Best Soil and Water Management Practices for Bioenergy Sorghum Production in Texas

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Introduction

Bioenergy sorghum is a second generation biofuel crop with high biomass yield potential, nitrogen (N) and water use efficiencies, and genetic tractability. As a C4 crop originally from Africa, it has great potential to be successfully grown in the southern U.S. Texas is geographically located in the southcentral U.S. and leads the nation in several agricultural areas and associated commodity production. Grain sorghum is well-adapted to Texas, and its ability to yield consistently in harsh environments makes it popular with growers. However, inappropriate soil and water management practices may occur due to lack of information concerning production requirements and environmental effects of bioenergy sorghum, which may ultimately affect biomass production, soil fertility, and greenhouse gas (GHG) emissions in the long run. Texas has a wide diversity of climates and soils due to its large geographical area, making it difficult to achieve the same economic, agronomic, and environmental goals by adopting the same management practices in each county. Thus, our objective was to determine the optimum soil and water management practices including tillage, N fertilization, aboveground biomass residue return, and irrigation, for bioenergy sorghum production in each county in Texas, in order to maximize yield, sustain soil fertility, and minimize GHG emissions.

Materials and Methods

Regional simulations of bioenergy sorghum production to the middle of this century were conducted for each Texas county under 45 residue return, N fertilization, and tillage management combinations at three different irrigation levels using the process-based biogeochemical model, DAYCENT. The model integrated representative GIS-based county-level weather, soil property and field operation schedules, and verified bioenergy sorghum growth information. Yield, soil organic carbon (SOC), and nitrous oxide (N_2O) emission were used as indices to determine best soil and water management practices for each county using life cycle analysis (LCA) of net GHG emissions.

