D5.1: Guidance document on recommendation for future inventory improvement

WP5: Improving national emission inventories and projections

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Introduction

This report contains a guidance on recommendations for future inventory improvements for non-CO_2 greenhouse gas (N_2O, CH_4) and ammonia (NH_3) emissions reporting from livestock systems.

In the context of WP2 of the MELS project, NH_3, N_2O and CH_4 emission data and activity/ancillary data from the manure storage and livestock housing components of the manure management chain were collated building on the DATAMAN database (https://www.dataman.co.nz/). Then, a key component analysis was conducted on the collated data to identify key influencing factors on GHG and NH_3 emissions from livestock systems (WP3).

In MELS WP5, the national inventories of the participating countries were assessed for their ability to adequately capture improved knowledge relating to N_2O, CH_4 and NH_3 emissions from livestock systems (T5.1). This report contains the outcomes of this assessment, thus giving an overview of the status of emission estimation methods used for manure management systems and managed soils in national inventories of 14 selected countries. These are matched with the analysis of the key influencing factors carried out in WP3, suggesting improvements to the inventories. It also provides a guidance on how to use the DATAMAN emission factor database to retrieve country-specific information on N_2O, CH_4 and NH_3 emission factors.

Assessment of GHG and NH_3 emission calculation methodologies

The national inventories of 14 selected countries were assessed to compare emission calculation methodologies and emission factor types used in GHG and NH_3 emission reporting in livestock systems. Countries included in the study were: Germany, France, Greece, Denmark, Ireland, Poland, Austria, Netherlands, Italy, Belgium, New Zealand, Chile, Brazil and China. The European Union (EU), as a party to the UNFCCC, reports annually on greenhouse gas (GHG) inventories for the years between 1990 and the current calendar year (t) minus two (t-2), for emissions and removals within the area covered by its Member States. The present report used is the official inventory submission of the European Union (EU) for 2020 under the United Nations Framework Convention on Climate Change (UNFCCC) and also under the Kyoto Protocol. Additionally for the EU, the JRC Technical report on "Methodological overview on the calculation of air pollutant and greenhouse gas emissions from agricultural activities[1]"provides an overview of the different methodologies and parameters needed to estimate air pollutant and GHG emissions from all agricultural sub-sectors, following the EMEP/EEA and IPCC guidelines. For the non-EU member countries, (Brazil, China, New Zealand and Chile) country-specific GHG emission inventory and air pollutant emissions inventory reports were consulted.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC121579

The emission reporting categories assessed from Annual European Union greenhouse gas inventory 1990–2018 and inventory report 2020 were:

- CH_4 emissions from manure management for cattle and swine (CRF Source Category 3.B.1),
- N_2O emissions from manure management for cattle and swine (CRF Source Category 3.B.2),
- N_2O emissions from "Urine and Dung N Deposited by Grazing Animals" (CRF 3.D.1.3).

The emission reporting categories assessed by the JRC Technical Report 2020 were NH_3 emissions from manure management, and NH_3 emissions from agricultural soils.

The emission calculation methodologies reported in the inventories were Tier 1 (T1), Tier 2 (T2), Tier 3 (T3) and country-specific (CS). The emission factor types were divided into two categories namely: default (D) and country-specific (CS). Summaries of calculation methodologies for each country are presented in the Table 1-4.

Regarding CH_4 emissions from cattle manure management, the assessment showed that 11 countries use T2 methodology, 2 countries use a mix of CS and T2 and 1 country uses a mix of T1 and T2 methodology. Eleven out of 14 countries use CS emission factors and 3 countries use a mix of D and CS emission factors for this category. For CH_4 emissions from manure management for swine, 8 out of 14 countries use T2 methodology, 1 country uses a mix of CS and T2 methodologies, 1 country uses a mix of T1 and T2 and 4 countries use T1 methodology. For this emission category, 9 countries use CS emission factors, 3 countries use a mix of D and CS emission factors and 2 countries use D emission factors. Some countries are using T1 methodology and D emission factors to calculate manure management CH_4 emissions from swine since they do not consider swine as a key animal category.

