Climate-Smart Specialty Crop Calculator Methods Overview

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Funded by the Walmart Foundation

Introduction

The Climate Smart Specialty Crop Calculator was developed to support specialty crop growers participating in programs or supply chain initiatives incentivizing soil GHG emissions reporting. The analysis and tool development was a joint effort of the Stewardship Index for Specialty Crops (SISC) and Colorado State University (CSU) and was funded by the Walmart Foundation. The analysis and tool is similar to COMET-Planner (www.comet-planner.com), however it focuses on specialty crops only, is crop specific, and uses a reporting format more conducive to engaging supply chain initiatives. This first version of the tool is for California only and includes the most common specialty crops in California for which sufficient data was available for DayCent model parameterization (see the Modeling section for more details). The analysis and tool were restricted to California, as there is very limited data on specialty crop management for other regions in the U.S. To expand the coverage of the tool, additional data would need to be gathered through surveys and state-level cost and return studies. Further, each crop modeled in DayCent must be parameterized and tested using field measurements, which is time consuming and often limited by adequate field measurements. This analysis and tool only estimates GHG emissions from soils, including soil organic carbon (SOC) and soil nitrous oxide (N2O), and does not include other emissions sources, such as emissions from field operations, embodied emissions in fertilizers, transportation, processing, etc. However, this dataset has been incorporated in the SISC Stewardship Calculator, which also includes energy use and other stewardship metrics.

Management Practices

Management scenarios and practices were determined from interviews and surveys with California commodity crop grower groups and the University of California-Davis Cost and Return Studies (https://coststudies.ucdavis.edu/). The interviews/surveys helped the SISC/CSU teams determine the typical conventional management, as well as the most likely climate-smart practices to be adopted on farms. Management details, such as planting/harvest dates, fertilizer rates, tillage, etc, were determined from both the interviews/surveys and the Cost and Return Studies. Baseline/current and future scenarios for modeling allow for practice changes in tillage, compost application, cover cropping and fertilizer reductions. We created a full factorial of baseline/current (2015-2024) and future (2025-2034) practice changes, with the exception that a climate-smart practice in current use could not be reverted in the future. For example, if cover crops were planted in the current scenario, they could not be removed in the future. In total, 267 unique scenarios were modeled per crop.

Modeling

The quantification approach for SOC and N_2O emissions for this tool was a sample-based, meta-modeling analysis using the DayCent® model, a process-based ecosystem model. Prior modeling of specialty crops using the DayCent model were conducted using an earlier version of the model (circa 2016-17), and therefore specialty crops needed to be re-parameterized to the current version of the model. The initial list of specialty crops to be modeled included: almonds, avocados, broccoli/cauliflower, carrots, cherries, citrus, grapes, lettuces, olives, peaches, pistachios, strawberries, and tomatoes. A literature review was conducted to identify field experiments in specialty crop systems that measured yield, woody biomass (if orchard/vineyard crop) and soil GHGs. The team could not find sufficient field experiment data for carrots and strawberries, so those crops are not included at this time. Crops were then tested, parameterized, and validated in the DayCent model. Further details on model parameterization of specialty crops will be published in Hong et al. (2024).

Following model parameterization, we conducted statewide modeling for each crop for the regions it has been grown. We determined those areas using the Statewide Crop Mapping dataset (CADWR 2020), which identifies individual fields and crops grown in fields. A random sample of 500 points was generated for each crop, across the fields identified for that crop. One of the goals of the project was to present emissions per unit yield, or a greenhouse gas intensity (GHGI). Therefore, we simulated continuously grown monocultures in annual crops, despite many of these crops being grown in rotation with other crops. Allocating emissions from soils among multiple crop types grown in sequence is difficult given legacy effects of prior crop management in the rotation. Soil characteristics were determined for each sample point from SSURGO (USDA-NRCS 2022) and daily weather data was extracted from the PRISM Climate Data (PRISM Climate Group 2020). The management scenarios described in the previous section were applied for each point/crop. A schematic of the modeling process is provided in Figure 1.

