D4.3: Guidance Document on Priority Technical Improvements to Existing GHG DSS

WP4: Farm-scale GHG decision support

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Authors:

Teagasc: Saoirse Cummins, Donal O'Brien

AUA. Evangelos Alexandropoulos, Vasileios Anestis

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Lead Author	Donal O'Brien (Teagasc) Email: donal.obrien@teagasc.ie
Other authors	Saoirse Cummins (Teagasc)

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1. Introduction

Modelling greenhouse gas (GHG) and ammonia at the farm-scale has an important role to play in mitigating emissions from livestock production systems. Farm-scale GHG tools or models quantify emissions and removals from the major sources and sink within an agricultural system. They attempt to represent the complex interrelationships among GHG sources and sinks in a livestock system, which are often challenging to measure simultaneously on site. This feature of farm-scale models can be particularly useful in identifying practices or technologies that decrease a specific gas or emission source, but increase emissions from non-target sources, potentially causing a net increase in a farm's emissions. Several tools already exist to quantify emissions from livestock farming systems with some providing decision support systems (DSSs).

This guidance document aims to provide a better understanding of where emission estimates in current farm-scale GHG DSSs can be improved. It links the information and results generated in the component modelling work package (WP3) with the findings of a survey undertaken by AUA that characterized existing farm-scale GHG DSSs (WP4.1). A follow on survey was carried out that involved a target audience of experienced DSS end-users. The feedback from this survey, along with the findings from WP3 and WP4.1, provided a basis to formulate recommendations for priority technical improvement of existing DSSs. This advice will contribute towards the development and specification of a prototype farm-scale GHG DSS *(T4.5).*

2. Existing farm-scale GHG DSS

2.1 Gaseous emissions

Each of the farm-scale GHG DSSs reviewed in WP4.1 and CAP'2ER, a French environmental model of livestock systems, were carefully analysed with regard to gaseous emission computations. The DSSs were classified into three broad categories: a) emission calculators, b) all-pillar sustainability models and c) bi-pillar sustainability models. These DSS categories have been previously defined in the aforementioned review led by AUA. Greenhouse gas emissions relevant to the livestock sector, namely carbon dioxide, methane and nitrous oxide were included in all of the emission calculators and 6 bi-pillar sustainability models. Three of the 6 all-pillar sustainability models quantified constituent emissions. Five of the farm-scale DSSs reported ammonia emissions as well. Emission calculators and bi-pillar sustainability models computed GHG losses according to the approaches described in the 2006 Intergovernmental Panel on Climate Change (IPCC) for national GHG inventories. All-pillar sustainability models that calculated GHG emissions generally applied their own methodology.

***Table 4** Gaseous emissions and modelling methods for selected farm-scale greenhouse gas (GHG) decision support systems.*

Name	Classification	Gaseous Emissions	Modelling Method
Cool Farm Tool v2.0	Bi-pillar sustainability model	N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
FarmAC	Emission calculator	NH_3 and N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
Overseer	Bi-pillar sustainability model	N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
Carbon Navigator – Beef	Bi-pillar sustainability model	N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
Carbon Navigator – Dairy	Bi-pillar sustainability model	N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
KSNL - Kriteriensystem Nachhaltige Landwirtschaft	All-pillar sustainability model	NH_3 and N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
SMART - Sustainability Monitoring and Assessment RouTine	All-pillar sustainability model	No applicable	FAO Guidance (SAFA guidance)
SAFA	All-pillar sustainability model	Not applicable	FAO Guidance (SAFA guidance)
RISE 3.0 - Response-Inducing Sustainability Evaluation	All-pillar sustainability model	N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
BEK - Berechnungstandard für einzelbetriebliche Klimabilanzen in der Landwirtschaft	Emission calculator	NH_3, N_2O, CH_4, CO_2, CO_2eq	
AgBalance®	All-pillar sustainability model	NH_3, N_2O, CH_4, CO_2, CO_2eq	IPCC method
DLG-Nachhaltigkeitsstandard (based on REPRO)	All-pillar sustainability model	Not applicable	DLG method
HOLOS	Bi-pillar sustainability model	N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006
EX-ACT	Emission calculator	N_2O, CH_4, CO_2, CO_2eq	IPCC 2006 method
GLEAM I	Emission calculator	N_2O, CH_4, CO_2, CO_2eq	IPCC 2006 method
CAP'2ER	Bi-pillar sustainability model	NH_3, N_2O, CH_4, CO_2, CO_2eq	IPCC method 2006

Farm-scale GHG DSSs normally rely on the default methods and emission factors (EFs) in the IPCC (2006) guidelines, known as tier 1 methods, to calculate minor sources of emissions e.g.,

CO_2 loss from lime application. More advanced tier 2 or 3 emission factors are employed to estimate GHG released from key sources e.g., enteric fermentation in ruminants. Tier 1 methods and EFs are derived from continental or global studies, whereas tier 2 or 3 approaches are country specific and use local activity data.

