Is Agriculture receiving sufficient attention from the Software community to support its Environmental management tool requirements?

In recent years there has been a fair amount of software tool development supporting a business' environmental management system (EMS). A good summary on the most recent ones available has been published during 2011 in different issues of the Environmentalist [12,14]. It includes a plethora of tools that provide different levels of functionality, ranging from basic data management through macros embedded in an MS Excel environment (Cool farm from Unilever [4]); to a fully blown EMS software enabling an organisation to record/reduce and manage its basic resources; i.e. energy, waste, water and CO_2 with the aim of minimising its environmental impact (Hara [8]).
The following aims to demonstrate the type of challenges the software community still needs to solve, in order to satisfy the requirements of the environment sector. Given the broadness of issues that must be addressed, the discussion centres on software tools to manage greenhouse gas emissions (GHG) at farm level in the agricultural sector. It is a particularly interesting application area because Agriculture is the only economic sector, which has natural means to control its emissions by capturing/sequestering Carbon through an intelligent land management strategy. Additionally, little attention has been granted to this very important sector of the economy, judging by the type of tools currently available [8].
The emission of GHG constitutes a complex environmental impact, poorly managed by most economic sectors, if it is managed at all, as demonstrated by the results published in the IEMA report [6] in the second half of 2010. In addition to the absence of appropriate governmental regulations, the main reason referred to by the majority of the people involved in the IEMA study, for the appalling state of affairs, is associated to:

other competing priorities in the organisation that were business critical or legally required.

For Agriculture, the following attempts to demonstrate that a third barrier is associated to the absence of adequate tool support for GHG management, and the lack of uniformity that exists across those that are currently available. This is done by assessing the most popular ones accessible to the farming community, and concludes that the current state of the art on the functionality they provide has to affect the community's interest in taking up this particular type of activity.
Although tools for environmental management, in particular the calculation of GHG emissions, are not normally advertised as targeting a specific business sector, it is worth noting that Agriculture has a greater need for tools designed to satisfy its special requirements as it is important to record factors not relevant to the other economic sectors. Its capacity for exploiting the natural Carbon sequestering potential at its disposal, in addition to its being an important contributor to GHG other than carbon dioxide (CO_2), such as methane (CH_4) and nitrous oxide (N_2O), are probably the most striking differences that set it apart from the other sectors. After listing the factors deemed appropriate to assess tools for GHG estimation in the Agriculture sector, the results of an assessment carried out on the ones currently advertised for the UK on the Business Link website [1] are briefly outlined.

Evaluation criteria, factors used to assess the main Carbon calculators available to the Farming sector

In addition to being advertised in the Business Link website [1], the tools discussed are all registered at (http://www.environmenttools.co.uk/), the Environment Tools Directory referred to in [12, 14]. The additional ones associated to the Agriculture sector that appear in the directory provide features to estimate the emissions in other business sectors, and incorporate

functionality that is more applicable to them, therefore they are more generic and probably not so useful to the Farming community. For this reason, the final list of tools included in this assessment is the following one:

- Carbon Accounting for Land Managers (CALM): a web-based business activity-based calculator that shows the balance between annual emissions of the key GHGs and carbon sequestration associated with the activities of land-based businesses [3].
- Cool Farm Tool, [4] a Carbon calculator, developed by the University of Aberdeen in partnership with global businesses, and being trialled by PepsiCo on various partner farms.
- CPLAN Carbon Footprint Calculator [5], a web-based carbon equivalent application developed by a team of farmers and research scientists in the UK and designed for agricultural enterprises. For this assessment only the free version of the calculator was used.

In the context of GHG estimation, any tool claiming to provide this functionality should comply with the IPCC Guidelines for National Greenhouse Gas Inventories [7] as all countries have signed up to it as a first step to achieve the consistency that will enable each one to compute and manage its emissions, and will also facilitate their collaboration in reducing them. The guidelines include a specific volume for agriculture and land use, both aspects critical to the success of any farming activity, and demonstrating the importance of managing GHG emissions through a tool specifically tailored to meet the needs of this sector, as the estimation framework for any of the other sectors is covered in the three additional volumes that make up the guidelines.

	Criteria	CALM	Cool Farm	CPLAN
1	Execution Platform	Web based	Microsoft Excel	Web based
2	Scope (boundaries)	Geographical boundary of the Farm	Geographical boundary of the Farm	Geographical boundary of the Farm
3	Tier	1,2	1,2	1,2
4	Accuracy	No information given	No information given	provide the upper and lower bound of the estimated values
5	Scenario analysis	Tool can be used for what-if analysis with additional work from the part of the user	Tool can be used for what-if analysis with additional work on the side of the user	Tool can be used for what-if analysis with additional work on the side of the user
6	Usability	Simple although navigating through the different web-pages takes getting used to	Navigating through the Excel worksheets is not the simplest user interface, but it is manageable for any experienced user with MS tools	A simple web interface but it takes time to operate because no data or results are automatically stored as the information is fed to the tool
7	Output generation	Apart from the final tonnes of CO2e GHG emitted, a standard report is generated. It includes a generic list of suggestions for reducing emissions not tailored to the specific needs of the user	Only calculates the emissions. Does not provide guidelines on ways to reduce them	Only calculates the emissions. Does not generate guidelines on ways these may be reduced
8	Handling complexity	Not relevant to this operational context as the tools are tailored to one user, i.e. farm owner and/or manager in all cases		
9	Analytical power	Not possible to assess	Nothing more complicated than what can be achieved using an Excel sheet	Not possible to assess
10	Auditability	If the scenarios/results generated with the tool are properly managed, created, labelled and stored by the user, it should be possible to perform a reasonable audit	As auditable as any data generated/stored in an MS Office tool can be	The purpose of the tool is to generate estimates but not to manage stored data. It is up to the user to deploy additional mechanisms to allow auditability
11	Improved transparency	As transparent as any web-based application can be	It is completely transparent as it is possible to follow the thread of calculations; the user manual also includes list of references describing the sources for the tables included in the tool	As transparent as any web-based application can be

