Simulating Impacts of Bioenergy Sorghum Residue Return on Soil Organic Carbon and Greenhouse Gas Fluxes Using the DAYCENT Model

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Introduction

Bioenergy sorghum has been promoted as a next generation biofuel crop due to its features of high biomass yield and nutrient and water use efficiency. Agricultural residues increase soil organic carbon (SOC) sequestration through enhanced aggregate formation. Residue return, however, lowers the amount of available feedstock and may increase soil microbial activity and greenhouse gas (GHG) emissions, thereby offsetting benefits associated with biofuel production. Previous studies have focused on corn stover and cereal residues for biofuel production and their environmental impacts, with minimum return rates being proposed for corn stover to establish sustainable harvest criteria. However, information is lacking on impacts of bioenergy sorghum residue return on the soil environment, SOC, and GHG emissions. Sustainable harvest rates need to be estimated in order to balance biofuel feedstock production, soil quality and environmental health. DAYCENT is a process-based biogeochemical model used to simulate soil environmental factors such as soil temperature and water fluxes, plant and soil carbon (C) and nutrient dynamics, and GHG fluxes, and has been effective in many traditional agricultural systems. Few bioenergy crop production systems have been modeled to date. The objective of this study was to parameterize and validate DAYCENT performance in simulating soil temperature and water content, SOC, carbon dioxide (CO_2) and nitrous oxide (N_2O) fluxes in a bioenergy sorghum production system with variable biomass (residue) returns.

Material and Methods

The field study associated with this research was established at the Texas A&M AgriLife Research Farm near College Station, TX (30°32'15''N, 96°25'37''W) in 2008. The study used a randomized complete block design to study effects of bioenergy sorghum residue return: 0 or 50% of sorghum biomass yield returned at harvest with each treatment replicated three times. Plots were 9.14-m long by 4.08-m wide, with four 1.02 m rows. Data of soil temperature, soil volumetric water content, SOC, and soil GHG (CO_2, N_2O) fluxes were measured in 2010 and 2011. GHG flux measurements for 2010 occurred from 27 May 2010 through 3 March 2011 and for 2011 from 6 May 2011 to 1 March 2012. The DAYCENT model was used to simulate and compare with the field observations. Linear regression analyses were used to compare measured vs. modeled soil temperature, soil water content, SOC, and daily GHG fluxes, with coefficient of determinations (r^2) computed.

Fig. 1. Abovegound biomass (upper left), SOC (upper right), and GHG (bottom) measurements

