Simulating Net Greenhouse Gas Balance under Cover Cropping in Semi-Arid Regions using DayCent model

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Challenges of Semi-arid Cropping System

- Long-fallow periods between cash crops can limit biomass production and soil organic carbon (SOC) accumulation in arid/semi-arid regions.
- In the semi-arid Great Plains, increasing weather variability, decreasing precipitation, and declining water reserves have led to the rapid transition of croplands from irrigated to limited irrigation or dryland, further challenging crop production.
- Cover cropping can reduce the fallow period, increase residue returned to the soil and increase SOC.
- Despite the multiple benefits of cover cropping, there is uncertainty in greenhouse gas (GHG) mitigation potential and subsequent cash crop yield in arid and semi-arid regions.

Cover Cropping for Partial Fallow Replacement

Objective: the main goal of this project was to simulate long-term GHG emissions with cover cropping in semi-arid cropping systems
Study site: NMSU Agricultural Science Center (ASC) at Clovis, NM
Climate: Semi-arid, average annual precipitation 428 mm
Management: Cover crops (oat and pea) were grown for three months in spring (Fig 1.)

Fig 1. Cover crop study at ASC Clovis, NM.

DayCent Model

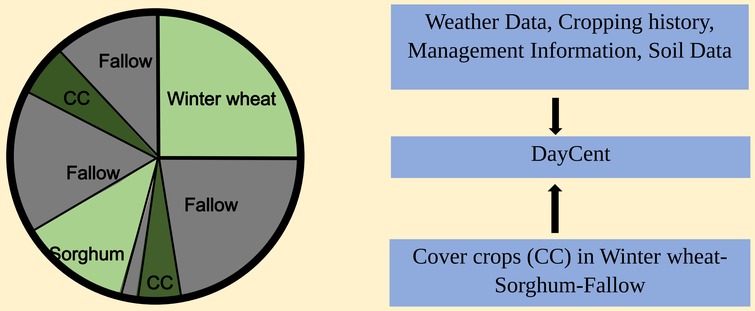

Fig 2: Schematic of Cover crops in winter wheat-sorghum-fallow rotation and DayCent model inputs.

- DayCent, an ecosystem model, can perform complete GHG analysis, explicitly representing soil processes such as SOM transformations and nitrification and denitrification at a daily time-step (Del Grosso et al., 2011; Parton et al. 1998).
- The study evaluated the impacts of cover crops on SOC sequestration and net GHG balance.
- Five years of cash crop yield, cover crop biomass, SOC, and soil organic nitrogen (SON) data were used to calibrate and evaluate the model.

Results and Discussion

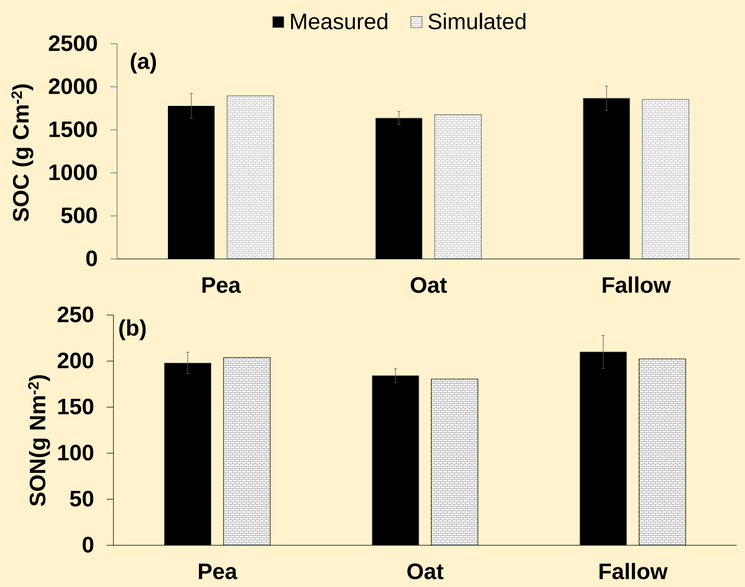

Fig 3. Mean measured vs. simulated soil organic carbon (SOC) (a) and soil organic nitrogen (SON) (b) for the top 0-20 cm for cover crops (pea and oat) and no-cover crop (fallow) treatments (2016-2020).