Regarding N_2O emissions from cattle manure management, 11 countries use T2, 1 country uses a mix of CS and T2, 1 country uses a CS and 1 country use a T1 methodology, where 5 countries use CS emission factors, 5 others use a mix of CS and D emission factors and 4 countries use D emission factors. For swine, 10 countries use T2 methodology, 3 country use T1, while 1 country (Chile) does not report emissions under this category. Three out of 14 countries use CS emission factors, 5 countries use a mix of CS and D emission factors, and 5 countries use D emission factors.

N_2O emissions from "Urine and Dung Deposited by Grazing Animals" are usually estimated by T1 methodologies (11 countries), or by a combination of T1 and T2 methodologies (2 countries), while 1 country (Brazil) does not report emissions under this category. 10 countries out of 13 use D emission factors, 3 use a combination of D and CS emission factors.

The methodologies for the assessment of NH_3 emissions from manure management are quite heterogeneous: 1 country uses a T3 approach with CS emission factors, 2 countries use a mix of T3 and T2 methodologies with CS emission factors, 6 countries use T2 methodology with CS or a mix of CS and D emission factors, 1 country uses a mix of T1 and T2 with CS emission factors. Other countries use simpler approaches: Chile uses T1 methodology with D emission factors, New Zealand uses a CS method with D emission factors and 1 country. Differently, China uses a CS method with CS emission factors, while Brazil does not report emissions under this category. Brazil is at the moment testing the IPCC methodology to calculate the NH_3, but other methodologies are being considered for better comparability. Simpler methodologies are usually adopted when NH_3 from manure management is not considered a key emission category. For instance, New Zealand's Greenhouse Gas Inventory (MfE, 2017) states that dairy cattle, non-dairy cattle (beef), sheep and deer are largely grazed outside all year round, and intensive housing of major ruminant livestock species is not practised in New Zealand. Laubach et al. (2015) also identified that New Zealand's inventories omit NH_3 emissions from the animal sheds and yards, probably due to lack of specific data.

The most advanced methodology is the one from the Netherlands, whose inventory calculates emissions of NH_3 and other N compounds (NO_x, N_2O) from animal housing, manure storage, manure application and grazing using a Total Ammoniacal Nitrogen flow model (Vonk et al., 2018). A system to assess the emissions of N species (NH_3, N_2O, NO, N_2) from manure management, developed by Dämmgen and Hutchings (2008), assumes 52.3% of the TAN (ammonia plus ammonium) is available for NH_3 volatilisation from the total N excreted and deposited by housed animals in milking parlour and holding yard. Since the time spent by dairy cows in the milking parlour and holding yard is the same irrespective of grazing and or a fully housed dairy farming system, Laubach et al. (2015) considered that Dämmgen and Hutchings (2008) modelled values can be relevant for New Zealand.

To calculate the NH_3 emissions from agricultural soils, most countries (7) use a mix of T1, T2, T3 methodologies with a mix of CS and D emission factors, 1 country uses T3 method with CS emission factors, 2 countries use T2 with CS emission factors, 1 country uses a CS method with CS emission factors and 1 country uses T1 with D emissions. Brazil and China do not report emissions under this category.

Table 1 Manure management CH_4 emission estimation methods

Member State	Method (Cattle)	EF information (Cattle)	Method (Swine)	EF information (Swine)
Germany	T2	CS	T2	CS
France	T2	CS	T2	CS
Greece	T2	CS,D	T1	D
Denmark	CS, T2	CS,D	CS, T2	CS,D
Ireland	T2	CS	T2	CS,D
Poland	T2	CS	T1	CS
Austria	T2	CS	T1	D
Netherlands	T2	CS	T2	CS
Italy	T2	CS	T2	CS
Belgium	T2	CS	T2	CS
New Zealand	CS, T2	CS	T1	CS
Chile	T2	CS	T2	CS
Brazil	T2	CS	T2	CS
China	T1, T2	D, CS	T1, T2	D, CS

Table 2 Manure management N_2O emission estimation methods

Member State	Method (Cattle)	EF information (Cattle)	Method (Swine)	EF information (Swine)
Germany	T2	CS,D	T2	CS,D
France	T2	CS,D	T2	CS,D
Greece	D	D	T1	D
Denmark	T2	D	T2	D
Ireland	T2	CS,D	T2	CS,D
Poland	T2	CS	T2	CS
Austria	T2	CS	T2	CS
Netherlands	CS	D	T1	D
Italy	T2	CS,D	T2	CS,D
Belgium	T2	D	T2	D
New Zealand	CS T2	CS	T1	D
Chile	T2	CS	-	-
Brazil	T2	CS	T2	CS
China	T2	D, CS	T2	D, CS