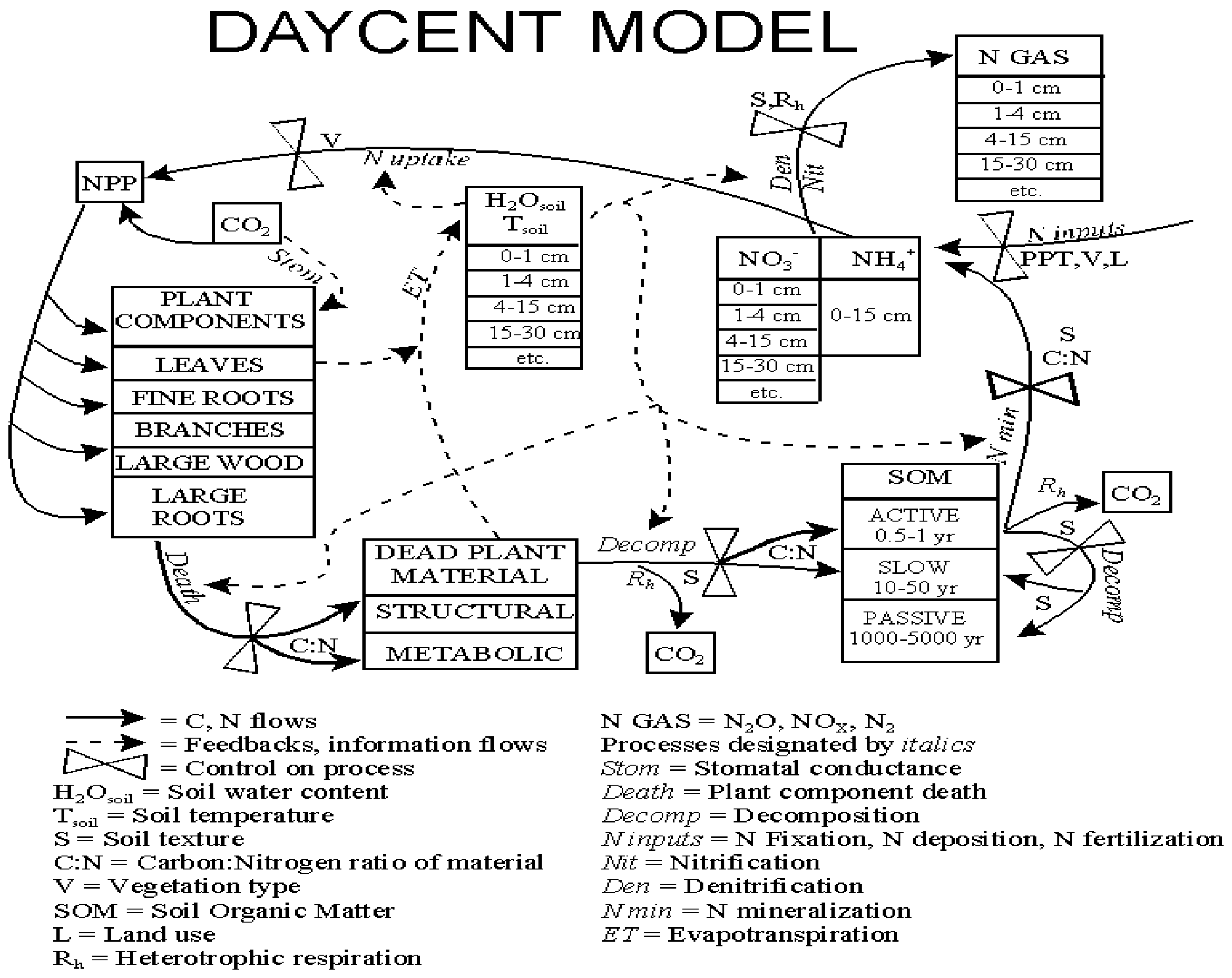

Fig. 1. Conceptual diagram of the DAYCENT ecosystem model (Del Grosso *et al.*, 2001)

