18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

CEST 2023

Review and evaluation of the methods for building the Carbon Farming Calculation Tool

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Abstract: Agriculture accounts for around 30% of total GHG emissions worldwide. Carbon calculators are vital to accurately measure GHG emissions from farms and decrease their impact through carbon harvesting techniques. This paper aims to review various carbon calculator models and group them into typologies to provide helpful information on selecting the most appropriate calculator for different farming systems. Farm scale calculators enable farmers to monitor GHG emissions and reduce them by adopting sustainable agricultural practices. Landscape-scale calculators are useful in larger areas, with different land uses and agricultural practices. The AgRE Calc, Cool Farm Tool, and Solagro carbon calculators were the most adequate to estimate greenhouse gas emissions from agricultural activities. By comprehending GHG emissions in agriculture, accurately calculating them, and adopting sustainable practices, farmers can strive to achieve carbon neutrality by 2050.

Keywords: carbon harvesting, carbon neutrality, farm scale carbon calculator, sustainable agriculture

1. Introduction

Greenhouse gases (GHG) are essential for the existence of life, they are present in low concentrations in the atmosphere and are responsible for maintaining the global temperature between 16-18ºC. However, especially after the Industrial Revolution in the 19th century, the constant increase of GHG concentrations in the atmosphere contributed to raising the average temperature of the planet. Consequently, the climate is changing and directly influences agriculture due to the increase in the frequency of occurrence of extreme events such as intensive precipitation, floods, droughts, tornadoes, low and high temperatures, and changes in the hydrological cycle (IPCC, 2001).

Carbon farming and carbon forestry are land management concepts that gain worldwide importance to manage terrestrial carbon offering incentives to agriculture. In 2015, the Paris Agreement and in 2019 the European Green Deal emerged bringing a change of mindset with the goal to cut greenhouse gas emissions by at least 55% by 2030 and achieve climate neutrality by 2050 (Davide *et al.*, 2021). Considering total GHG emissions worldwide, agriculture, forestry, and other land use (AFOLU) represent about 30%, one of the main sources of GHG emissions (Colomb *et al.*, 2013).

There are several types of carbon calculators applied at different geographical areas, but none is capable of encompassing all the services produced by agriculture and forestry (e.g., food, goods, landscape value and revenue). Using this tool, it's possible to indicate the connection between GHG emissions and the productivity of the area, but one of the main difficulties is producing a realistic assessment of the various production systems since there are very high levels of uncertainty (Colomb *et al*., 2013).

The aim of this article was to review carbon calculator models suitable for agriculture in the Mediterranean region, group them into typologies, evaluate them and propose the most appropriate to estimate incentives for farming and change mindsets.

2. Methodology

Searches were carried out using a variety of electronic databases, including Google Scholar, Google, Science Direct, Scopus and the Search Library Discovery at the University of Algarve. The search used relevant or a combination of keywords such as "carbon harvesting", "carbon neutrality", "farm-scale carbon calculator", "landscape-scale carbon calculator" and "sustainable agriculture" The inclusion criteria for the literature review were: (1) English-language publications, (2) academic articles, books, reports, and policy documents and grey literature (3) publications focusing on carbon calculator models suitable for agriculture.

3. Carbon calculators

Measurement of GHG emissions in agriculture can be done directly in the soil-plant-animal components of a farm or unit of land, however, when it is necessary to perform the procedure in more than a few sites, it's impractical and expensive. That's why, there was a need to create indirect measurement methods to monitor emissions at different scales. The current approaches to tracking emissions tend to focus on individual gases and may not adequately consider system-level effects, leading to potential inaccuracies at smaller scales due to limited relevant data (Olander *et al.*, 2014). To address this issue, monitoring emissions at the landscape scale can help aggregate changes in emissions or removals across diverse land uses, enhancing flexibility in mitigation options. Similarly, monitoring emissions at the farm scale serves multiple objectives that reflect farmer's needs, making it a useful approach for emissions tracking. Agriculture carbon calculators can be grouped in farm scale, and landscape-scale. Both are important to understand the influence of carbon dynamics and they differ mainly in the spatial and temporal scope of their greenhouse gas (GHG) emissions calculations, which allows farmers to monitor their GHG emissions and adopt agricultural practices that reduce their emissions (Rosenstock *et al.*, 2013).