Table 3 N_2O emissions from Urine and Dung N Deposited by Grazing Animals estimation methods

Member State	Method	EF information
Germany	T1	D
France	T1,T2	D
Greece	T1	D
Denmark	T1	D
Ireland	T1	D
Poland	T1	CS,D
Austria	T1	D
Netherlands	T1	D
Italy	T1	CS,D
Belgium	T1	D
New Zealand	T2	CS,D
Chile	T1	D
Brazil	-	-
China	T1, T2	D CS

Table 4 Methods used for the estimation of NH_3 emissions from manure management and agricultural soils

Member State	Method	EF information
Germany	T3,T2	CS
France	T2	CS,D
Greece	T1,T2	CS
Denmark	T2	CS
Ireland	T2	CS
Poland	T2	CS
Austria	T3,T2	CS,D
Netherlands	T3	CS
Italy	T2	CS
Belgium	T2	CS,D
New Zealand	CS	D
Chile	T1	D
Brazil	-	-
China	CS	CS

Table 5 Methods used for the estimation of NH_3 emissions from agricultural soils

Member State	Method	EF information
Germany	T1,T2,T3	CS,D
France	T1,T2	D
Greece	T1,T2	D
Denmark	T1,T2	CS,D
Ireland	T2	CS,D
Poland	T2	CS
Austria	T3,T1	CS
Netherlands	T3	CS
Italy	T1,T2,CS	CS,D
Belgium	T2,T1,T3	CS,D
New Zealand	CS	CS
Chile	T1	D
Brazil	-	-
China	-	-

MELS key component analysis

In this part of the report, the main outcomes of the MELS key component analysis for emissions from livestock systems are presented. The results provide a guidance on the key factors influencing emissions from manure management which should be considered in the inventory assessments and future studies. Inventory compilers could find it beneficial to consider these key influencing factors when developing country-specific emission factors for inventory preparations.

Key influencing factors CH_4 emissions from manure management

Key influencing factors of CH_4 emissions from manure storage were analysed in WP3. In the context of MELS WP3, D3.1 revised CH_4 emission factors values were presented for slurry and solid manure storage types. The analysis showed there was no significant difference in the CH_4 emission factors for both slurry and solid storage between the two animal types therefore these were combined into single groups as slurry tanks (cattle and swine) and manure heaps (cattle and swine).

Key influencing factors of manure related CH_4 emissions from animal housing were analysed in WP3 for cattle and swine separately. For cattle, the only significant factor effecting CH_4 emissions was ventilation type (natural or forced). As stated in D3.3, this effect was likely due to the variation in indoor temperature caused by the ventilation systems. For swine, key influencing factors were analysed for slurry and solid manure and presented in Table 6.

Table 6 Key influencing factors of CH_4 emissions from swine housing

Key influencing factors	Slurry	Solid manure
Feed conversion ratio	✓	✓
Type of forced ventilation air inlets	✓	
type of forced ventilation air outlets	✓	✓
Type of bedding material		✓
Live weight gain per day		✓

The key drivers that significantly effect CH_4 emission factors for cattle and swine slurry storage and solid manure storage were identified in WP3 and a summary of the significant factors are presented in Table 7. Three influencing key factors relate to manure characteristics (DM, CN ratio, VS concentration), two key factor relates to environmental conditions (manure and air temperature). For all considered factors, the EF showed differences depending on the animal type.

Table 7 Key influencing factors of CH_4 emissions from manure storage

Key influencing factors	Slurry	Solid manure
Manure DM concentration	✓	✓
Manure CN ratio	✓	✓
Manure VS concentration	✓	✓
Manure mean temperature	✓	✓
Air mean temperature	✓	✓

Key influencing factors N_2O emissions from manure management

Key influencing factors of N_2O emissions from manure storage were analysed in WP3. In the context of MELS WP3, D3.1 revised N_2O EF values were presented for slurry and solid manure storage types. The analysis showed there was no significant difference in the N_2O EFs for both slurry and solid storage between the two animal types therefore these were combined into single groups as slurry tanks (cattle and swine) and manure heaps (cattle and swine).

