GHG assessment for agriculture and forestry sectors: review of landscape calculators

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ABSTRACT

In parallel to IPCC work, many GHG calculators have been developed to assess agriculture and forestry practices. All these tools provide results in tonne eqCO2/ha or eqCO2/product. A review has been carried out to highlight their methodological differences, propose a typology, and discuss mains issues when working at landscape scale. Calculators were tested and questionnaires sent to the tool developers. It appears that some tools are now available for "every situation, in each part of the world", although the most suitable tool is not always easy to identify. All tools are able to identify GHG "hotspots", with exception of land use changes and soil management that are often poorly accounted. Uncertainties remain very high, limiting possibilities for economic reward/taxes for carbon actions. At last, perimeter and methodological differences impede straight comparison between studies done by different tools, and restrain managers, policy makers and non-expert users to gain reference values.

Keywords: greenhouse gas emissions, tools, landscape assessment,

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1. Introduction

Climate change has probably been the most studied impact category amongst LCA. It is also the criterion that is most likely to be adopted on short term for food labelling and implementation of green taxes. As international negotiations and state regulations on climate change goes on, policy makers and project managers are demanding for tools to move towards green economy. Land based activities, mainly agriculture and forestry, can be both sources and sinks of greenhouse gases (GHG). In most countries, they represent significant share of total GHG emissions, around 30% at global level. In parallel to IPCC work and progress on methodological issues, many GHG calculators have been developed recently to assess agriculture and forestry practices. The aim of this review is to provide users with helpful information for choosing the most suitable tool for his need, and to highlight major methodological differences between the tools. This review is complementary to other comparative studies of GHG tools for agriculture (C-AGG, 2010; Driver et al., 2010; Denef et al., 2012; Milne et al., 2012) with either a different focus (e.g. small holders) or sticking to individual tool descriptions.

2. Methods

This study focuses on calculators with a territorial/landscape approach. Generally landscape scale starts above farm scale, and implies multiple stakeholders. However, if specific landscape tools are not available, territories can always be described as a large regional/national farm. Therefore this study also includes tools working at farm scale.

A large range of calculators has been identified through internet research and cross referencing. From this extended list, only multi-activity assessment tools were selected (i.e. including at least both crop and livestock production), corresponding to 18 tools. Product specific tools, such as bioenergy tools were not included. Only tools in French, English and Spanish have been included. These farm/landscape tools have been tested and compared on several criteria regarding practical and methodological aspects. Based on this work, a pre-filled questionnaire has been sent to each tool developer for completing and validating the analysis. The analysis has been done based on the experience of GHG assessment by EX-ACT team, specialised on developing countries project assessment and ADEME team, with deep knowledge of French territorial GHG assessment.

3. Results

GHG calculation can be implemented for different reasons, depending on stakeholders and local context. For GHG landscape assessment, specific tools designed for landscape approaches should be used (Table 1). However, if these tools are not available for the study area, farm tools can be used, simulating a "regional/national" farm. This attempt to classify each tool is not strict and some tools can correspond to several categories.

- Raising awareness: set of tools usually for farmers and farming consultants. The aim is to inform them about climate change issue and the role of agriculture. The tool must be very simple (no training required); user friendly and identify hotspots. Usually there are free online tools. Tools follow typical Tiers 1 approach and have a large uncertainty. Most of them exclude soil carbon and land use change (LUC).
- Reporting: These tools are based on a landscape or farm approach, and must be able to take into account the diversity of management practices in each area. They are using Tiers 1 or Tiers 2 approach. The aim is to analyse specifically the current situation, to make comparisons between countries or farms based on a common basis and elaborate adapted policy in the future.
  - Landscape tools: Assessment of GHG emissions demanded by official institutes. Tools must avoid double counting and correspond to official standards. They have large uncertainty on results due to uncertainty on both activity data and emission factors. These tools have to use average data, they can be quite time consuming, especially for data collection.
  - Farm tools: For farmers, knowing in detail the current situation is a first step to implement reduction strategy, even if these tools are not really built to assess changes.
- Project evaluation
  Tools for project evaluation compare a baseline to a "with project" situation. They can be split in between two sub categories, depending if they are carbon market oriented
  - Focus on carbon crediting schemes: Mostly in countries where agriculture is subjected to carbon credits.
  - Not focus on carbon crediting schemes: usually account for all possible mitigation options, and especially carbon storage. However the tools must be cost efficient and user friendly. They aim at providing information for project managers, stakeholders and donors.
- Market and product oriented tools. These tools provide GHG results per product. The aim is to compare different product rather than assessing a territory. This avoids omissions of GHG emissions during leakage and indirect LUC. Usually these tools will include process and transport.