Model Methodology

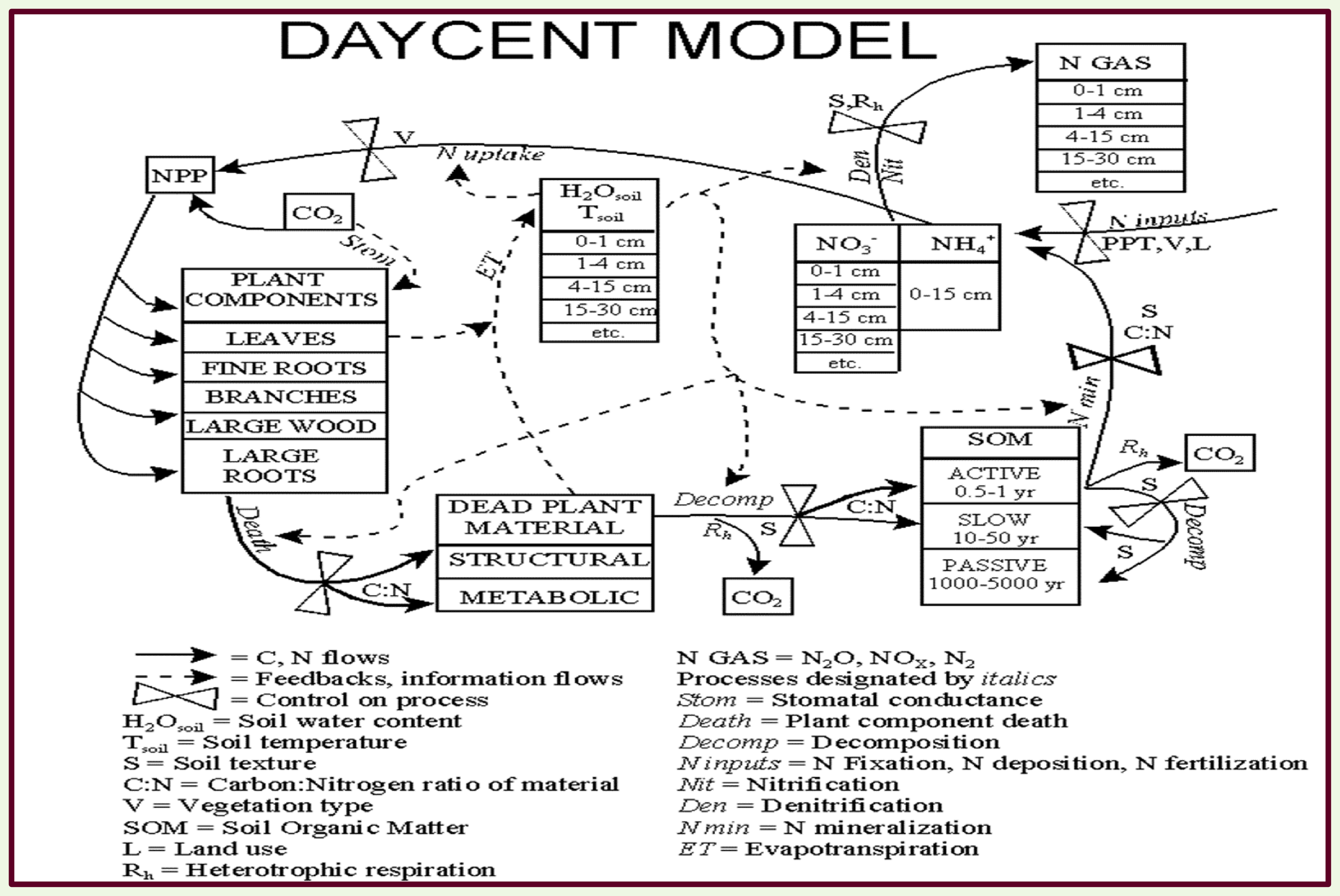

Fig. 2. Flow diagram for DAYCENT

DAYCENT is a biogeochemical model of intermediate complexity used to simulate flows of C and nutrients for crop, grassland, forest, and savanna ecosystems. Required model inputs are daily maximum and minimum temperature, daily precipitation, soil texture, current and historical land use, vegetation cover, and field management.