***Table 5** Emission factor type employed for major sources of methane within farm-scale greenhouse gas (GHG) decision support systems.*

Name	Enteric fermentation	Manure management
Cool Farm Tool v2.0	IPCC T2	IPCC T2
FarmAC	IPCC T2	IPCC T2
Overseer	Overseer Method	Overseer Method
Carbon Navigator – Beef	CS – IPCC T2	CS - IPCC T2
Carbon Navigator – Dairy	CS - IPCC T2	CS - IPCC T2
KSNL - Kriteriensystem Nachhaltige Landwirtschaft	Not mentioned	Not mentioned
SMART: Sustainability Monitoring and Assessment Routine	-	-
SAFA	-	-
RISE 3.0: Response-Inducing Sustainability Evaluation	RISE method(Mills et al. (2003)	IPCC T2
BEK - Berechnungstandard für einzelbetriebliche Klimabilanzen in der Landwirtschaft	BEK methodology	BEK methodology
AgBalance®	-	-
DLG-Nachhaltigkeitsstandard (based on REPRO)	-	-
HOLOS	IPCC T2	IPCC T2
EX-ACT	IPCC T1/T2	IPCC T1/T2
GLEAM I	IPCC T2	IPCC T2
CAP’2ER	IPCC T3, Sauvant et al, 2014	IPCC T1/T2

***Table 6** Emission factor type applied for major sources of nitrous oxide within farm-scale greenhouse gas (GHG) decision support systems.*

Name	Manure storage	Manure spreading	Synthetic fertiliser spreading	Manure from grazing animals
Cool Farm Tool v2.0	IPCC T1/2	IPCC T 1/2	IPCC T 1/2	IPCC T 1/2
FarmAC	IPCC T2	IPCC T2	IPCC T2	IPCC T2
Overseer	Overseer Method	Overseer Method	Overseer Method / IPCC 2006 EF	Overseer Method
Carbon Navigator – Beef	IPCC T 1	IPCC T 1	IPCC T 1	IPCC T 1
Carbon Navigator – Dairy	IPCC T 1	IPCC T 1	IPCC T 1	IPCC T 1
KSNL - Kriteriensystem Nachhaltige Landwirtschaft	Not mentioned	Not mentioned	Not mentioned	Not mentioned
SMART - Sustainability Monitoring and Assessment RouTine	-	-	-	-
SAFA	-	-	-	-
RISE 3.0 - Response-Inducing Sustainability Evaluation	IPCC T2	IPCC T 1	IPCC T1	-
BEK - Berechnungstandard für einzelbetriebliche Klimabilanzen in der Landwirtschaft	BEK methodology	BEK methodology	BEK methodology	BEK methodology
AgBalance®	-	-	-	-
DLG-Nachhaltigkeitsstandard (based on REPRO)	-	-	-	-
HOLOS	IPCC T2	IPCC T2 / Holos method	IPCC T2 / Holos method	IPCC T2
EX-ACT	-	IPCC T1/T2	IPCC T1/T2	IPCC T1/T2
GLEAM I	IPCC T2	IPCC T2	IPCC T2	IPCC T2
CAP'2ER	IPCC T1/T2	IPCC T1/T2	IPCC T1/T2	IPCC T1/T2

2.2 Carbon sequestration

Some of the farm-scale GHG DSS tools reviewed i.e. CAP'2ER, Cool Farm Tool, EX-ACT and Holos estimated the amount of GHG emission offset by carbon sequestration in soils and vegetation. Generally, farm-scale DSSs that attempt to quantify carbon sequestration rely on a basic tier 1 approach or use average sequestration rates for different land uses based on national research. For example, CAP'2ER assigns a carbon sequestration rate of 0.57 t C/ha per year to permanent grassland in France and assumes a rate of 0.08 t C/ha per year for leys. A few of the DSS tool utilize advanced soil or biogeochemical models to estimate carbon sequestration. Detailed historical climate, land and management information is usually required to operate these tools.