Table 3 Tool typology based on final aim

Objective of the user		Tools and geographic zone of application
Raising awareness		Carbon Calculator for New Zealand Agriculture and Horticulture (NZ), Cplan v0 (UK); Farming Enterprise GHG Calculator(AUS); US cropland GHG calculator (USA).
Reporting	Landscape tools	ALU (World); Climagri (FR), FullCam* (AUS)
	Farm tools	Diaterre(FR); CALM (UK); CFF Carbon Calculator (UK); IFSC (USA)
Project evaluation	Focus on ECTS schemes	Farmgas (AUS), Carbon Farming tool (NZ); Forest tools: TARAM (world), CO2 fix (world)
	Not focus on ECTS schemes:	EX-ACT (World);US AID FCC (Developing countries), CBP (World), Holos(CAN), CAR livestock tools(USA)
Market and product oriented tools		Cool farm tool (World); Diaterre (FR), LCA tools and associated database (SimaPro, ecoinvent, LCA food etc: data mainly for developed countries.)

AUS: Australia; CAN: Canada; FR: France, NZ: New Zealand; UK: United Kingdom; USA: United States of America;
FullCam: tool used by Australia for its national accounting. Only evaluate carbon and N_2O fluxes, not CH_4. High accuracy level obtained coupling extensive dataset and bio-physical process models.

Based on this classification, user can follow the following process to identify the most suitable tool for its use. An important point when choosing a tool is to select one including all major sources in the study area. For more details on the perimeter please refer to the full report (Colomb et al., 2012)

Choosing one carbon tool: a 4-step process

1.Define your aim for doing carbon evaluation and identify appropriate set of tools
2.Define geographical area and select the tool(s) that is/are available for this context
3.Check that the perimeter (forest, soil, LUC etc.) of your chosen tool is adapted to your aim, if the local tool is not adapted, you will have to choose more global tools.