Key influencing factors of N_2O emissions from manure storage in animal housing were analysed in WP3 for cattle and swine separately. For N_2O emissions from cattle housing, only climate zone (wet or dry) was an influencing factor. For swine, key influencing factors were analysed for slurry and solid manure and presented in Table 8.

Table 8 Key influencing factors of N_2O emissions from swine housing

Key influencing factors	Slurry	Solid manure
Mean housing temperature		✓
Type of forced ventilation air inlets		
type of forced ventilation air outlets	✓	
Type of bedding material		✓
Live weight gain per day	✓	✓
Type of ventilation system		✓
Swine sub-category	✓	✓

The key drivers that significantly effect N_2O emission factors for cattle and swine slurry storage and solid manure storage were identified in WP3 and a summary of the significant factors are presented in Table 9. Four influencing key factors relate to manure characteristics (DM, organic C and total N concentration and CN ratio), one key factor relates to environmental conditions (manure temperature) while N_2O emission increased with longer storage duration. For some of the considered factors, the EF showed differences depending on the animal type.

Table 9 Key influencing factors of N_2O emissions from manure storage

Key influencing factors	Slurry	Solid manure
Manure DM concentration	✓*	✓ *
Manure organic C concentration	✓ *	✓*
Manure CN ratio	✓ *	✓ *
Manure total N concentration	✓	✓
Manure mean temperature	✓*	✓ *
Storage duration	✓	✓

* EF showed differences depending on the animal type

Key influencing factors NH_3 emissions from manure management

Key influencing factors of NH_3 emissions from manure storage were analysed in WP3. Five storage types namely; slurry tanks (cattle and swine), pits (swine), manure heaps (solid), lagoons (slurry), and manure heaps (swine) were assessed for classifying emission factors values for swine and cattle manure storage. For slurry, the analysis showed there was no significant difference in the NH_3 EF between the two animal types therefore these were combined into a single group as cattle and swine slurry stored in slurry tanks. In the context of MELS WP3, D3.1 revised EF values were presented for above mentioned storage types.

Key influencing factors of NH_3 emissions from manure storage in animal housing were analysed in WP3 for cattle and swine separately. For NH_3 emissions from cattle housing, four significant key factors were housing temperature, housing and floor type, climate zones (wet or dry), ventilation type (natural or forced). For swine, key influencing factors were analysed for slurry and solid manure and presented in Table 10.

Table 10 Key influencing factors of NH_3 emissions from swine housing

Key influencing factors	Slurry	Solid manure
Feed conversion ratio		✓
Type of forced ventilation air inlets	✓	
type of forced ventilation air outlets	✓	✓
Type of bedding material		✓
Live weight gain per day		✓
Type of ventilation system		✓
Swine sub-category	✓	✓
Housing type		✓

The key drivers that significantly effect NH_3 emission factors for cattle and swine slurry storage and solid manure storage were identified in WP3 and a summary of the significant factors are presented in Table 11. Five influencing key factors relate to manure characteristics (DM, organic C, TAN and total N concentration and pH), one key factor relates to environmental conditions (air temperature), while NH_3 emission increased with longer storage duration. For some of the considered factors, the EF showed differences depending on the animal type.

Table 11 Key influencing factors of NH_3 emissions from manure storage

Key influencing factors	Slurry	Solid manure
Manure DM concentration		✓
Manure organic C concentration	✓	✓*
Manure pH	✓	✓ *
Manure total N concentration	✓ *	
Manure TAN concentration	✓*	✓ *
Air temperature	✓	
Storage duration	✓	
Floor type	✓	
Housing temperature	✓	

* EF showed differences depending on the animal type

Improvement of the emission inventory methodologies based on the requirements of the MELS functional relationships

Default emission factors provided in the EMEP/EEA Guidebooks and IPCC Guidelines offer each country the possibility to compile an inventory and report air pollutant and GHG emissions from anthropogenic sources. However, default emission factors do not reflect the real conditions of a country. The availability of activity data is a relevant determinant on the choice of the methods for the calculation of air pollutants and GHG emissions from agricultural activities, thus influencing the selection of the most appropriate emission factors. For example, the manure management emission calculations in accordance with a Tier 2 or Tier 3 method require data on (i) animal performance (animal weight, weight gain, milk yield, milk protein content, milk fat content, numbers of births, numbers of eggs and weights of eggs), and on (ii) feeding details (phase feeding, feed components, protein and energy content, digestibility and feed efficiency). Several data can be retrieved from National Statistics (NS), FAO, reporting under UNFCC (CRF Tables), reporting under UNECE (IIRs), Eurostat and other sources.

