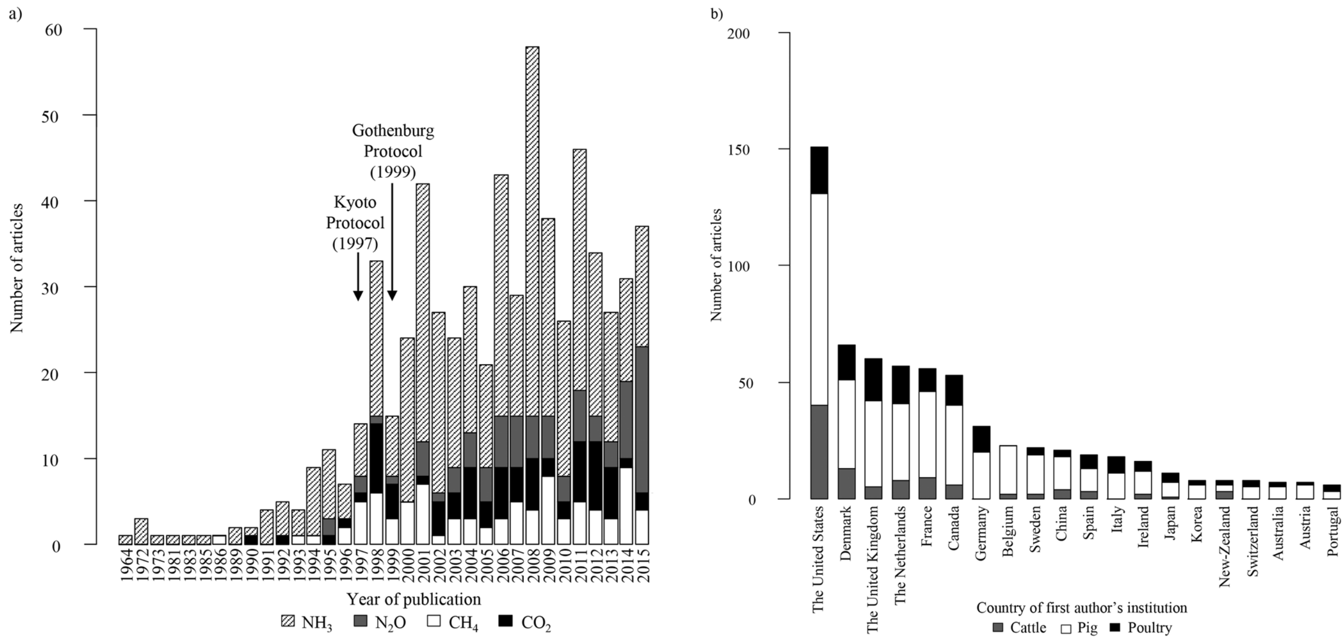

Fig. 3. (a) The number of peer-reviewed articles by year of publication (1964–2015) and by gas concerned in the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database, and (b) the number of peer-reviewed articles (1964–2015) by country of the institution of the first author and type of animal production (for countries contributing more than five peer-reviewed articles) in the ELFE database.

with the most emission values (45 and 81%, respectively). The database thus allows the most and least studied livestock systems in the literature to be identified.

Completeness of Emission Values

Although many key variables have high degrees of completeness, others do not (Fig. 5). Missing information leads to larger animal categories and thus higher intra-category variability and higher uncertainty in emission factors. It also leads to coarser definitions of livestock systems and thus uncertainty in characterizing them.

Feeding strategy is an important way to reduce NH_3 emissions. Feed crude protein content is thus considered a key variable influencing nitrogenous emissions. Only 22, 43, and 37% of NH_3 emission values have the feed crude protein content specified for cattle, pig, and poultry production, respectively (Table 3).

