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Analyzing Organic Crop Rotations Using the COMET Farm Soil Carbon Model

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Calculating Soil Carbon Emissions

Although initially not emphasized or sometimes even addressed in most early agricultural LCAs, changes to soil carbon due to agriculture are now understood to be an important long-term carbon emissions sink/source. IPCC Tier 1 and Tier 2 methods are known to be inaccurate due to the worldwide and regional variation in climate and crop management. In the US, Several soil models have been developed to examine emissions from common conventional crops like corn and soybeans.

Assessing soil carbon emissions in organic systems is often more difficult due to the complexity of organic rotations, which are often for longer periods and use unique cover/forage crops combinations compared with conventional cropping rotations.

As part of a research project analyzing the life cycle impacts of organic rye as a swine feed ingredient, we considered which soil carbon model could meet our need to evaluate organic crop systems that include winter rye. The criteria included the required soil science knowledge for understanding the model and its inputs/outputs, the amount of soil, climate, and crop data that the user would need to correctly source and enter, and whether the model was widely accepted by the scientific and LCA communities.

After considering these criteria, we chose to work with the COMET model Developed by Colorado State University and the USDA (CSU 2024). The COMET model has the ability to examine soil carbon flux of many different crops, rotations, and management practices. It is web-based, with a background database of weather, soils, and cropping information covering much of the US. As its background calculation engine, it uses the well-established Daycent soil carbon model (Del Grosso et al. 2006). A study by Ball et al. (2023) suggests that the model's results are similar to other models.

Before using COMET for our organic swine-rye analysis, we were interested in examining how functional it would be for our organic crop rotations. We were also interested in examining how some of the common model limitation could be minimized or overcome.

Choosing a Soil Carbon Model for LCA

Our criteria for selecting a soil carbon model
- Understandable to non-soil scientists
- Limited need for detailed soil & climate data
- Defensible method for soil carbon change accounting

Organic Cropping System Complexity

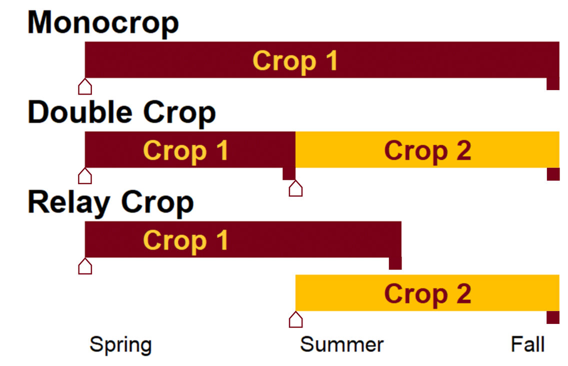


Figure 1- Planting (⌂) and harvest (■) timing of monocrops, double crops, and relay crops. These are all systems of growing crops that maintain cover on organic fields

<u>Issue: Inability to model relay crops</u>
There is insufficient background research data to allow the underlying COMET model to examine relay cropping

<u>Solution: Model crops as double crops</u>
Relay crops can be modeled as double crops without tillage in-between.

Organic Crop Rotation Length

Multiple Model Runs with the same crop Rotation

Run Number	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	GHG Results
1	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F	Crop A	Crop B	Crop C	Crop D	3.4
2	Crop F	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F	Crop A	Crop B	Crop C	2.9
3	Crop E	Crop F	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F	Crop A	Crop B	3.3
4	Crop D	Crop E	Crop F	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F	Crop A	3.8
5	Crop C	Crop D	Crop E	Crop F	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F	2.6
6	Crop B	Crop C	Crop D	Crop E	Crop F	Crop A	Crop B	Crop C	Crop D	Crop E	3.1
										Average for Rotation	3.18

Table 1- Example of multiple model runs for a 6 year rotation with the starting year for the crop rotation offset in each run.

<u>Issue: Model is built for short rotations</u>
The 10 year management change analysis is not sufficient for organic systems that might have 7 or 8 years in a full rotation.

Occurrence of each crop in final results

Run Number	Crop A	Crop B	Crop C	Crop D	Crop E	Crop F
1	2	2	2	2	1	1
2	2	2	2	1	1	2
3	2	2	1	1	2	2
4	2	1	1	2	2	2
5	1	1	2	2	2	2
6	1	2	2	2	2	1
Average Crop Occurance	1.67	1.67	1.67	1.67	1.67	1.67

Table 2- Representation of each crop in the final result from these runs based on their occurrence.