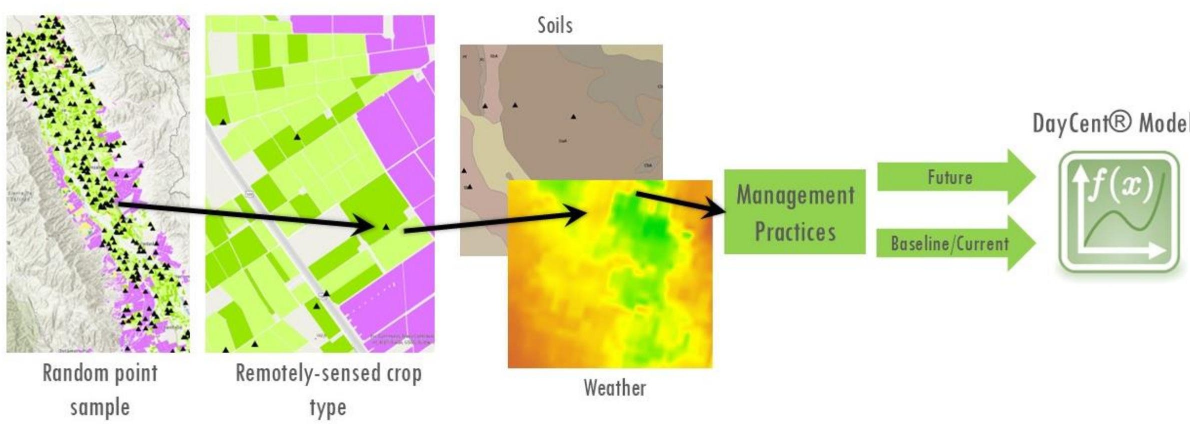

Figure 1. Process flow of the modeling analysis to evaluate soil GHG emissions from specialty crops.

The point-level DayCent SOC and N_2O estimates were aggregated to the county-rectified Major Land Resource Areas (MLRA) scale (Figure 2). MLRAs are geographic regions defined by the USDA-NRCS and represent regions of similar biophysical characteristics and agricultural systems, and generally contain multiple counties. The resulting estimates represent a regional average impact of management practices by crop over 10 years. Emissions were converted to CO_2 equivalents, using the Global Warming Potential values provided by USDA Methods for Entity-Scale Inventory (Table 1) (Hansen et al. 2024).

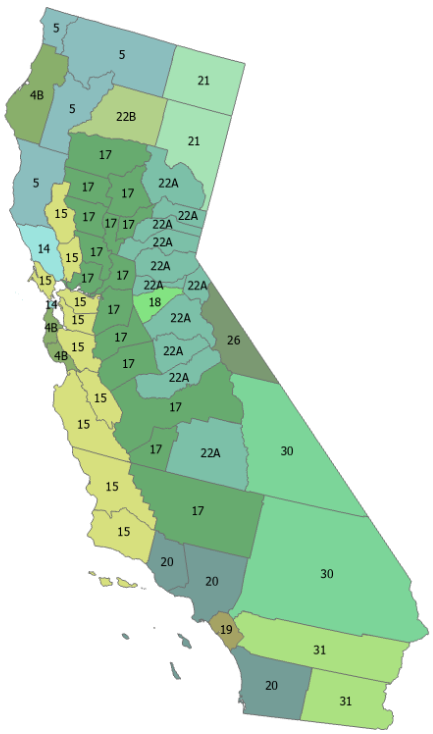

Figure 2. California counties classified into USDA-NRCS MLRAs and labeled with MLRA symbols.

Table 1. Global warming potential (GWP) values used in this analysis. Table adapted from Hansen et al. (2024).

GHG	Chemical Formula	Lifetime (Years)	GWP
Carbon dioxide	CO_2	Variable	1
Nitrous oxide	N_2O	121	265

Greenhouse Gas Intensity Calculations

Within the tool, default county average yield values are provided to the users to calculate soil GHG emissions per unit yield. The default yield values were derived from the USDA National Agricultural Statistics Survey (NASS) and represent a county-level average over 2018-2022 (USDA-NASS 2018-2022). Within the tool, users may also replace the default value with their own yield estimate.

Greenhouse Gas Intensity (yield-scaled emissions) (unitless) = Soil Emissions (Mg CO_2 eq/acre/yr) / Total Annual Yield (Mg/acre/yr)

*Total Annual Yield (Mg/acre/yr) = Average NASS yield (tons/acre) (or user entered yield) * Harvests per year * 0.91 (Mg/ton)*

[Megagrams (Mg) = 1 metric ton]

References

CADWR. 2020. Statewide Crop Mapping, California Department of Water Resources. Downloaded at: https://data.ca.gov/dataset/statewide-crop-mapping

Hanson, W.L., C. Itle, K. Edquist (eds). 2024. Quantifying greenhouse gas fluxes in agriculture and forestry: Methods for entity-scale inventory. Technical Bulletin Number 1939, 2nd edition. Washington, DC: U.S. Department of Agriculture, Office of the Chief Economist.

Hong, M., Zhang, Y., Li, L., and Paustian, K. (2024). Enhancing Simulations of Biomass and Nitrous Oxide Emissions in Vineyard, Orchard, and Vegetable Cropping Systems. (In review).

PRISM Climate Group. 2020. PRISM Gridded Climate Data. Oregon State University, https://prism.oregonstate.edu

USDA-NASS. 2018-2022. Crop Reports compiled by the California County Agricultural Commissioners. California Field Office, National Agricultural Statistics Service, U.S. Dept. of Agriculture. Accessed at: https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/index.php

USDA-NRCS. 2020. Soil Survey Geographic (SSURGO) Database. Natural Resources Conservation Service, U.S. Dept. of Agriculture.