Inventories on air pollutants and GHG emissions from agricultural activities are required to be comparable, complete, transparent, and accurate. To this end, the Tier 2 is a highly advisable method that can reflect changes in livestock production and productivity and measure the effects of the changes in the agricultural sector. However, the Tier 3 method goes further, as it can include more detailed facility-level data and/or sophisticated models taking in consideration a detailed diet composition, seasonal variation of animal population or feed quality, the application of abatement measures, possible mitigation strategies. All the methods can provide an accurate view of the changes of the agricultural sector only if the activity data and emission factors are sufficiently specific and are updated on regularly basis. The IPCC 2006 Guidelines provide methods/equations for the calculation of both emissions and emission factors for GHGs (CH_4 and N_2O) in the agricultural sector, as well as default emission factors. The EMEP/EEA Guidebooks (2013, 2016, and 2019) provide methodologies and default emission factors for the estimation of air pollutant emissions from agricultural activities. However, these emission factors vary and require an accurate selection procedure by the countries to be more representative for their conditions.

By the end of 2018, almost all EU countries applied a Tier 2 method to calculate NH_3 emissions from the manure management subsector. Methodologies to estimate air pollutant and GHG emissions from the manure management subsector are more advanced for cattle, swine, and sheep categories. Almost all EU countries apply a Tier 2 method and in some countries a Tier 3 method is used. This is linked with the fact that these livestock categories are key sources of air pollutant and GHG emissions in almost all EU countries. Both IPCC and EMEP/EEA provide flexibility on how a Tier 2 method can be applied. For instance, an elaborated excel tool, applying a Tier 2 methodology, is provided by the EMEP/EEA Guidebook 2019 to calculate the NH_3, N_2O, NO and N_2 emissions using the N mass-flow approach. Some countries apply dynamic emission factors to estimate NH_3 emissions from livestock activities better reflecting the changes in time of the manure management system. However, there are countries that use static emission factors, which cannot reflect changes in livestock production, productivity, and associated air pollutant and GHG emissions over time.

There is a lot of information in the EU countries that, if organised well, can provide an adequate starting point for compiling an inventory using the Tier 2 method. Country-specific emission factors in manure management are used to a small extent, mainly for the calculation of NH_3 emissions and partly for NOx emissions. The use of models gives the possibility of introducing methods for the calculation of activity data which are not available and for which the default values are not provided. However, to improve the estimates of air pollutant and GHG emissions from a certain activity, these models should regularly update their inputs and compare those with activity data provided by countries.

Activity data collection has a significant impact on data quality. The definition of activity data collection methodologies should ensure the best balance between quality and uncertainty. Performing regularly farm-level surveys or introducing questionnaires that cover many aspects of farm activities can improve the quality of activity data minimising uncertainties. The way forward to improve agricultural emission estimates should be:

- Encouraging the application of country-specific activity data and emission factors,
- Increasing the transparency related to country specific activity data and emission factors,
- Improving the reporting of country-specific emission factors related to each system of manure management and each category of agricultural soils activities,
- Improving the reporting template to provide the possibility of collecting country-specific emission factors in an unified measurement unit which will facilitate not only the comparison with default values but also the comparison among countries,
- A deeper investigation of the relationship between activity data and emission factors,
- Support the application of surveys and questionnaires on farms statistics.