Results

Soil Temperature and Water Content

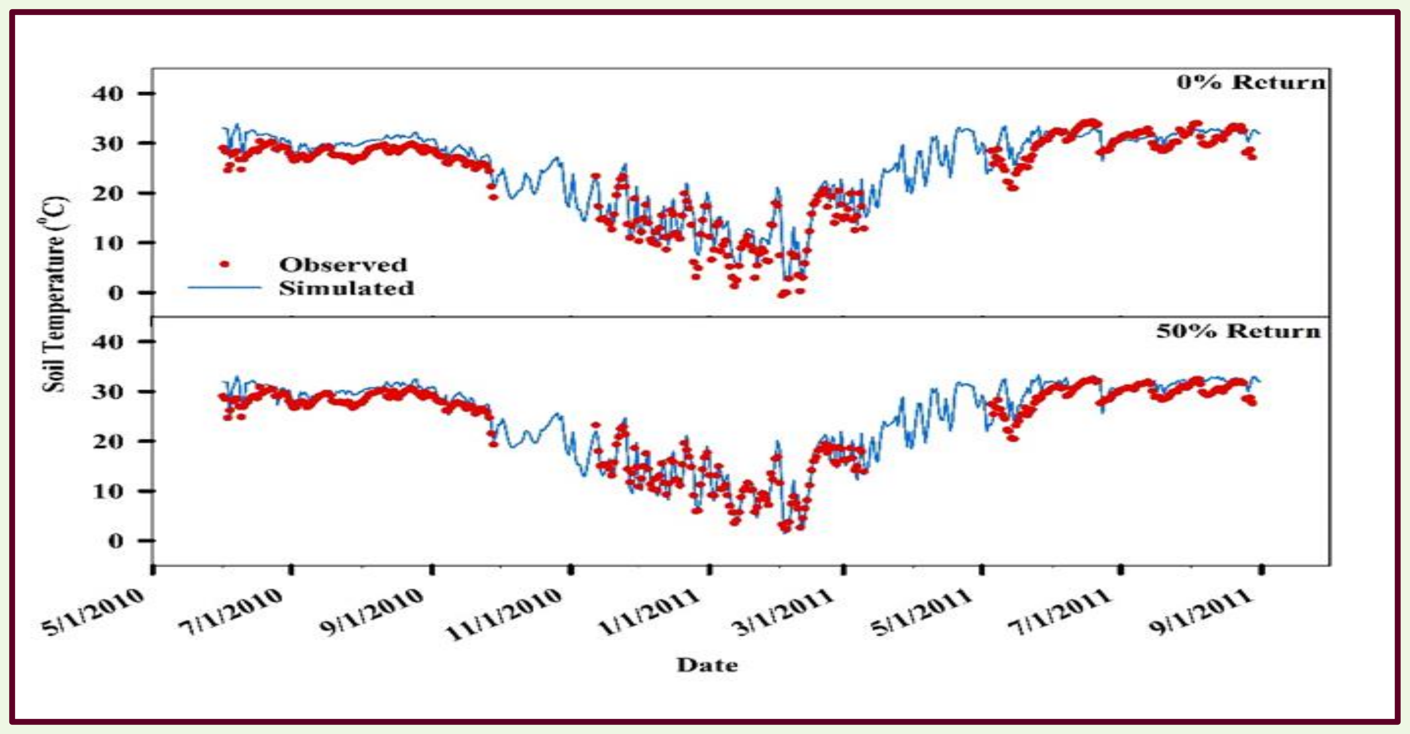

Fig. 3. Observed and simulated soil temperature from the beginning of 2010 growing season to the end of 2011 growing season