Carbon calculator at farm scale considers GHG emissions and removals from a single farm property (Figure 1). These tools are typically empirical and are useful for the possibility to account different sources of GHG in the farm, using non-specialist data. The use of these tools is across users from diverse backgrounds to provide enterprise-level carbon footprints and many of them are publicly available (Table 1). An example of calculating GHG emission in a farm scale analysis, it's at a coffee-dairy farm reviewed by Ortiz-Gonzalo *et al.* (2017).

Figure 1: A farm-scale orchard, at Alte, Portugal.

At the landscape-scale, the carbon calculator considers GHG emissions and removals across a larger area than a single farm, such as an agricultural landscape that includes multiple farm properties with different land uses and agricultural practices (Figure 2). The landscape-scale carbon calculator allows for the aggregation of changes in emissions or removals from different land uses and the adoption of management practices that may have positive impacts on GHG emissions (Rosenstock *et al.*, 2013).

Using landscape-scale analysis assists stakeholders in better understanding carbon dynamics within the landscape and that can encourage mitigation initiatives, which brings better potential for adoption when compared to individual farm strategies. Thereby, facilitates access to carbon markets, subsidies, and other incentives that can spread the costs. The main uncertainties are the result of activity data (inventory), yearly variability (due to climate and management practice variation) and emission factors. To have heterogeneity in landscape scale analyses, there's a need to have a balance between cost, scale, and accuracy, therefore ensuring a high level of accuracy for those activities with greatest impact on the result (Colomb *et al.*, 2012).

Figure 2: A Landscape-scale farm, Quinta do Freixo, at Loulé - Portugal.

There are several available carbon calculators used in landscape-scale analyses, to Colomb *et al.* (2013), some calculators perform better than others in certain areas, because they can focus on a particular region. Landscape calculators must consider the diversity of management practices in the study area (Table 2).

4. Suitable calculators for agriculture in Mediterranean region

Numerous calculators and tools have been developed to estimate agricultural emissions. The process of selecting a suitable calculator was divided into four steps that are based on the distinctive features of each calculator (Figure 3). First, the aim of the assessment was determined, and a set of calculators aligned with that goal was identified. Second, the geographical area being assessed was defined and one or more calculators that are available for that area were selected. Third, the scope of the calculator (e.g., forest, soil, LUC) was evaluated if it is appropriate for the intended purpose (in case there was no suitable calculator for the study sites and the required scope, a more general calculator that is less geographically restricted could be chosen). Finally, it was verified if the calculator is suitable for the available time and level of expertise.

Table 1: Farm scale calculators.

Calculator	Geographical area	Temperate crops	Tropical crops	Rice	Grassland	Agroforestry	Perennial (orchards, vineyards)	Horticultural/Greengouse	Forest
CALM	United Kingdom	x	no	no	x	no	x	no	x
CFF Carbon Calculator	United Kingdom	x	no	no	x	x	x	x	x
Diaterre	France	x	no	no	x	x	x	no	no
IFSC	USA	x	no	no	x	no	no	partially	no
Cool Farm tool	World	x	x	x	x	no	x	x	x
Farm Carbon Calculator	United Kingdom	x	x	no	x	x	x	x	x
Holos	Canada, Sweden	x	no	no	x	x	x	no	no
FarmGAS	Australia	x	no	no	x	x	x	partially	no
CPLANv2	United Kingdom	x	no	no	x	no	x	no	x

Table 2: Landscape-scale calculators.

Calculator	Geographical area	Temperate crops	Tropical crops	Rice cultivation	Grassland	Agroforestry	Perennial production (orchards, vineyards)	Horticultural/Greenhouse	Forest
ALU	USA	x	x	x	x	x	x	no	x
Climagri®	France	x	no	no	x	x	x	x	x
FullCam	Australia	x	x	no	x	no	no	no	x
CcaLC2	United Kingdom	x	x	x	no	no	x	partially	no
Impacct	Europe	x	x	no	x	no	x	x	no
EX-ACT	World	x	x	x	x	no	x	x	x
AFD calculator	Developing countries	x	x	no	x	no	no	no	no
Carbon benefit project CPB	Developing countries	x	x	x	x	x	x	no	x
AFOLU CC	World	no	no	x	no	x	no	no	x

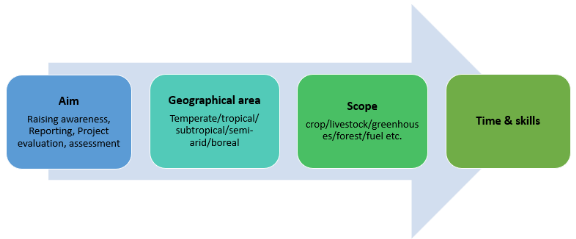

Figure 3: Process for selecting a GHG calculator (adapted from Colomb et al. 2013).