2.3 Mitigation measures

Users of existing farm-scale GHG DSSs normally have a range of practices and technologies to select from when designing action plans to mitigate emissions. For animal production systems, the measures available for reducing emissions vary across DSSs and depend to some extent on the biophysical environment, regional or national science, and the livestock enterprise under appraisal. Mitigation options in farm-scale DSSs generally focus on five major sources of gaseous emissions: 1) Animals, 2) Manure, 3) Soils, 4) Plants (e.g., crop residues) and 5) Machinery (Table 4). They either target emissions from a particular source or aim to reduce emissions across multiple sources. The benefits of these measures in terms of emissions can arise pre-farm as well as on-farm e.g., decreasing imports reduces emissions related to transport. The mitigation of emissions from pre-farm sources is only considered in DSSs whose boundaries extend beyond the farm i.e. life cycle assessment based tools such as CAP'2ER, the Cool Farm Tool and GLEAM.

***Table 7** Measures for mitigating emissions in farm-scale greenhouse gas (GHG) decision support systems by source category.*

Name	Animal	Manure	Soils	Plants	Machinery/Energy
Cool Farm Tool v2.0	×	×	✓	✓	×
FarmAC	✓	✓	✓	✓	✓
Overseer	✓	✓	✓	✓	×
Carbon Navigator – Beef	✓	✓	✓	✓	×
Carbon Navigator – Dairy	✓	✓	✓	✓	✓
KSNL - Kriteriensystem Nachhaltige Landwirtschaft	-	-	-	-	-
SMART - Sustainability Monitoring and Assessment RouTine	×	×	×	×	×
SAFA	×	✓	✓	✓	×
RISE 3.0 - Response-Inducing Sustainability Evaluation	✓	✓	✓	✓	✓
BEK - Berechnungstandard für einzelbetriebliche Klimabilanzen in der Landwirtschaft	-	-	-	-	-
AgBalance®	×	X	✓	✓	✓
DLG-Nachhaltigkeitsstandard (based on REPRO)	-	-	-	-	-
HOLOS	✓	✓	✓	✓	×
EX-ACT	✓	✓	✓	✓	✓
GLEAM I	✓	✓	×	✓	×
CAP'2ER	✓	✓	✓	✓	✓

Emission reductions associated with a management change or new technology can be estimated with several of the farm-level GHG DSSs categorised as emission calculators. A few of these decision support tools e.g., Holos and CAP'2ER also attempt to quantify the potential gain in carbon sequestration caused by a change in land use or management. Generally, a "what-if" form of scenario analysis is employed to quantify emission reductions and carbon sequestration gains in DSSs. Custom mitigation scenarios can be created in some DSSs e.g., GLEAM I, while others e.g., Carbon Navigator provide a set menu of options. Emission factors from the IPCC (2006) guidelines and/or representative studies are typically used to work out the mitigation benefits of custom or pre-defined scenarios. Farm-level GHG DSSs report reductions in emissions or gains in carbon sequestration on an absolute basis or in relative terms. For example, Holos reports the amount of GHG abated by mitigation measures in tonnes of CO_2 equivalent, whereas the Beef and Dairy Carbon Navigators report the percentage reduction in GHG emissions.

An alternative approach for analyzing mitigation measures in farm-scale GHG DSSs is a scoring system. Scores are qualitative measures of the impact of a farm's actions on emissions and sequestration. Optimizing farm management and using low emission technologies generally leads to a better emission or sustainability score in DSSs. Equal weights are usually assigned to mitigation practices and technologies in qualitative farm-level GHG DSSs, which may lead to an over or underestimate of their potential benefit in terms of gaseous emissions or carbon sequestration. Quantitative tools that rely on scoring systems such as AgBalance usually weight mitigation measures based on their potential to reduce emissions. Weighting mitigation measures helps to direct efforts on the actions that have the greatest potential to reduce emissions. The results of an emission scoring system are presented on qualitative scales in farm-level GHG DSSs. Score results are normally of limited use for those interested in monitoring absolute or relative emission reductions, unless scores can be converted to emission values, which may be possible for quantitative DSSs.