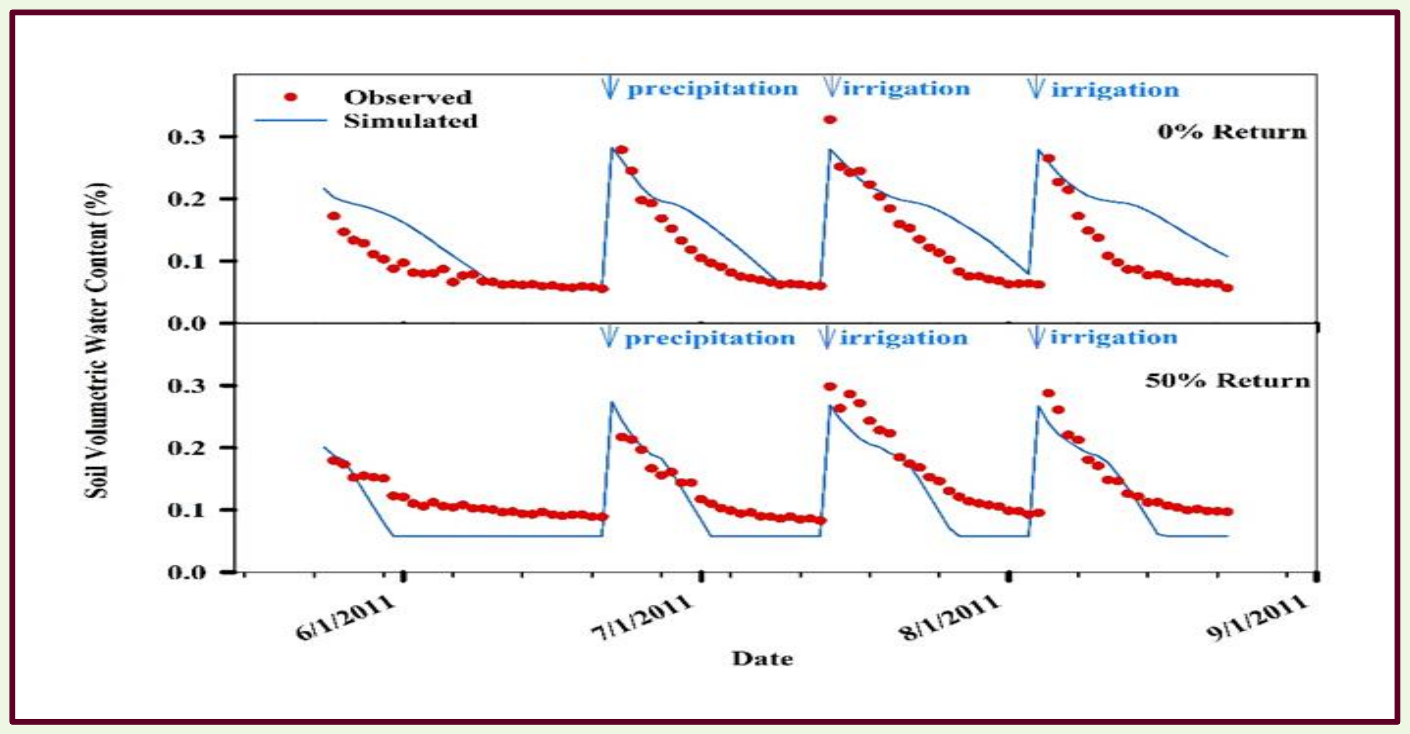

Fig. 4. Observed and simulated soil water content in the 2011 growing season

Soil moisture dynamics and soil temperature profiles are major environmental drivers of the ecosystem processes in the model. Highly favorable simulation results of soil water content (r^2 = 0.81) and temperature (r^2 = 0.94) justified the model validation of C cycle and nutrient dynamics.