	Criteria	CALM	Cool Farm	CPLAN
12	Cutting costs	This particular criteria cannot be properly assessed while the Government is still undecided on how to handle the move to a Zero Carbon economy		
13	Engagement and workflow	Not relevant to this operational context as the tools are tailored to one user, i.e. farm owner and/or manager in all cases. If the users are part of a larger enterprise, implementing the links to the rest of the change of production requires additional work not covered in the current versions of any of the tools evaluated		

Table 1 Carbon calculators for the Farming sector, evaluation criteria and results

The set of criteria used to compare the benefits, or otherwise, derived from using each of the tools under evaluation is listed in the second column of Table 1. Criteria 1-6 were specified on the basis of the experience gained through the study and use of this type of tool, and correspond to a set of generic attributes usually used to assess the convenience of investing in a software tool. Criteria 7-13 are aligned with the factors listed in [12], which are driving different businesses to invest on software tools to manage the various aspects associated to an EMS.

The results of the evaluation are listed in columns 3-5 of Table 1. They confirm that all the tools satisfy to some degree each of the evaluation criteria under consideration. Each tool complies with the expected usability, although the web-based applications provide easier access as they are free web-based tools, present a standard web-based user interface, and are therefore immediately available to anybody who has Internet access. All of them generate estimates for Scope 1, direct emissions, with the exception being the emissions resulting from the Energy consumed, which unless it is produced on the farm, it is coming from an energy supplier and is therefore an indirect emission [15]. In all cases, the calculations carried out to estimate the GHG emissions use a combination of Tier 1 and Tier 2 methods depending on the level of detail of the input data, and the accuracy of the emission factors available to the tools. In this evaluation, all the factors assessed were considered to be equally important, but this can well vary from one user to another depending on the priorities they may have when using the tool.

Results of the case studies

The final part of the evaluation consisted in running each of the tools with a set of scenarios representing "typical" farms operating in the UK. They were put together using averages calculated from the farm data available at the DEFRA website [7]. All the GHG estimates generated where compared against the results recorded on the National Atmospheric Emissions Inventory (NAEI), the UK's official record of GHG estimates computed for each of the country's economic sectors, and which constitutes the benchmark most often quoted by the Government, other official bodies and research centres when discussing environmental matters. The results of the study are presented in Table 2 and were produced performing a two-sample T-test analysis that compared the NAEI estimates mean against the mean of the estimates computed by each of the tools. The test was performed once for each tool, and the relevant results in each case are listed in one of the rows in the Table.

Test name	Sample name	N	Mean	StDev	SE Mean	Test outcome
Two-sample T-Test for NAEI vs C-PLAN Difference = mu(NAEI) - mu(C-PLAN)	NAEI	4	5980	3959	1979	Estimate for difference: 2239 90% CI for difference: (-3395, 7872)) T-Value = 0.80 P-Value = 0.460 DF = 5
	C-PLAN	4	3741	3949	1974	
Two-sample T-Test for NAEI vs CALM Difference = mu(NAEI) - mu(CALM)	NAEI	4	5980	3959	1979	Estimate for difference: 5040 90% CI for difference: (356, 9724) T-Value = 2.53 P-Value = 0.085 DF = 3
	CALM	4	940	417	209	
Two-sample T-Test for NAEI vs Cool farm Difference = mu(NAEI) - mu(Cool farm)	NAEI	4	5980	3959	1979	Estimate for difference: 5153 90% CI for difference: (465, 9841) T-Value = 2.59 P-Value = 0.081 DF = 3
	Cool farm	4	827	449	225	

Table 2 results Two-sample T-Test, 90% CI for difference = 0 (vs not =)

The main conclusion that can be drawn is that there is no consensus in the manner in which the GHG estimates are currently generated by the various tools available to the public. In the case of CALM, and Cool farm, there is sufficient evidence to reject the test's null hypothesis (H_0), i.e. that the sample means are equal. In the case of C-PLAN, it is not possible to reach any conclusion regarding H_0 because the acceptable confidence level (0.1) is smaller than the p-value that was computed. Even though all the tools are based in the IPCC GHG calculation methodology [11], the uncertainty in the emission factors used in the computations, together with the absence of evidence on matters such as the soil's capacity to sequester Carbon, make it extremely difficult to produce a consistent set of results which will convince users on their usefulness.

To finish on a more positive note, it is important to point out that the various bodies supporting the Agriculture sector in their efforts to operate in a more sustainable manner, such as, DEFRA, Natural England, the CLA, are all aware of the short-comings described and have recently launched a large project aimed at improving the current shortcomings in the estimation of GHG emissions for this particular sector [8]. This research is mainly centred on improving the uncertainty associated to the emission factors currently employed in the calculations. This effort could be greatly improved by providing software tools supporting the rigorous management of the inherent uncertainty associated to the area, as discussed in [1,12].

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