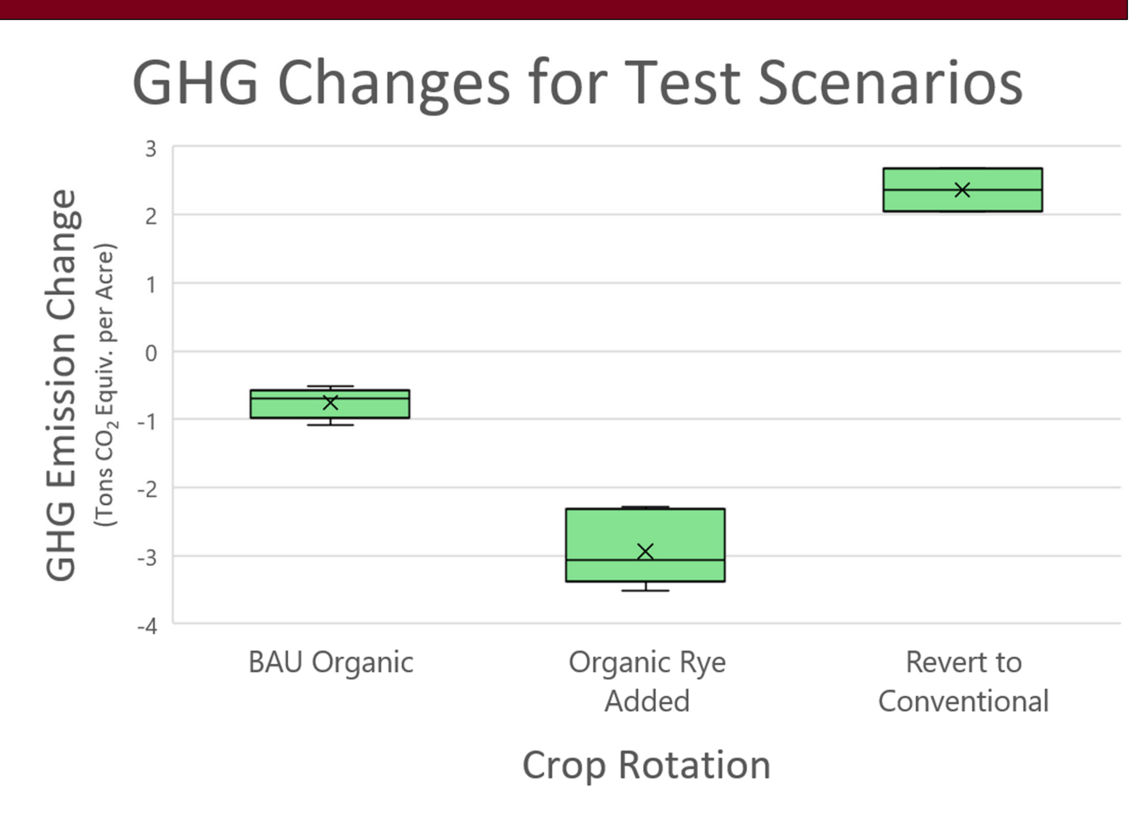
<u>Solution: Average multiple starting points</u>
Run the model multiple times using each different starting point and average the results to get a more stable assessment of emissions.

Evaluating Organic Crop Soil Carbon Emissions with the Comet Model

To better understand and evaluate the operation, calculations, and results of the COMET model, a basic organic crop rotation was evaluated using alternative future crop management strategies. In addition to the soils, weather, and crop variable for the specific study site in West Central Minnesota, the crop history and alternative scenarios were:

Time Period	Management	Specific Rotation
Historic (pre-2000)	Conventional Agriculture	Corn, Bean
Recent Management	Basic Organic	Corn, Beans, Silage, Alfalfa, Alfalfa, Alfalfa
<u>Future Alternatives</u>		
-BAU (business as usual)	Basic Organic	Corn, Beans, Silage, Alfalfa, Alfalfa, Alfalfa
-BAU + Organic Rye	Enhanced organic	Corn, Beans, Silage + Rye, Rye + Alfalfa, Alfalfa, Alfalfa
-Return to Conventional	Conventional Agriculture	Corn, Beans

Figure 2- GHG emissions modeling results from three alternative management scenarios. The BAU-organic rotation (n=6), the organic rotation with rye (n=6) and a reversion to non-organic agriculture (n=2) were run through the COMET farm model. The box plot shows the resulting changes to soil GHG emission, which match expectations based on crop biomass and nutrients added to the site being modeled.



Overall findings: The project team was able to successfully test its organic rotations with the COMET farm model. While the model work-arounds required to run the more complex organic rotations will likely impact the results somewhat, the model is more useful to non-soil scientists than the basic formulas of the IPCC or other more specialized soil carbon models that require extensive training, data, and the ability to calibrate.

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Citations and Credits

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Citations:

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