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Farm-Scale Greenhouse Gas Emissions' Decision Support Systems †

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Abstract: In this paper, 15 farm-scale Green House Gas-based (GHG-based) decision support (DS) tools were evaluated based on a number of criteria (descriptive evaluation), as well as the parameters requested as inputs and the outputs, all of which are considered important for the estimation procedure and the decision support approach. The tools were grouped as emission calculators and tools providing indicators in terms of more than one pillar of sustainability. The results suggest an absence of automatic consultation in decision support in most of the tools. Furthermore, dairy and beef cattle production systems are the most represented in the tools examined. This research confirms a number of important functionalities of modern GHG-based DS tools.

Keywords: GHG-based decision support; GHG emissions' estimation; multi-pillar assessment; calculators

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1. Introduction

Nowadays, the need to communicate high-quality estimates of greenhouse gases' (GHG) emissions as well as the effect of mitigation strategies at the livestock farm level to various stakeholders has become more and more intense [1]. Furthermore, high-quality measurements of GHG emissions at the livestock farm level are, in practical terms, almost impossible. In this respect, the role of farm-scale GHG-based Decision Support Systems (DSSs) is expected to increase in importance [2].

Until today, most of the research that has been conducted provides information about how GHG emissions are estimated and how these are involved in the sustainability assessment of an agricultural system [3]. In this review, various aspects of DSSs related to GHG emissions' estimation and modeling, their use, as well as the information requested and provided were analyzed. As a result, basic characteristics of a modern GHG-based DSS are suggested.

2. Materials and Methods

A literature search was conducted and resulted in a selection of relevant, previously published review papers [4], papers focusing on specific tools, project reports, and case studies. Fifteen tools with potential for GHG emissions mitigation strategy selection were finally identified and used based on this literature search and proposals from the partners of a European research project. Two evaluation sections can be distinguished: (a) based on descriptive criteria; (b) based on checklists.

3. Results and Discussion

3.1. Evaluation Based on Descriptive Criteria

Table 1 shows the criteria and sub-criteria based on which the studied DS tools were descriptively evaluated.

Table 1. Decriptive evaluation criteria and their evaluation parameters.

Criterion	Sub-Criteria
Degree of accessibility	Availability. Registration required. Complexity in access.
User Friendliness	Level of expertise. Degree of information provision—website and user interface. Provision of manuals/guidance. Degree of simplicity. Presentation of results. Availability of results for downloading or saving. Error management. Design of user interface.
Stakeholders	Agriculture sub-sector represented. Target group. Stakeholders' involvement.
Methodology of sustainability	Level of sustainability assessment. Types of gas emissions (farm level). Estimation methodology. Decision support approach.
Modeling aspects	Software. Type of modeling. Modeling method transparency.

3.2. Checklists

3.2.1. Inputs of DS Tools

Table 2 presents the input categories and the types of inputs whose existence or non-existence was checked for the various DS tools studied.

Table 2. Input categories and types of inputs checked in the tools evaluated.

Input Categories	Types of Inputs
Soil-related	Soil type. Year of soil analysis. Soil organic matter content. Soil pH. Soil drainage. Soil component percentages (clay, sand, silt).
Crop-related	Crop type. Crop diversity. Crop rotation. Residue management. Use of fertilizers. Composition of fertilizers. Use of pesticides. Cutting frequency. Irrigation type. Irrigation frequency.
Climate-related	Country of tool's validity. Agro-ecological zone. Climate type.
Livestock-related	Livestock species. Livestock breed. Livestock Age. Stage in livestock development.
Manure management-related	On-farm manure management. Manure field application.
Livestock feed management-related	Livestock ration. Cost of feed.

3.2.2. Outputs of DS Tools

The categories of outputs that were checked in the DS tools evaluated were the following: (a) Environmental Impact Category Indicators (EICIs); (b) Emission per source; (c) CO_2 (emission to air); (d) CH_4 (emission to air); (e) N_2O (emission to air); (f) Total GHG emissions (in CO_2 eq); (g) NH_3 (emission to air); and (h) Feed consulting.

3.3. DS Tools' Evaluation

A short description of the DS tools in the context of the evaluation criteria (Section 3.1) and the inputs and outputs (Section 3.2) is given in Table 3.