Lack of information can prevent the conversion of emission values into a common unit or the characterization of those that can be converted. For example, to calculate average NH_3 emissions from manure storage into grams of NH_3 per square meter per day as a function of manure type, cover, and physiological stage, it is necessary to know this information. Of the NH_3 emission values for pig production during manure storage, 99% have the type of manure stored specified. Next, 100% of these values have the use of cover specified, but only 71% of them also have the physiological stage specified. Finally, only 53% of these values could be converted into grams of NH_3 per square meter per day. Thus, only half of NH_3 emission values for stored pig manure have sufficient information to be exploitable

Table 1. Distribution of publications included in the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database by topic (*n* = 345). Total percentages exceed 100% because one publication can address multiple topics.

Topic	Percentage
	%
Animal production	
Cattle	51
Pig	70
Poultry	30
Emission source	
Animal housing	56
Manure storage and treatment	44
Manure spreading	43
Gas	
NH_3	62
N_2O	29
CH_4	41
CO_2	29
Experimental studies	98
On-farm conditions	88
Laboratory	12
Modeling studies	2

Table 2. Numbers of publications and emission values in the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database by topic.

Topic	No. of publications	No. of emission values
Animal housing		2712
Cattle	53	657
Pig	166	1742
Poultry	32	313
Manure storage		1579
Cattle	41	434
Pig	84	1047
Poultry	12	74
nd†	1	24
Manure spreading		864
Cattle	39	559
Pig	23	227
Poultry	13	74
Mixed	1	4

† nd, the animal that produced the manure was not documented.

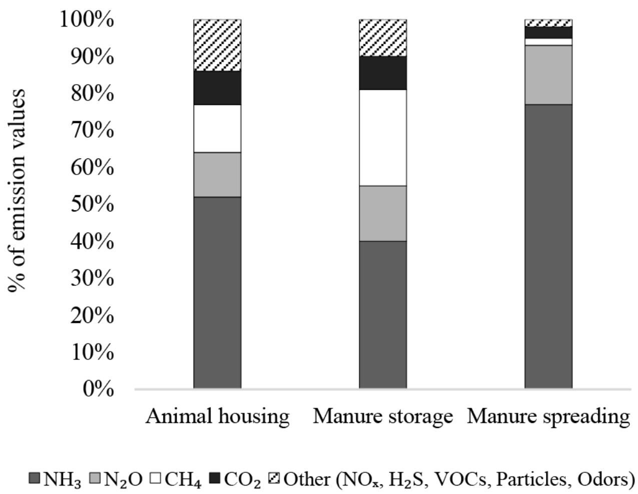

Fig. 4. Distribution of emission values as a function of the gas, by emission source. VOC, volatile organic compound.

for the analysis using these four criteria. Therefore, there is a need for shared and standardized reporting protocols for both the livestock system itself and the measurement conditions to make the observed emission values available for accurate emission factor estimates and well-defined animal categories and livestock systems.

Units of Emission Values

Emission values are expressed in a wide variety of units in the literature. For example, NH_3 emissions from pig production during animal housing are expressed in 54 different units in the database (Table 4). Some of these units are multiples of SI units (e.g., to convert g NH_3 h^{-1} to g NH_3 d^{-1}), whereas others need information about the livestock system (e.g., converting kg NH_3 livestock unit [LU, 500 kg live weight] $^{-1}$ yr^{-1} to kg NH_3 animal yr^{-1} requires the animal's weight). This variety of units increases the difficulty in using observed emission values as estimates of emission factors.

Summary

This project developed a database to contain published values on gas emissions from the international literature covering the diversity of livestock systems. For now, this project focuses on the main emission sources included in emission inventories and involved in practices for mitigating gas emissions. The next step will be to include two additional emission sources: manure treatment (emissions from manure treatment facilities) and grazing (animal and manure emissions during outdoor grazing). Sheep, goat, and horse production will also be included to consider additional types of ruminant production, and emissions of CO_2, NO_x, H_2S, VOCs, PM, and odors will be studied in more detail. This project will continue to review the literature on gas emissions from livestock systems and update the list of the main information needed to make the emission values from the literature usable.