3. Survey of DSS end users

A survey was developed and circulated among experienced DSS end users (n=9) in order to gain insight into the capabilities and shortcomings of such tools. The tool most commonly reported in use was FarmAC with some end users also reporting on CAP'2ER, Cool Farm Tool and GLEAM. Regarding the capacity in which DSS were used, the majority of respondents utilised such tools for research with less (1-2) end users using them for advisory and/or policy also.

3.1 Advantages of DSS

The strengths identified in the survey for current DSSs were:

- Multi criteria tool, outputs are well made.
- Can be used for inventory accounting.
- Flexible and adaptable.
- Can simulate effects of mitigation measures on livestock production and can capture knock-on environmental effects in terms of emissions.
- User friendly with instant results, many parameters, cost management, many graphical results, many livestock and crop options.
- Life cycle approach for multiple livestock categories; assessment of more than one environmental dimensions; national, sub-national, regional scale for all FAO countries; very useful for compiling life cycle models for livestock products.
- Transparent tool, farm carbon and nitrogen flows estimation, presentation of herd requirements. Use of Tier 2 methodologies to describe flows in livestock and manure management and Tier 3 methodologies for crops and soil. Use of agro ecological zone in the estimations.
- Provides complete and long-term C and N balances; it is rather open (including missing crops is possible).
- Combined economic and GHG assessment, default values available.

3.2 Disadvantages of DSS

The weaknesses highlighted for existing DSSs were:

- Grasslands and grassland management is less well represented. Farm scale GHG DSS tool generally developed to optimise production and not environment.
- Some tools do not incorporate mitigation strategies.
- Good flexibility comes at the price of complexity. Balancing inputs and outputs can be challenging, especially for grazing livestock systems.
- Only online version.
- Does not take into account the economic and social dimensions of sustainability; it is focused on GHG emissions' accounting; it has therefore little use for assessing other environmental impact categories.
- Bad error management (the function of the tool stop when an error appears). It is not a proper tool for inexperienced users (it is suitable for researchers). It has some designing problems (it has no boundaries). It is difficult for inexperienced users (i.e. it is suitable for researchers).
- Poor flexibility in dealing with crop rotations; lack of estimated emissions per unit of saleable product (e.g. milk); comparison with a regional/typical average could provide guidance to less experience users; it is not so user-friendly.

Survey respondents provided the following suggestions to overcome current weaknesses in farm-level GHG DSSs:

- Full transparency of calculations.
- An ability to account for soil C storage.
- Incorporate additional GHG mitigation measures in tools.
- Keep up to date with GHG estimation methodologies based on new research results. i.e. implementation of revised models from the 2019 refinement of the IPCC 2006 Guidelines for GHG emissions' estimation and of the EMEP/EEA 2019 Guidebook for other gaseous emissions' estimation; include the new emission factors' functions developed in the context of the MELS project, using the DATAMAN datasets; Inclusion of the effect of mitigation strategies/practices on CH_4, N_2O and NH_3 as assessed in the context of the MELS project
- To ensure user friendliness i.e. interface, documentation and user guidance.
- Improved results presentation (more graphical schemes) and the option to compare the results between years, mitigation methods etc.

4. Improving farm-scale GHG DSSs

4.1 Emission factors

The accuracy of the emission results of many of the current farm-scale GHG DSSs can be increased by applying the revised EFs and component models developed in WP3. Briefly, within this work package a statistical analysis of DATAMAN (Beltran et al., 2021), a database for greenhouse gas emissions from manure, was conducted. This analysis focused on the livestock housing and manure storage information that had been added to DATAMAN. The housing database contained 1275 EFs for ammonia, 385 EFs for methane and 354 EFs for nitrous oxide. The storage database had 1317 EFs (50% for ammonia, 18% for methane and 32% for nitrous oxide). The outputs from the statistical analysis of DATAMAN produced revised ammonia, nitrous oxide and methane EFs for the housing and storage stages of the manure management chain (Table 5). These EFs may suit farm-scale GHG DSSs that lack data on the key drivers of emissions or GHG tools that rely on global or continental defaults i.e. tier 1 EFs.