Based on the above process, three farm scale calculators were selected as the most suitable for Mediterranean region: AgRE Calc, Cool Farm Tool, and Solagro. Each tool's degree of comprehensiveness and usefulness depends on the specific production systems being evaluated. For instance, some tools may excel in measuring emissions from crop production or livestock systems, as well as managing carbon sequestration, more effectively than others (Leinonen *et al.*, 2019).

AgRECalc is a versatile tool that calculates emissions at different scales, including whole farm emissions, enterprises' emissions, and product-basis emissions. The tool requires several inputs, including land and crops, grass and forage (area, productivity, type, and quantity of fertilizer applied, type of manure applied), monthly livestock numbers (by type), weights (kg) of animals bought and sold, and fate (sold, dead), quantity and type of feeds bought (kg), quantity of hay (kg), and bedding (straw) used (kg), energy used (e.g. liters of petrol, diesel used, kW electricity used, renewable energy produced, water (liters) consumed, and waste (kg plastic) produced. The main outputs of the tool are emissions calculated for the whole farm, per enterprise, and per unit of saleable product (Yetisgin *et al.*, 2022).

The Cool Farm Tool (CFT) is a greenhouse gas (GHG) emissions quantification tool originally developed by researchers at the University of Aberdeen and Unilever. The CFT assesses GHG emissions and soil carbon sequestration changes resulting from management activities. It is designed for farmers, supply chain managers, and companies interested in quantifying their agricultural carbon footprint and identifying practical ways to reduce it. The CFT is recognized as the most appropriate carbon calculator for estimating GHG emissions from livestock on a farm scale (Sukhoveeva, 2020). Farmers prioritize cost, productivity, and soil health in their management decisions. The CFT can demonstrate how these decisions can sequester carbon or reduce GHG emissions, which are concerns for customers. It does include the ability to assess land-use changes to or from forestry as part of the agricultural system (Usaid, 2019).

The Solagro carbon calculator is designed for the Joint Research Center of the European Commission to assess the life cycle greenhouse gas (GHG) emissions from different farming systems across the European Union (Metayer & Haastrup, 2016). The assessments conducted with that carbon calculator are carried out at farm scale, on a reporting period of one year. Solagro carbon calculator employs a life cycle approach, considering all emissions upstream of the farm. Direct and indirect GHG emissions are considered, including emissions due to the processing and distribution of inputs at farm level. However, emissions out of the farm, such as distribution, storage by industries, transportation of farm products, and processing out of the farm, are not included in the assessment (Bochu *et al.*, 2013). Besides promoting an assessment of GHG emissions, it also offers 16 possible mitigation and sequestration actions, and for each established mitigation action, the carbon calculator evaluates the impact of a change in farming practices on the GHG profile.

5. Conclusion

Several methods were developed to quantify GHG emissions avoidance potential, to serve as key performance indicators for project monitoring and disbursements of grants, and to inform rural managers and policymakers. There is no one-size-fits-all solution when it comes to addressing greenhouse gas (GHG) emissions from agriculture and complying to the requirements for knowledge sharing purposes. However, the development and use of GHG calculators can play a critical role in reducing emissions and promoting low-carbon farming practices. To ensure the accuracy and consistency of GHG calculations, it is important to standardize the approach to tracking emissions across different tools and models. Therefore, the selection of a suitable calculator for the Mediterranean region should be made carefully, also considering the information provided in this article about AgRE Calc, Cool Farm Tool, and Solagro calculator. Accurate measurement of GHG emissions is crucial to ensuring fair treatment for farmers and cost-effective outcomes for society. Further development and improvement of GHG calculators and policy instruments are needed to address the challenge of GHG emissions from agriculture.

Acknowledgment

Work funded by Project "Carbon Farming Geolocation Support by Establishing a Spatial Soil Database Management System" - LIFE20 PRE/GR/018 LIFE GEOCARBON.

References

Ballard T., Ogle S., Smith J., Johnson K., and Williams S. (2019). Landscape-scale variation in greenhouse gas emissions from agriculture: A case study in the U.S. Southern Great Plains. *Journal of Environmental Management*, **240**, 10-20.