The ELFE database has two main potential uses and, if necessary, emission values in the database can be converted into reference units explicitly defined for emission factors and based on international guidelines and norms (USEPA, 2018; UNFCCC, 2019), depending on the emission source. These reference units can be chosen to address different objectives for using emission factors (e.g., for animal housing, g LU^{-1}

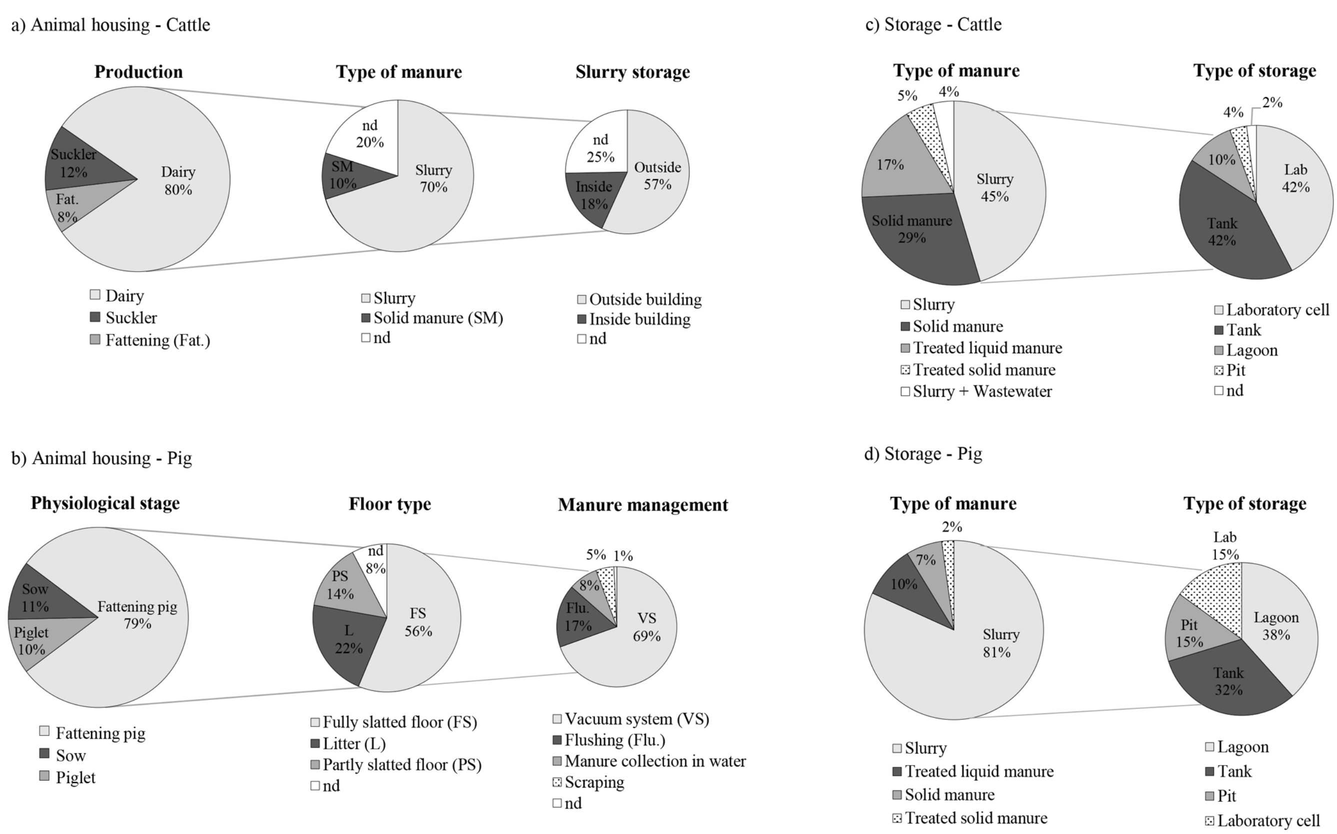

Fig. 5. Distribution of emission values among cattle and pig livestock systems in the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database.