***Table 8** Revised ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4) emission factors[1] (EFs) for manure storage*

Manure type	Storage type	Livestock type	Mean NH_3 EF	Mean N_2O EF	Mean CH_4 EF
Slurry	Tank	Cattle & swine	0.00442	0.0497	0.0691
Slurry	Lagoon	Swine	-	0.108	-
Solid	Heap	Cattle	0.0101	0.061	0.0285
Solid	Heap	Swine	0.0164	0.125	0.0014

[1] Ammonia EF in kg NH_3-N/kg N, N_2O EF in kg N_2O-N/kg N, and CH_4 in kg CH_4/kg volatile solids

4.2 Functional relationships and mitigation measures

The result in WP3 demonstrated that duration of storage affects ammonia and nitrous EFs for slurry tanks and the nitrous oxide EF for manure heap (Figure 1). The EFs for the gases and storage systems effected by duration can be adjusted with the statistical relationships developed in WP3.

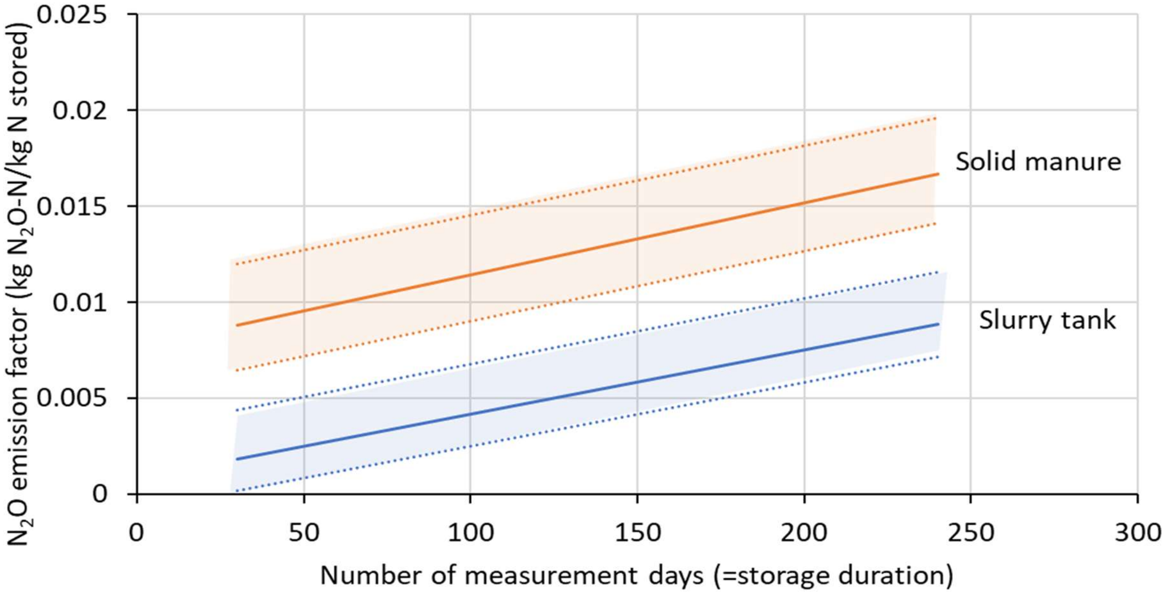

Figure 10 Influence of measurement duration on nitrous oxide emission factors for slurry tank and solid manure heap. Mean EF (solid line) ± 95% confidence interval (dotted line and shaded area).

Similar functional relationships were developed for the drivers of emissions from housing, manure storage and manure application. A multi-variable modelling approach was used to develop functional relationships between emissions and activity/ancillary data. Relationships were only developed when there was sufficient empirical data (>25 observations) for variable(s). Climatic conditions and manure characteristics i.e. DM, organic carbon, pH, N, total ammoniacal nitrogen, C/N ratio and temperature were included as variables i.e. driving factors in the multi-variable models describing functional relationships The variables or driving factors selected for multi-variable models were significant in single variable models. Three variable models were identified to describe functional relationships for NH3 EFs for slurry storage and solid manure storage. Slightly simpler, 2 variable models explained N_2O and CH_4 EFs for manure storage. A selection of the functional relationships developed for these sources is presented in Table 6.