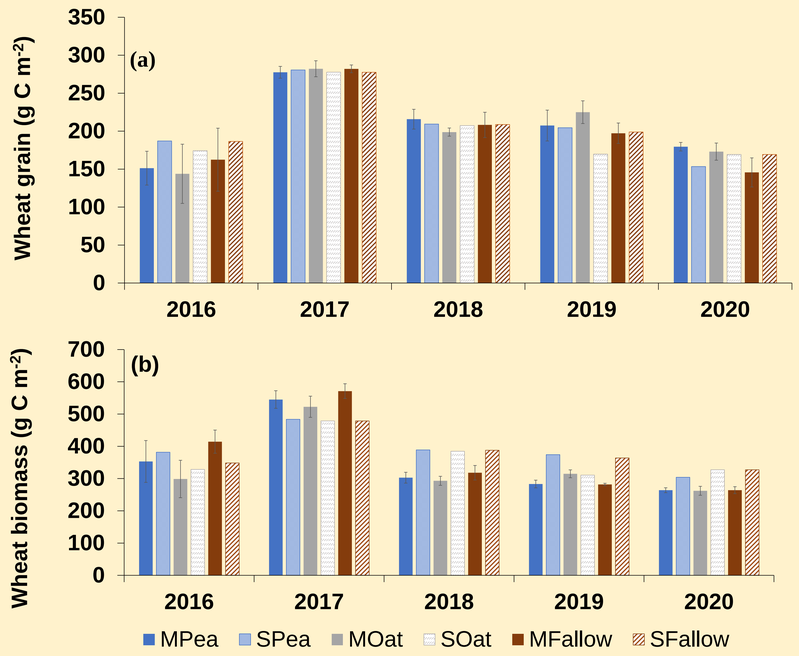

Fig 4. Measured (solid color bars) vs. simulated (pattern filled bars) wheat grain carbon (a) and aboveground biomass carbon yield (b) for cover crops (pea and oat) and no-cover crop (fallow) treatments for different years.

Results and Discussion

Table 1: Statistics (root mean square error (RMSE: g C or N m^{-2}) describing DayCent's model performance for soil organic carbon (SOC) and soil organic nitrogen (SON), wheat grain, and biomass C yield.

Treatments	SOC	SON	Wheat Grain	Wheat Biomass
	(g C m^{-2})	(g N m^{-2})	(g C m^{-2})	(g C m^{-2})
Pea	163.5	13.77	20.13	66.11
Oat	111.75	8.70	28.59	55.64
Fallow	120.24	24.25	15.21	75.54

Table 2: Estimates of annual (2016-2050) methane (CH_4) oxidation, nitrous oxide (N_2O) emissions, and changes in soil organic carbon (2050 vs. 2016), and calculated net greenhouse gas (Net GHG) for cover crops and fallow treatments. Positive values represent emissions from soil, whereas negative values represent carbon sink to the soil.

Treatments	CH_4	N_2O	ΔSOC	Net GHG
	(Kg CO_2-eq. ha^{-1} yr^{-1})			
Pea	-115	575	704	-245
Oat	-115	518	722	-319
Fallow	-112	431	506	-187

- The DayCent model captured the observed trend and treatment difference in SOC, SON, and wheat grain and biomass with no significant bias (Fig.3, Fig. 4, &Table 1).
- The model predicted 39.2 % to 42.7 % more SOC sequestration with cover cropping and no-tillage together compared to no-tillage fallow alone in three decades (Table 2).
- Cover crops increased the potential of no-tillage fallow to reduce net GHG balance by 30.9% to 70.5% .

Conclusion

- DayCent simulated soil carbon, nitrogen, and crop yield in a semi-arid cropping system.
- Cover crops can reduce net GHG balance while maintaining similar cash crop yield as no-till fallow.

Reference

Del Grosso, S. J et al. 2011. Special features of the DayCent modeling package and additional procedures for parameterization, calibration, validation, and application. In Methods of introducing system models into agricultural research (eds L.R. Ahuja and L. Ma).

Parton, W. J., et al.1998. DAYCENT and its land surface submodel: description and testing. Global Planet. Change. 19(1), 35-48.