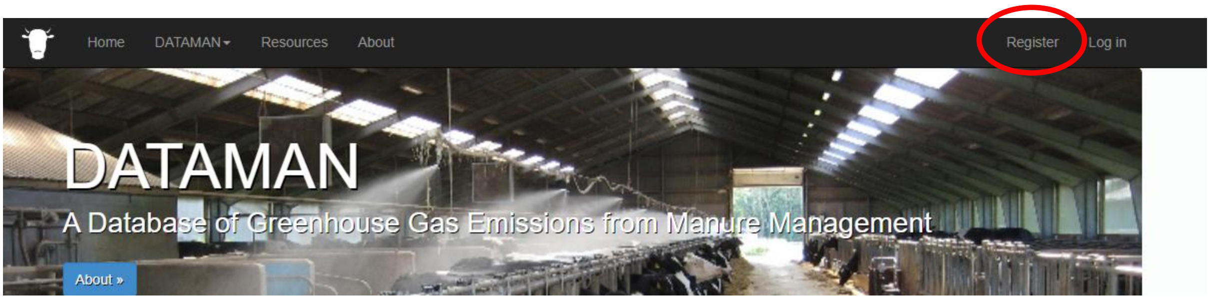
Guidance on how to use the DATAMAN database to generate ammonia, nitrous oxide and methane emission factors

Background

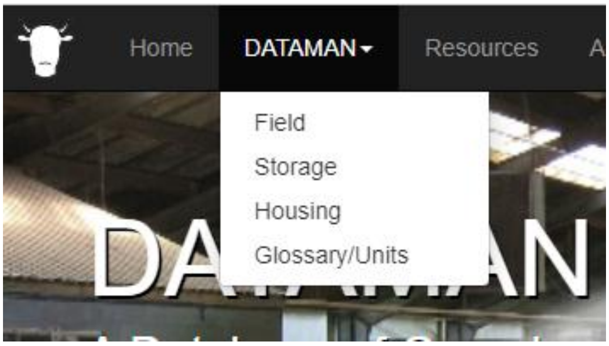
The DATAMAN project was created to build a publicly available global database of methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3) emissions (plus relevant activity and ancillary data) relating to livestock housing, storage, and field application of manure (including excreta deposited during grazing) (Beltran et al. 2021; Hassouna et al. 2023). The overall aim of the DATAMAN project is to provide researchers and policy makers alike with the most up-to-date knowledge on methods for managing GHG and NH_3 emissions from manure. DATAMAN contains three databases: (1) housing, (2) storage, and (3) field-based emissions. In future, DATAMAN will be expanded to include a fourth database focusing on NH_3 and N_2O emission factors for synthetic N fertilisers.

How to access and download the data

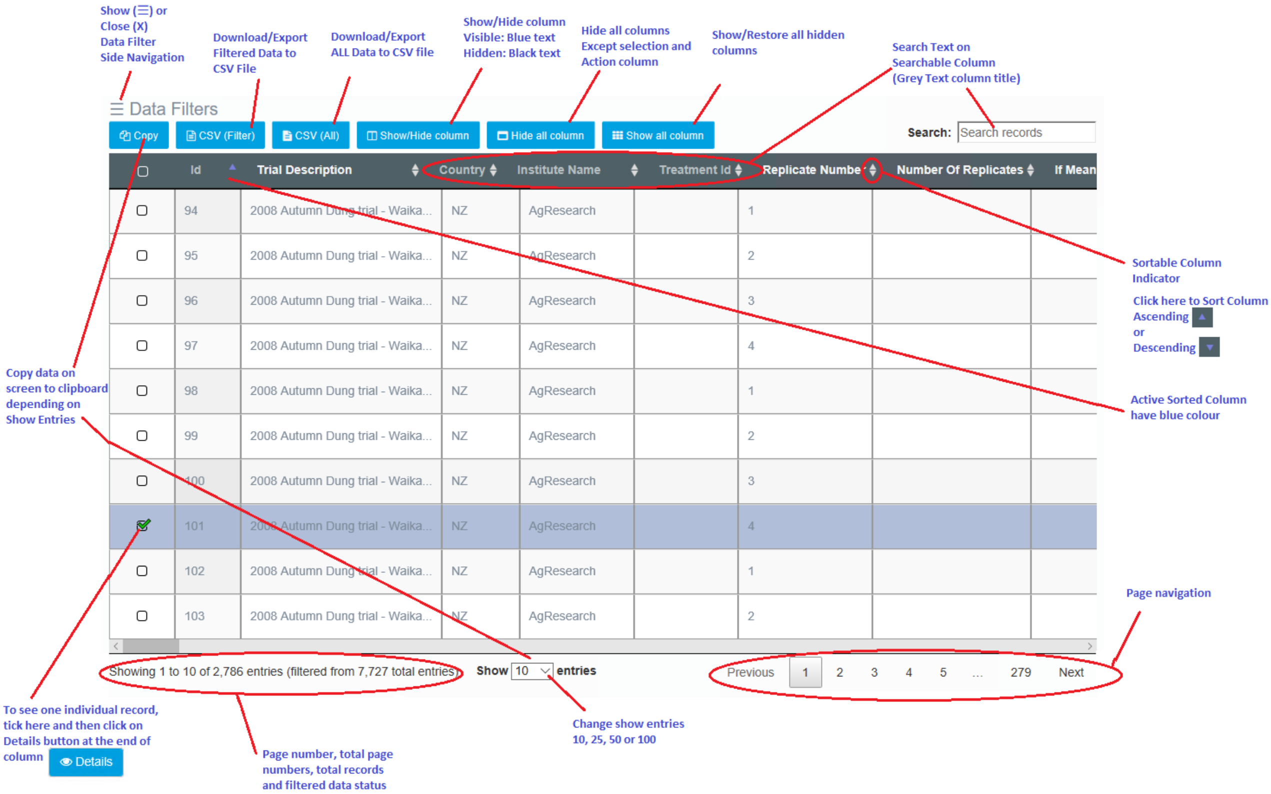
The first step is to register as a user of DATAMAN. There is no cost to register, just simply click on Register (circled below) and follow the steps. If registered, then log in.