4.Check your time and skill availability

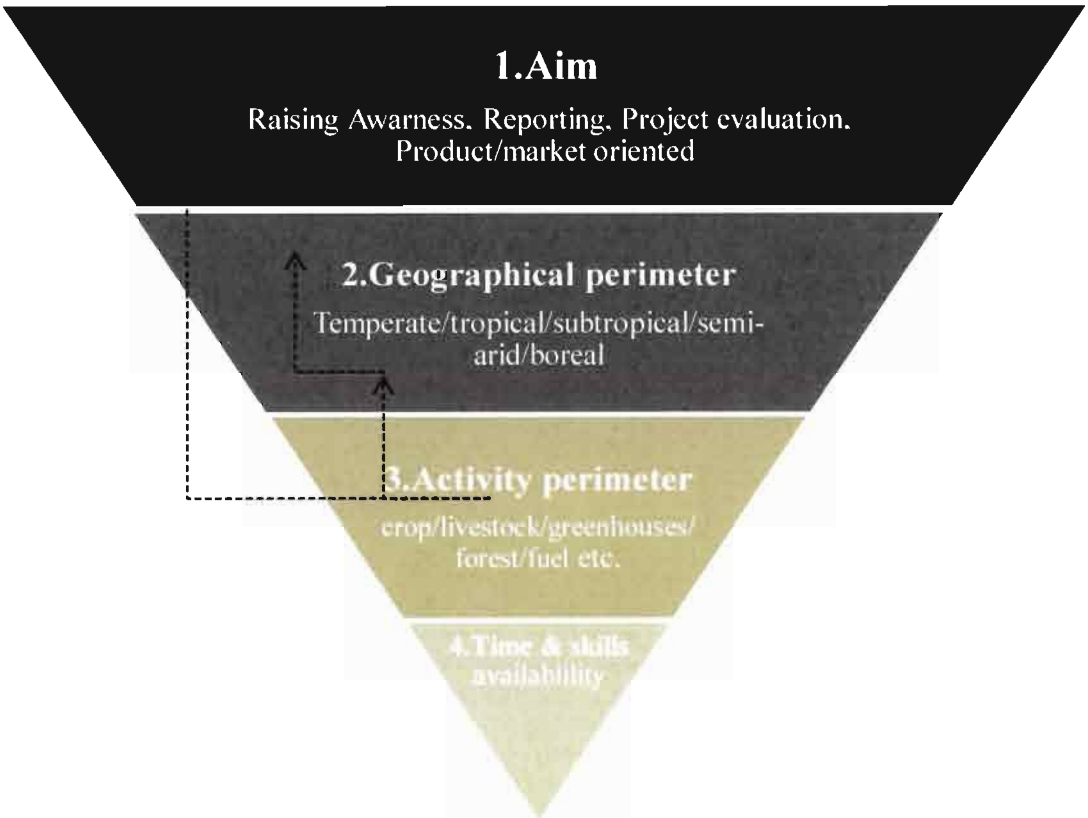

Figure 1. Tool selection process

4. Discussion

Environmental assessment at landscape scale implies several challenges (UNEP, 2012). Up scaling implies a change in data availability. At plot scale and farm scale, technical data are easily available and can be provided directly by farmers. At regional scale, data inventory often needs to be obtained from statistical data base or expert knowledge, increasing uncertainties. However uncertainty on activity data is not correlated in a linear way with scale. Indeed, it is easier to get reliable data for administrative regions such as state or counties, rather than for a watershed. Increasing scale can also reduce uncertainty with some local heterogeneity (ex: soil, management practices, micro-climate) getting balanced by working on medium rather than small scale (Post et al., 2001). In addition of these uncertainties on activity data, there are uncertainties due to year to year variability (climate and induced management practice variation) and uncertainty on emission factors themself. Only uncertainties for the emission factors are sometime mentioned by calculators.

A major challenge with landscape assessment is how to consider pedo-climatic and management heterogeneity. Indeed GHG emission and carbon stocking processes can be quite site specific, and depend strongly on mangement practices (ex: soil N_2O emissions). Moreover, good accounting of soil emission is crucial for agriculture calculators considering that N_2O account for 40% of agriculture emission on global scale, and soil carbon storage/destocking is the highest carbon sink potential, with the ability to store or release the equivalent of several years of global emissions (Baumert et al., 2005; Powlson et al., 2011). For soil related emissions, calculators either use biophysical models, such as the soil organic matter dynamic models Roth-C or Century (Cerri et al., 2004), or average emission factors provided by IPCC or national studies (IPCC 2006). The use of bio-physical models allows more accurate estimations than IPCC average factors (once the model has been properly calibrated). However, these models work at field scale and need to be linked with spatially explicit dataset ("soil maps") to work at landscape scale, these dataset not being available in most situations. In the future, proxy (NIRS) or remote sensing (satellites image analyses) technologies might enable for cheap direct measurement of the carbon stock changes or GHG emissions at large scale.

Accounting for time dynamic is also important, especially considering LUC and carbon storage. Project manager doing GHG assesment should keep in mind that landscape are under constant changes. Therefore more and more tools now suggest to evaluate a initial situation, a "business as usual" scenario and a "with project" scenario (Bernoux et al., 2010).

At landscape scale, management choices (changing, increasing or decreasing production) can induce changes on other territories (leakage), considering that food demand is not flexible. However, LUC depends not only on offer-demand balance, but also on many socio-economic parameters. Production increase can be obtained either by increase of yields (no LUC induced, but management changes induced) or by extension of cultivated land. On the ground, the drivers for LUC can be more land tenure issues, production capacities and state regulations rather than global or even local food demand. Therefore it is really difficult to establish clear consequential relationship between changes in one territory and changes in other ones. Such LUC, called indirect is calculated either by economical modelling or consequential assessment (hypothesis based on expert knowledge). Although it is clear that there are some interactions between distant territories, quantifications is really difficult and one major challenge for environmental assessment (Plevin et al., 2010; De Cara et al., 2012). So far only direct LUC is sometime accounted in the calculators.

One major point raised by this study is the lack of homogeneity concerning accounting perimeters. Indeed every GHG calculator account for different sources. Some include energy, some infrastructures and transport, some include emissions from N inputs by plant residues, some soil carbon dynamics etc. This impedes any direct comparison of results between studies done by different tools. For a better interpretation of results, users need to have references and standard in mind, seldom provided by user guides.