***Table 9** Selection of functional relationships developed for estimating ammonia (NH_3), nitrous oxide (N_2O) and methane (CH_4) emission factors for manure storage systems.*

Gas	Manure storage system	Variables	Coefficient	Std. error
NH_3	Slurry	Intercept	-5.444	0.711
		Manure DM	0.288	0.093
		Manure TAN concentration	0.079	0.036
		Air temperature (average over entire experiment)	0.056	0.028
N_2O	Slurry & Solid	Intercept	-6.187	0.305
		Manure DM	-0.034	0.018
		Manure mean temperature	0.062	0.016
CH_4	Slurry & Solid	intercept	-2.79079	0.52513
		Manure DM	-0.15029	0.04038
		Air temperature	0.06437	0.03054

Integrating functional relationships for emissions from manure management with existing farm-scale GHG DSSs will enhance the tools sensitivity to regional factors such as air temperature, soil type and housing system. Moreover, these relationships are likely to increase current farm-level GHG DSSs capacity in terms of mitigation measures and improve the DSSs ability to capture the benefits of low emission practices and technologies. The latter could be achieved by combining the mitigation strategies established in WP3.2 (20-30 observations per category) with the functional relationships discussed. This could be done simultaneously or in sequence. The first step for most farm-scale GHG DSSs would be to add the mitigation measures identified for emissions from manure, which are listed below by gas:

4.2.1 Ammonia (NH_3)

- Slurry tank covers reduce ammonia EF for cattle and pig slurry.

- Natural crust on slurry tank reduces ammonia EF, but not significantly as crusts can sink when bubble formation ceases (Figure 1)
- Floating and rigid covers have similar effectiveness (Figure 1)
- Acidification, compaction or composting did not have a significant effect on ammonia when tested.

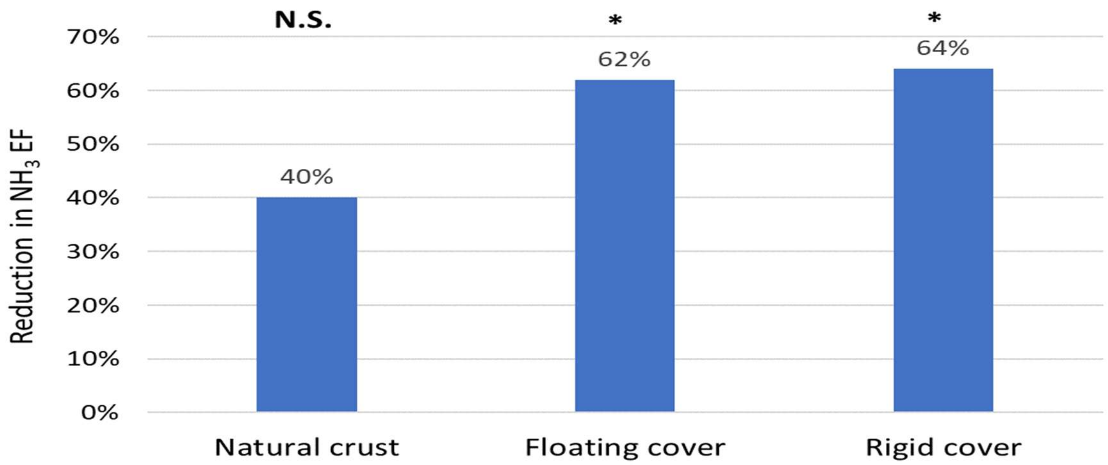

Figure 11 *Influence of storage covers on ammonia emission factors for cattle and pig slurry*

4.2.2 Nitrous oxide (N_2O)

- There was no significant difference between the nitrous oxide EF for cattle and swine manures.
- Storage type (slurry tanks, manure heaps) was found to have a significant effect on emissions, therefore animal types (cattle/swine) were combined
- Manure stored as slurry in tanks had a lower nitrous oxide EF than manure stored in solid heaps (Figure 3).
- No significant effects of manure treatments (covered slurry tanks, composted manure heaps or compacted manure heaps) on nitrous oxide EF.