The use of scores for sustainability indicators is the major difference in the results presentation between the emission calculators and the all-pillar DS tools. Dairy and beef cattle production seems to be the livestock sub-sector that is most represented in the DS tools examined. Nevertheless, in the majority of these DS tools, stakeholders are not involved in their development. Scenario analysis, contribution analysis and progress monitoring seem to be the decision support approaches that are used by the majority of the DS tools examined. With respect to the provided outputs, a minority of emission calculators further provide livestock feed consultation as a type of output. Furthermore, the evolution to consulting decision support would be innovative and of importance for the wider use of such tools [5].

Table 3. Evaluation of the DS tools examined.

a/a	DS Tool	Evaluation
1	Cool Farm Tool v2.0	Online. Quantitative modeling approach. Includes the majority of inputs. Various Livestock systems. GHG emissions and farm costs. It does not provide NH_3 emissions and consulting.
2	FarmAC	Emission calculator. Quantitative modeling approach. Focus on cattle GHG emissions. Majority of soil inputs not included. Provides NH_3 and herd energy requirements estimations.
3	Overseer	Country-specific license purchased online tool. Quantitative modeling approach. Includes almost all inputs. Provides feed consulting and management functions, N-balance and GHG emissions.
4, 5	Carbon Navigator—Beef and Dairy	Developed for the Irish beef and dairy production systems. Quantitative modeling approach. Focus on beef and Dairy GHG emissions. It includes economic analysis.
6	KSNL	A questionnaire-form online multi-pillar tool made for German agricultural production systems. Semi-quantitative approach. Provides a multi pillar sustainability assessment with various multi pillar indicators.
7	SMART	A sustainability assessment tool based on SAFA indicators. Semi-quantitative approach. It is not freely accessible. Provides a sustainability assessment with various multi pillar indicator.
8	SAFA	A free educational, sustainability assessment tool (FAO). Semi-Quantitative approach. Three indicators for GHG emissions
9	RISE 3.0	A free informative multi-pillar sustainability assessment tool which estimates GHG and NH_3 emissions. Both online and offline functionality. Semi-quantitative modeling approach.
10	BEK	MS Excel spreadsheet tool. For German agricultural production systems. Semi-quantitative modeling approach. Provides a template for GHG emissions' calculations for various processes.
11	AgBalance®	An LCA-based tool. Quantitative modeling approach. Contribution analysis. Refers to crop production processes (no livestock-related inputs). Provides GHG and NH_3 emissions' estimation.
12	DLG	A sustainability assessment tool developed for German agricultural production systems. Semi-quantitative modeling approach. Includes the GHG emissions in the sustainability assessment.
13	HOLOS	A tool for Canadian livestock systems. Quantitative modeling approach. Does not include many of the soil-related inputs. Provides GHG and NH_3 emissions' estimates and a feed estimation report.
14	EX-ACT (version 8.0)	A freely accessible MS Excel spreadsheet tool (FAO). Quantitative modeling approach. Does not include the majority of soil related inputs and the majority of livestock inputs. Estimates GHG emissions.
15	GLEAM 2.0 (GLEAM-I):	A freely accessible MS Excel spreadsheet tool (FAO). LCA-based. Quantitative modeling approach. Provides GHG estimates for various livestock systems based on three input categories herd, feed and manure.

4. Conclusions

A modern GHG-based DSS for livestock systems would need to include clearly defined system boundaries and recently published emission estimation algorithms (e.g., the 2019 refinement of the IPCC 2006 Guidelines and Tier 2 approaches). It would need to consider GHG and ammonia emissions from all sources at the farm level (including feed crop production in case this in under the control of the livestock farmer) as well as soil carbon sequestration, by respecting the N and C cycles. Inputs from all the categories described for the emission calculator tools would be required in this respect. It would finally need to: (a) have an online user interface; (b) be easily accessible; (c) target inexperienced users and provide detailed guidelines regarding its use (but also be transparent with respect to the methodology followed); (d) provide easily comprehensible errors and easy

handling of them; (e) involve stakeholders' opinions before its release; and (f) have multi-national validity.

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