Results units are key criteria in the calculator structure, and strongly influence results interpretation. Results can be expressed in tonne equivalent CO_2 (Teq CO_2)/year, TeqCO_2/project (several years), TeqCO_2/year/ha, TeqCO_2/kg product. Results might also be expressed in net value (Emission – Storage); or provide both values. The most suitable unit depends on the aim of the project assessed, and the type of agriculture concerned. Indeed, industrial agriculture is clearly market oriented, has high productivity level and provides a considerable share of total food for humans. Its main challenge is to develop better efficiency and reduce the carbon footprint per kg of product, especially considering that GHG emissions are global, with no local threshold on toxicity or decontamination potential. Thus results should always be related somehow to productivity level, meaning eqCO_2/kg product, eqCO_2/kg Dry matter; eqCO_2/calorie; eqCO_2/proteins etc. Several tools are developing this approach: LCA tools; calculators with GES per kg of product, Climagri® with a "Territory Feeding potential indicator" etc. These methodologies require either allocation rules or very general productivity indicators (ex: dry matter, calories, proteins) for territories with more than one output (Schau and Fet, 2008; Cherubini et al., 2009). Not considering productivity levels in these cases induce a strong risk of leakage. On the opposite, in project oriented towards rural development, agriculture productivity is not an issue at global scale but rather a local socio-economical issue. The aim is to maximize population welfare and improve population life conditions. The eqCO_2/kg product is less suitable. Indicators should be more oriented towards socio-economy criteria, such as eqCO_2/\$; eqCO_2/job created; eqCO_2/HDI point (Human development index) etc... These indicators would be a good way to promote low carbon development path for "low income countries". No such approach has been identified so far. At the moment for small holders and developing countries, calculators are more oriented toward carbon credits and possibility to get monetary benefits from reduction emissions compare to baseline.

The link between GHG assessment and economic parameter is often poor in calculators, which restrain action plan feasibility evaluation. However there has been some attempt to use carbon tools with economic tools. For instance, EX-ACT has been used with Margin Abatement Cost Curves (MACC), providing information on the cost of carbon sequestration depending on chosen options. Such studies can show that which actions are profitable for the economy, which have a reasonable cost and which are unsuitable. It also enables cross-sectorial comparison for mitigation project. Such economic approaches indicate that carbon storage and reduction of deforestation are amongst the most efficient way to fight against climate change (Smith et al., 2008). Studies indicate the potential of GHG emission for different carbon prices, showing the possible effect of a carbon tax or carbon market (Smith et al., 2008).

At last, carbon calculators are environmental assessment tools focused only on one criterion. For the analyses and solution proposed, special care for trade off must be considered (C-AGG, 2010). Some solutions that reduce carbon footprint might worsen biodiversity (ex: large biofuel plantations), increase water consumption or induce health risk (ex: growth hormone). Developing sustainable agriculture and forestry activities implies management practices that improve overall environmental footprint of products. More global methods that can be combined with carbon accounting are currently developed, such as "landscape" LCA or impact assessment analyses.

5. Conclusion

After this large review of carbon calculators, it appears that all tested calculators are accounting for main GHG sources and emissions and should be able to identify hotspots (with special care for area subjected to LUC). However there is a lack of homogeneity in methodologies, therefore it is impossible to do straight comparisons between studies done using different tools. Indeed all calculators refer to IPCC but this does not ensure homogenous approach as IPCC provide a general framework including many methodologies with different levels of details. Comparative studies are sometime available and confirm the ability of tested tool to provide coherent order of magnitudes (FAO, 2010; Soil Association Producer Support, undated). While interpreting results, it is a necessity to check for the perimeter accounted and while comparing project keep in mind uncertainties.

Some tools are now available for most activities to be assessed in every part of the world. The accuracy level is still restricted but active research is on-going and most calculator developers are frequently updating their tools. The trend is for tools to enlarge their perimeters (including more management options, more land types) and their geographical suitability. Improving accuracy implies more detailed input data, and more time demanding studies. Thus a balance must be found between efficiency and accuracy. The recent proliferation of tools testifies of this research for appropriate balance. It is not expected that one tool becomes dominant as each tool is dedicated to different situation. However there is some "competition" between tools with similar aim and geographical coverage. It might bring some confusion for non-specialist and we hope that this study will bring some clarity.

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