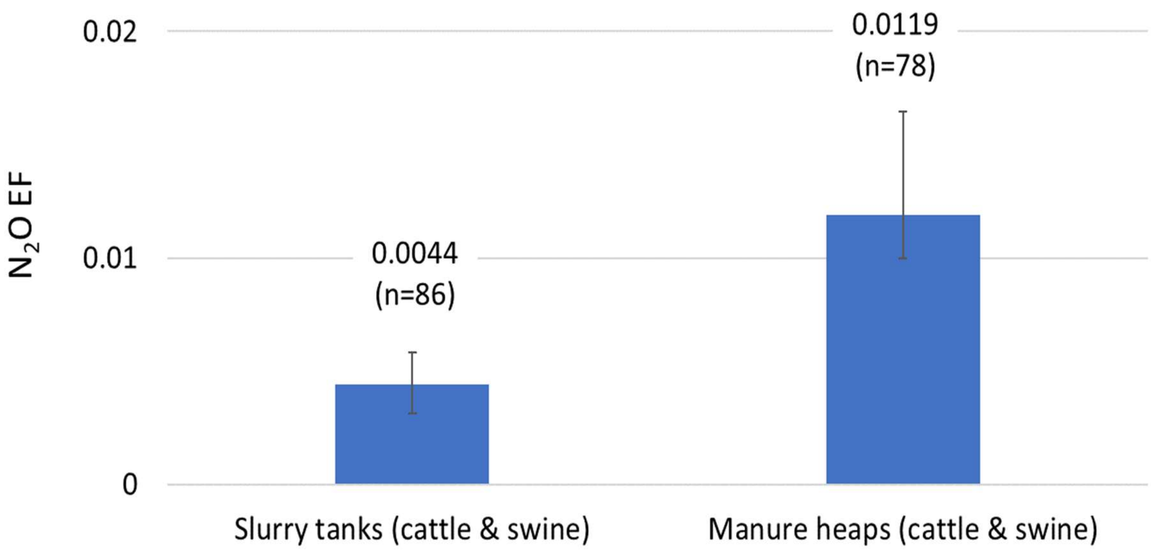

Figure 3. Influence of manure storage on nitrous oxide emission factors for combined animal types (animal type non-significant).

4.2.3 Methane (CH_4)

- No significant difference between animal type (cattle vs swine) ($p = 0.078$) for both slurry tank and manure heap, while storage type was marginally significant ($p = 0.057$).
- The overall mean methane EF for slurry tank was close to three times the EF of manure heaps (Table 5).

4.3 Data requirements

Incorporating new mitigation measures or functional relationships into farm-scale GHG DSSs will increase the activity data requirements for some tools. The inputs and output data required to estimate GHG emissions with existing farm-scale GHG tools have been documented in a survey led by AUA. This survey assessed 6 categories of inputs: a) soil-related, b) crop-related, c) climate-related, d) livestock-related, e) manure management-related and f) livestock feed management-related. Concerning section e, manure management, this section is divided into inputs describing 1) on-farm manure management and 2) field application. Regarding the former, FarmAC was the only DSS of those assessed that clearly distinguished between manure treatment and storage within the livestock housing system (e.g., tied stall, deep litter, cubical house with solid floor, cubical house with slatted floor, cattle housing with acidification of slurry) and a manure storage installation outside the livestock house (e.g. manure heap with/without cover). The Carbon Navigator-Beef and Carbon Navigator-Dairy considered duration of slurry storage, method of slurry application and timing. The other DSSs assessed, including the Cool Farm Tool, Overseer, RISE, HOLOS and GLEAM require further developments regarding housing and manure storage or treatment i.e. classifying housing systems by waste management system. Thus, the functional relationships concerning emissions from manure management and mitigation methods established in WP3 can currently only be considered in the activity data section of the FARMAC and Carbon Navigator tools where the current inputs can be further refined to include more accurate estimates of emissions from of manure management practices. Given that the manure management inputs of the 12 other DSS assessed are not as advanced, perhaps further development around the tools manure management inputs will be required i.e. distinguishing between manure treatments, prior to more complex functional relationships being added for GHG/ammonia mitigation techniques e.g., slurry amendments and manure covers. Climate and land related inputs is another area where many of the existing DSSs need development, particularly temperature and precipitation parameters. Functional relationships or models generally need climate parameters to compute emissions accurately, and require this data in conjunction with land management data to determine carbon sequestration in soils and biomass.