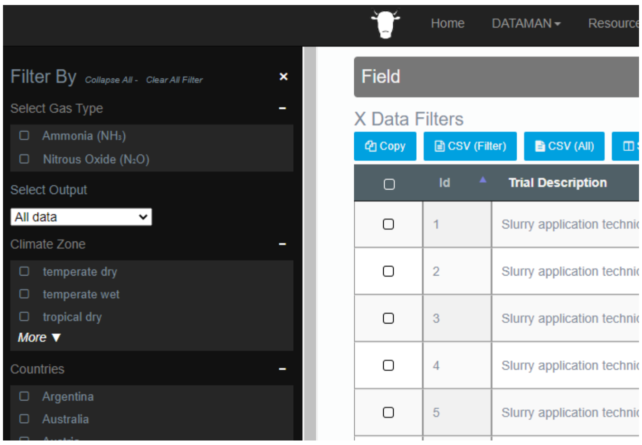
As noted, DATAMAN contains three databases (housing, storage, and field). The three databases, plus a glossary/units page, can be found in the DATAMAN tab in the Menu options at the top of the website screen:



The database has a number of options and functions (see below, showing the Field database). To download all of the data, simply click “CSV (All)”. However, if you are only interested in a subset of the database, then use the “Data Filters” function by clicking on the “Data Filters” hamburger menu (top left on screenshot shown below).



Once the menu is clicked, filtering options appear on the left:



These can be used for selecting data based on gas type (CH_4, N_2O, NH_3) and whether ‘all data’ or ‘emission factors only’ are required, followed by a list of factors that can be filtered.

Available factors for filtering include:

- Climate zone
- Countries
- Institutes
- Emission Measurement Method
- Animal Category
- Manure type
- Housing type (Housing only)
- Floor type (Housing only)
- Storage type (Storage only)
- Manure treatment (Storage and Field only)
- Manure application method (Field only)

Example of how to download data from a single country – 7 easy steps

How do I download all Brazilian data associated with N_2O emissions and emission factors for grazing and manure application to land?

1. Select ‘Field’ database
2. Click on ‘Data Filters’ menu
3. Select Gas type: Nitrous oxide
4. Select Output dropdown list: All data (this is the default setting)
5. Go down to Countries and expand the list of countries by clicking on the ‘more’ arrow
6. Select ‘Brazil’
7. Download Brazilian data by clicking ‘CSV (Filter)’. A comma separated values (CSV) file will be downloaded to your computer which can then be saved and used for examining and/or analysing.

Note: you can check what type of data is included in filtered subsets by clicking on the “Number of Observations” beneath the table of database entries.