Bochu J.L., Metayer N., Bordet C., Gimaret M., Tuomisto H., Haastrup P. and Constantin A.L. (2013). Development of Carbon Calculator to promote low carbon farming practices. Methodological

guidelines (methods and formula), Deliverable to EC-JRC-IES by Solagro.

Colomb V., Bernoux M., Bockel L., Chotte J.L., Martin S., Martin-Phipps C. and Touchemoulin O. (2012). Review of GHG calculators in agriculture and forestry sectors. *A Guideline for Appropriate Choice and Use of Landscape Based*. Retrieved May 2, 2022, from http://www.fao.org/fileadmin/templates/ex_act/pdf/Review_existingGHGtool_FR.pdf

Colomb V., Touchemoulin O., Bockel L., Chotte J.L., Martin S., Tinlot M. and Bernoux M. (2013). Selection of appropriate calculators for landscape-scale greenhouse gas assessment for agriculture and forestry. *Environmental Research Letters*, **8**(1), 015029.

Cool Farm Alliance (2019). Cool Farm Tool. Retrieved on March 04, 2023, from https://coolfarmtool.org/.

Davide M. (2021). Technical Guidance Handbook - Setting up and implementing result-based carbon farming mechanisms in the EU, Ecologic Institute US. Germany.

European Commission (2023). European Green Deal. Retrieved on February 28, 2023, from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en.

Eurostat (2022). Greenhouse gas emissions from agriculture**.** Retrieved on February 28, 2023, from https://ec.europa.eu/eurostat/databrowser/view/tai08/default/table?lang=en.

Frutas Lurdes. A farm scale farm, Frutas Lurdes, at Silves – Portugal. Retrieved on March 13, 2023, from https://frutaslurdes.com/processo/campo/.

IPCC - Intergovernmental Panel on Climate Change. Climate change 2001: the scientific basis (2001). *United Kingdom: Cambridge University*, 881p.

Leinonen I., Eory V., MacLeod M., Sykes A.S., Glenk K. and Rees, R.M. (2019). Comparative analysis of farm-based carbon audits. *Scotland's Rural College, Kings Buildings, West Mains Road, Edinburgh.*

Metayer C. and Haastrup P. (2016). The Farm Tool Carbon Calculator. *Solagro*. European Commission, Joint Research Center, Institute for Environment and Sustainability.

Nayak A.K., Rahman M.M., Naidu R., Dhal B., Swain C.K., Nayak A.D. and Pathak H. (2019). Current and emerging methodologies for estimating carbon sequestration in agricultural soils: A review. *Science of the Total Environment*, **665**, 890-912.

Olander L.P., Wollenberg E., Tubiello F.N. and Herold M. (2014). Synthesis and Review: Advancing agricultural greenhouse gas quantification. *Environmental Research Letters*, ***9***(7), 075003.

Ortiz-Gonzalo D., Vaast P., Oelofse M., de Neergaard A., Albrecht A. and Rosenstock T.S. (2017). Farm scale greenhouse gas balances, hotspots and uncertainties in smallholder crop-livestock systems in Central Kenya. *Agriculture, Ecosystems & Environment*, **248**, 58-70.

Quinta do freixo. A Landscape-scale farm, Quinta do Freixo, at Loulé – Portugal. Retrieved on March 13, 2023, from https://www.saia.pt/.

Rosenstock T.S., Rufino M.C., Butterbach-Bahl K. and Wollenberg E. (2013). Toward a protocol for quantifying the greenhouse gas balance and identifying mitigation options in smallholder farming systems. *Environmental Research Letters*, **8**(2), 021003.

Sukhoveeva O.E. (2020). Carbon calculators as a tool for assessing greenhouse gas emissions from livestock. *Doklady Earth Sciences*, **497**, 266-271.

Sykes A.J., Topp C.F., Wilson R.M., Reid G. and Rees, R.M. (2017). A comparison of farm-level greenhouse gas calculators in their application on beef production systems. *Journal of Cleaner Production*, **164**, 398-409.

Sruc 2020. New soil sequestration module to reduce carbon footprint. Retrieved February 27, 2023, from https://www.sruc.ac.uk/all-news/new-soil-sequestration-module-to-reduce-car.

Tuomisto H.L., De Camillis C., Leip A., Nisini L., Pelletier N. and Haastrup P. (2015). Development and testing of a European Union-wide farm-level carbon calculator. *Integrated environmental assessment and management*, **11**(3), 404-416.