SOC and GHG Fluxes

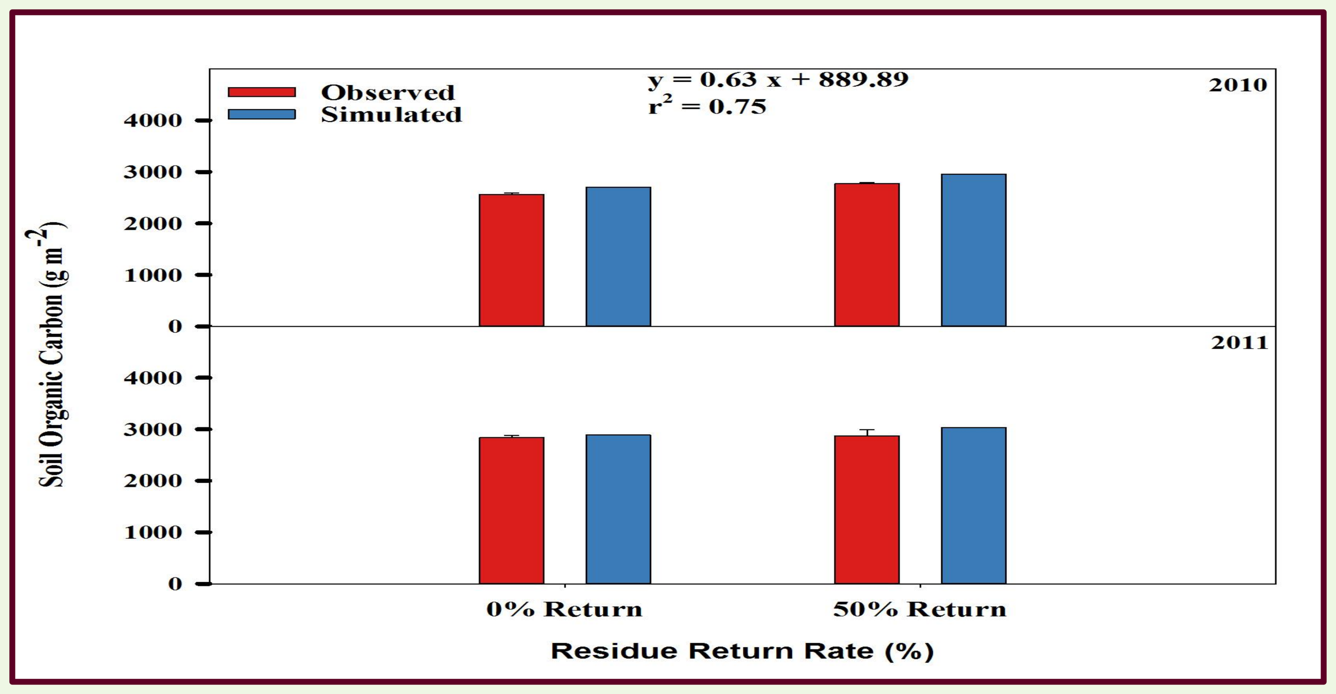

Fig. 5. SOC at 0 - 20 cm under different residue returns in 2010 and 2011

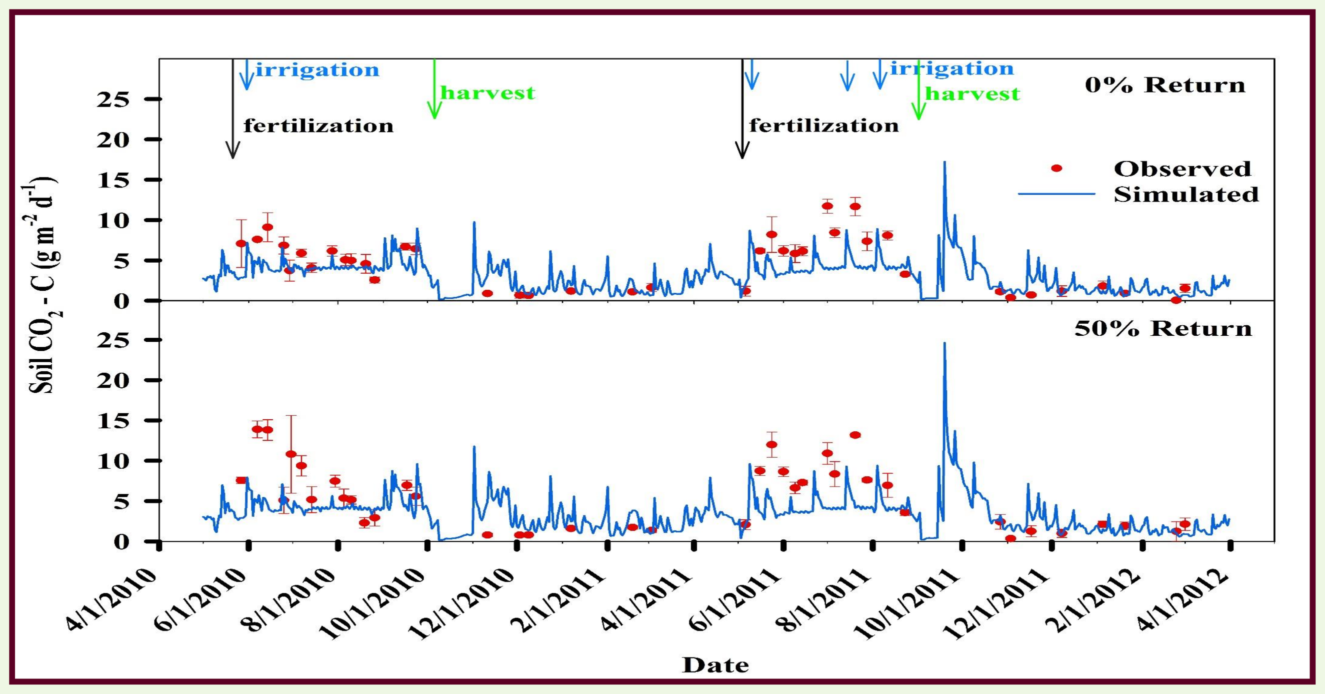

Fig. 6. CO_2 - C daily fluxes under different residue returns in 2010 and 2011

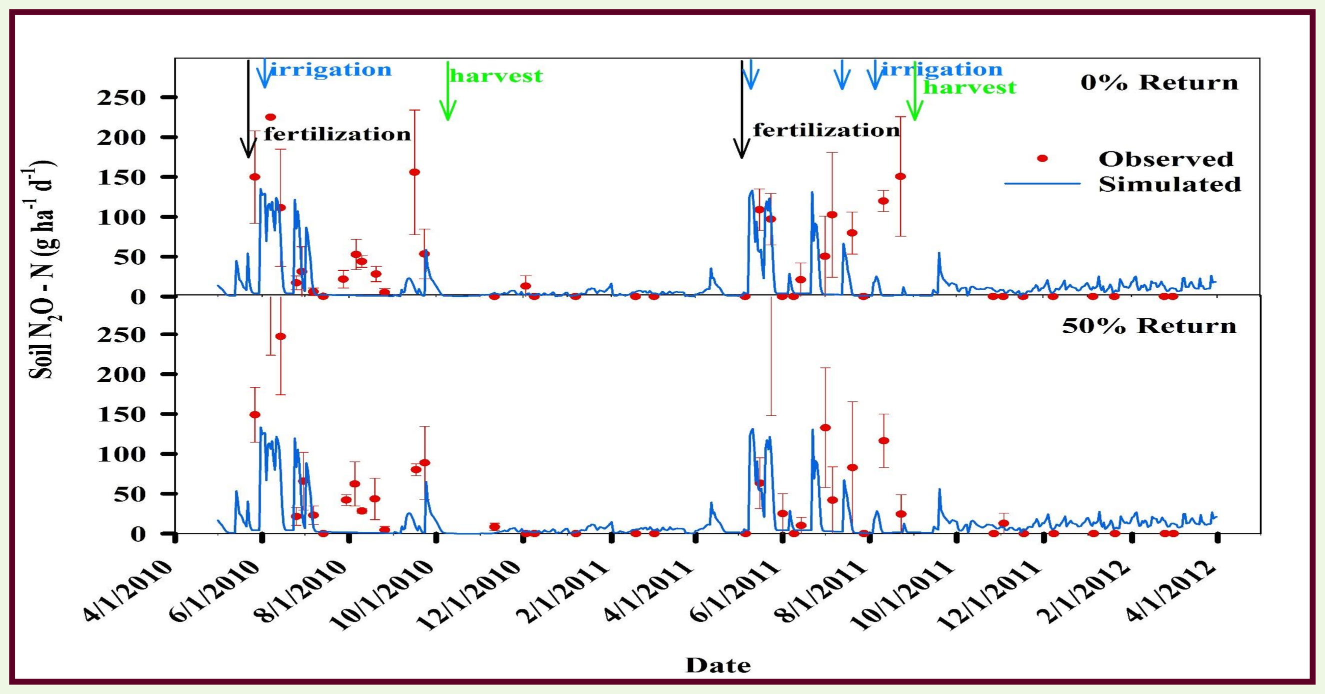

Fig. 7. N_2O - N daily fluxes under different residue returns in 2010 and 2011

Conclusions

•The DAYCENT model favorably simulated soil environmental factors (moisture & temperature) with r^2 of 0.81 and 0.94.

• Soil organic C reflecting residue return and annual variation for the same return rate was reasonably simulated by the model, with r^2 of 0.75.

• The model captured the main patterns of both GHG daily fluxes, while performed better for CO_2 fluxes than for N_2O, without simulating some measurements of high flux rates.

Acknowledgements

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