5. Conclusions

Our assessment of farm-scale GHG DSSs indicates there is considerable scope to refine the emission calculations in many of the existing DSSs. Several of the tools examined either rely on global or continental averages for calculating emissions from livestock housing, manure storage and/or manure application or do not collect sufficient information to accurately quantify emissions from the livestock waste and soils. Existing farm-scale GHG DSSs should therefore prioritise computing methane, nitrous oxide and ammonia losses from the major stages of manure management with more advanced, tier 2 or 3, emissions factors. Carbon sequestration in soil and biomass should be modelled in farm DSSs and validated, where possible, against the rate of sequestration measured in local or national studies. Refining emission and sequestration modules in farm-level GHG tools will increase activity data requirements, but will also provide more opportunity in terms of mitigation measures. The latter can be better determined with revised emission factors developed in MELS and by using functional relationship that predict manure related emissions based on key driving factors e.g., air temperature and duration. Further improvements to current farm-scale GHG DSSs can be made by switching to the new GHG calculation approaches in the 2019 refinement to 2006 IPCC guidelines for national inventories (IPCC, 2019). To preserve integrity of farm-scale GHG DSSs, additional environmental metrics e.g., P balance and ammonia loss should be monitored along with wider indicators of sustainability e.g., labour income. A broader sustainability assessment of livestock farms is essential for identifying GHG mitigation actions that do not harm the environment and the economy. Some DSSs have this capability, but most focus on a limited number of enterprises, particularly beef and dairy. Expanding farm-scale GHG DSSs to cater for various enterprises on a farm is another priority for the technical improvement of these tools, along with ease of access and the development of user-friendly interfaces.

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Annex

Question*	1	2	3	4	5	6
Respondent						
1	France	Cap2'Er	Research	Multi criteria, outputs are well made	Grasslands and grassland management is less well represented, was developed to optimise production and not environment	Better account for C storage in soil
2	France	PACRETE, Solagro	Research	Inventory tool	Not incorporating mitigation strategies yet	Incorporate mitigating tools
3	Denmark	FarmAC	Research	Flexible and adaptable. Can simulate effects of mitigation measures on production and can capture knock-on effects	Good flexibility comes at the price of complexity. Balancing inputs and outputs can be challenging, especially for grazing livestock systems	Documentation and user guidance is often deficient
4	Greece	Cool Farm Tool	Research	User friendly, instant results, many parameters, cost management, many graphical results, many livestock and crop options	Online version only.	Constant upgrade to the Estimation methodology based on the new research results. Better tool environment, more user friendly. And better user guides
5	Greece	GLEAM	Research, advisory, policy	LCA approach for multiple livestock categories;	Does not take into account the economic and social	Implementation of revised models from the 2019 refinement of the

				assessment of more than one environmental dimensions; national, sub-national, regional scale for all FAO countries; very useful for compiling life cycle models for livestock products	dimensions of sustainability; it is focused on GHG emissions' accounting, it has therefore little use for assessing other environmental impact categories	IPCC 2006 Guidelines for GHG emissions' estimation and of the EMEP/EEA 2019 Guidebook for other gas emissions' estimation; include the new emission factors' functions developed in the context of the MELS project, using the DATAMAN datasets; Inclusion of the effect of mitigation strategies/practices on CH_4, N_2O and NH_3 as assessed in the context of the MELS project
6	Greece	FarmAC	Research	Transparent tool, Farm Carbon and Nitrogen Flows estimation, Presentation of herd requirements. Use of Tier 2 methodologies to describe flows in livestock and manure management and Tier 3 methodologies for crops and soil. Use	Bad error management (the function of the tool stops when an error appears). It is not a proper tool for inexperienced users (it is suitable for researchers). It has some designing problems (it has no boundaries to the borders). It is not a proper tool for inexperienced users	Constant upgrade to the Estimation methodology based on the new research results. Better tool environment (designing) and user-friendliness. Better user-guides and better guidance during the use of the tool. Better results presentation (more graphical schemes). Possibility to compare the results on the same scheme or boarder.

				of agro ecological zone in the estimations	(it is suitable for researchers). It has some designing problems (it has no boundaries to the borders).	
7	Germany	FarmAC	Research	Provides complete and long-term C and N balances; it is rather open (including missing crops is possible)	Poor flexibility in dealing with crop rotations; lack of estimated emissions per unit of saleable product (e.g. milk); comparison with a regional/typical average could provide guidance to less experience users; it is not so user-friendly	Clearer, more user-friendly interface; abovementioned additional functions
8	Germany	IDB.THG	Advisory	Combined Economic and GHG assessment, Default values available	Still in progress	Full transparency, no black boxes
9	Germany	LfL THG.IDB	Advisory	economic and GHG-assessment, default-values available	Tool is still in progress	Full transparency, no black box-calculations

*Questions 1-6 were as follows:

1) In what country do you work?
2) Which DSS have you experience in using?
3) Target audience(s) of tool(s) used

4) Advantages of tool(s) used?

5) Disadvantages of tool(s) used?

6) How would you suggest improving existing DSS?