Table 3. Degree of completeness (%) of main key variables in the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database.

Animal housing				Manure storage†		Manure spreading	
Variable	Completeness			Variable	Completeness	Variable	Completeness
	Cattle	Pig	Poultry				
	——— % ———				%		%
Physiological stage	100	100	100	Manure type	97	Manure type	93
Number of animals	84	87	80	Manure DM‡	47	Manure DM	70
Animal weight	52	74	54	Manure TN§	56	Manure TN	68
Feeding strategy	56	58	46	Manure TAN¶	57	Manure TAN	82
Feed DM	32	8	10	Manure pH	62	Manure pH	64
Feed crude protein	22	43	37	Storage facility	99	Type of spreading	70
Manure DM	11	29	44	Volume	48	Equipment	70
Manure TN	17	28	27	Surface area	53	Application rate	95
Manure TAN	3	24	10	Height	21	Soil type	70
Floor type	71	94	87	Outside temperature	62	Outside temperature	42
Manure emptying system	34	45	37	Wind speed	25	Wind speed	24
Ventilation type	80	85	83	Rainfall	10	Rain	33
Ambient temperature	53	61	42	Measurement period	72	Measurement period	91
Ambient relative humidity	22	17	23	Sampling method	90	Sampling method	94
Measurement period	55	63	70	Method for measuring airflow rate	59	Method for measuring airflow rate	95
Sampling method	88	75	82	Determination of emissions	97	Determination of emissions	98
Method for measuring airflow rate	77	72	99				
Determination of emissions	98	83	89				

† Manure composition at the beginning of storage.

‡ DM, dry matter.

§ TN, total nitrogen.

¶ TAN, total ammoniacal nitrogen. Calculated only for NH_3 emissions.

Table 4. Number of units used to report emission values from the literature in the ELevage et Facteurs d'Emission (ELFE, Livestock and Emission Factors) database, by emission source.

Gas	Animal housing			Manure storage	Manure spreading
	Cattle	Pig	Poultry		
NH_3	42	54	24	45	15
N_2O	26	20	5	31	12
CH_4	28	20	5	48	8
CO_2	18	18	3	22	3

d^{-1}, to compare types of animal production; percentage of total excreted, to represent emissions during the manure management chain [EMEP/EEA, 2016]; and kg nimal-place^{-1} yr^{-1}, to compare emissions to regulatory standards such as the *Reference Document for the Intensive Rearing of Poultry or Pigs* [Giner-Santonja et al., 2017]). The two main potential uses are as follows:

1. To determine emission factors for national inventories. To this end, data can be selected (data corresponding to laboratory experiments or small scale measurement should be excluded) and organized in two ways to calculate averages and standard deviations of emission factors

   i. Animal and manure categories are organized by country-specific livestock system. Average emission factors and their standard deviations are determined from data corresponding to each system previously defined.

   ii. Effects of key variables (e.g., manure management inside the building, N content of feed) on emission factors are tested statistically. Livestock systems are then defined according to the variables that have significant effects on emission factors (e.g., if nitrogen content of feed significantly influences emission factors, they can be organized by representative nitrogen content).
2. To analyze variability in emission values by using multicriteria methods to determine the most influential variables. The ELFE database can also improve uncertainty analysis of emission factors.

In addition, the ELFE database can also be used to (i) highlight the lack of reporting information in the literature, (ii) propose recommendations for shared and standardized reporting protocols of both livestock systems and measurement conditions, (iii) identify the need for further research on specific livestock systems, (iv) improve the definition and choice of animal categories in inventories, and (v) examine relationships between emissions and measurement methods.

Conflict of Interest

The authors declare no conflict of interest.

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