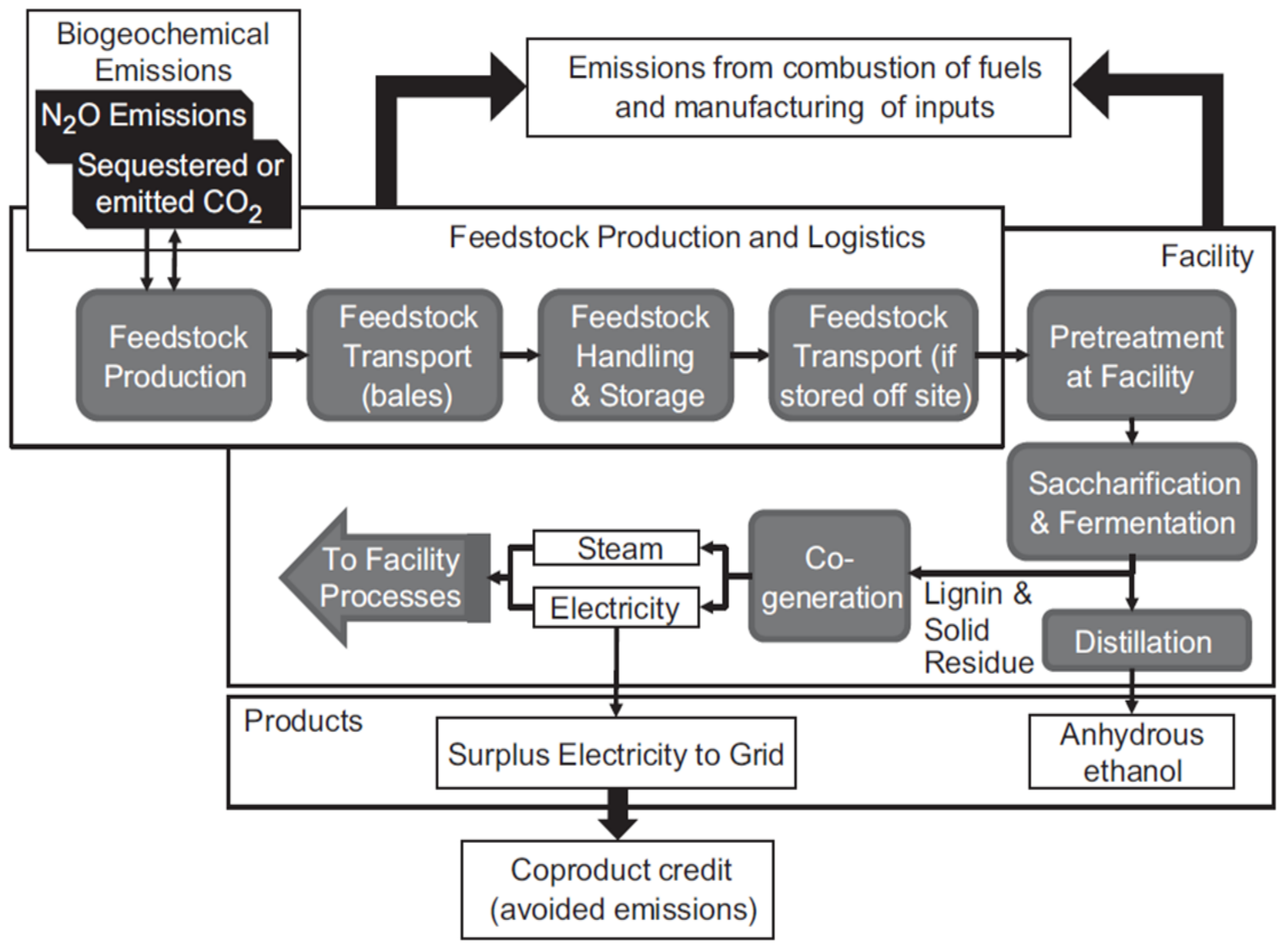

Fig. 2. Schematic of LCA system boundaries (Murphey and Kendall; 2015)

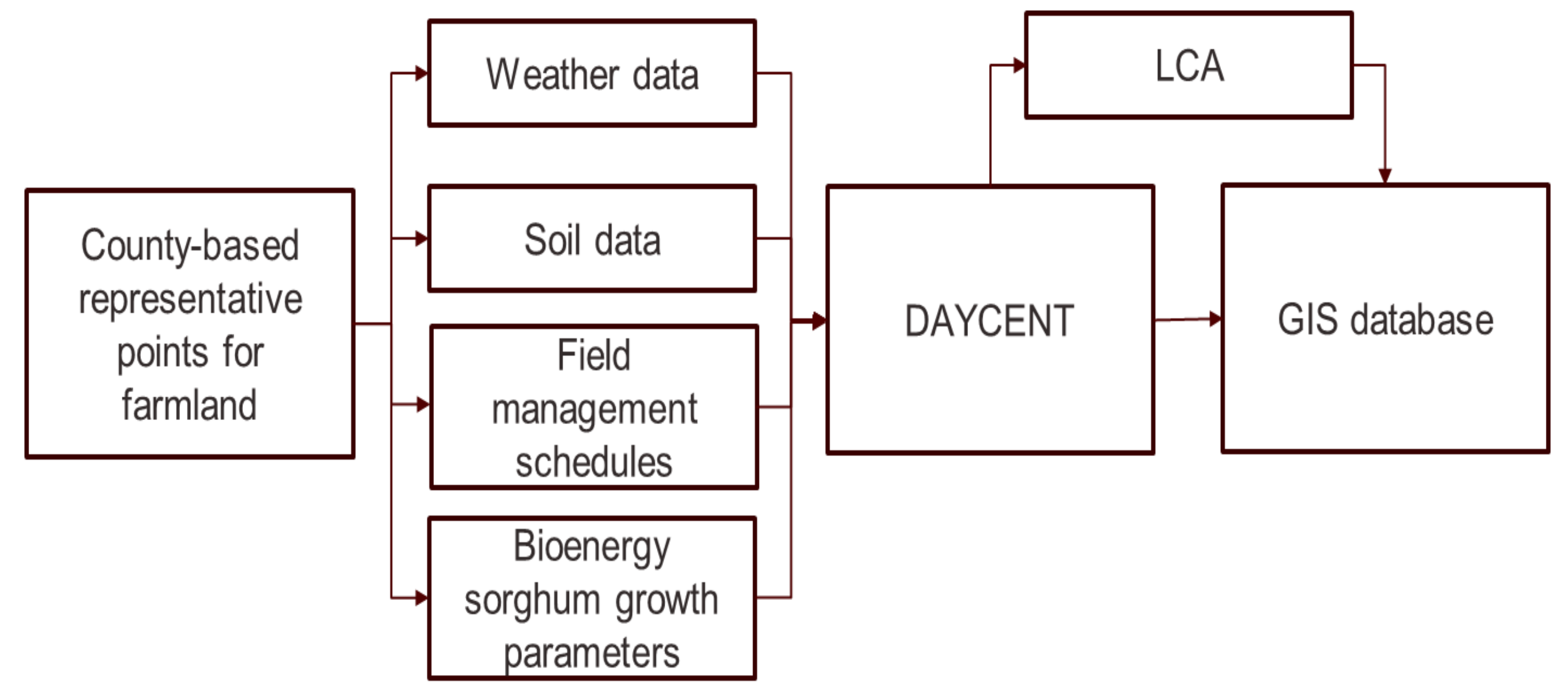

Fig. 3. Flow chart of regional simulations

Results

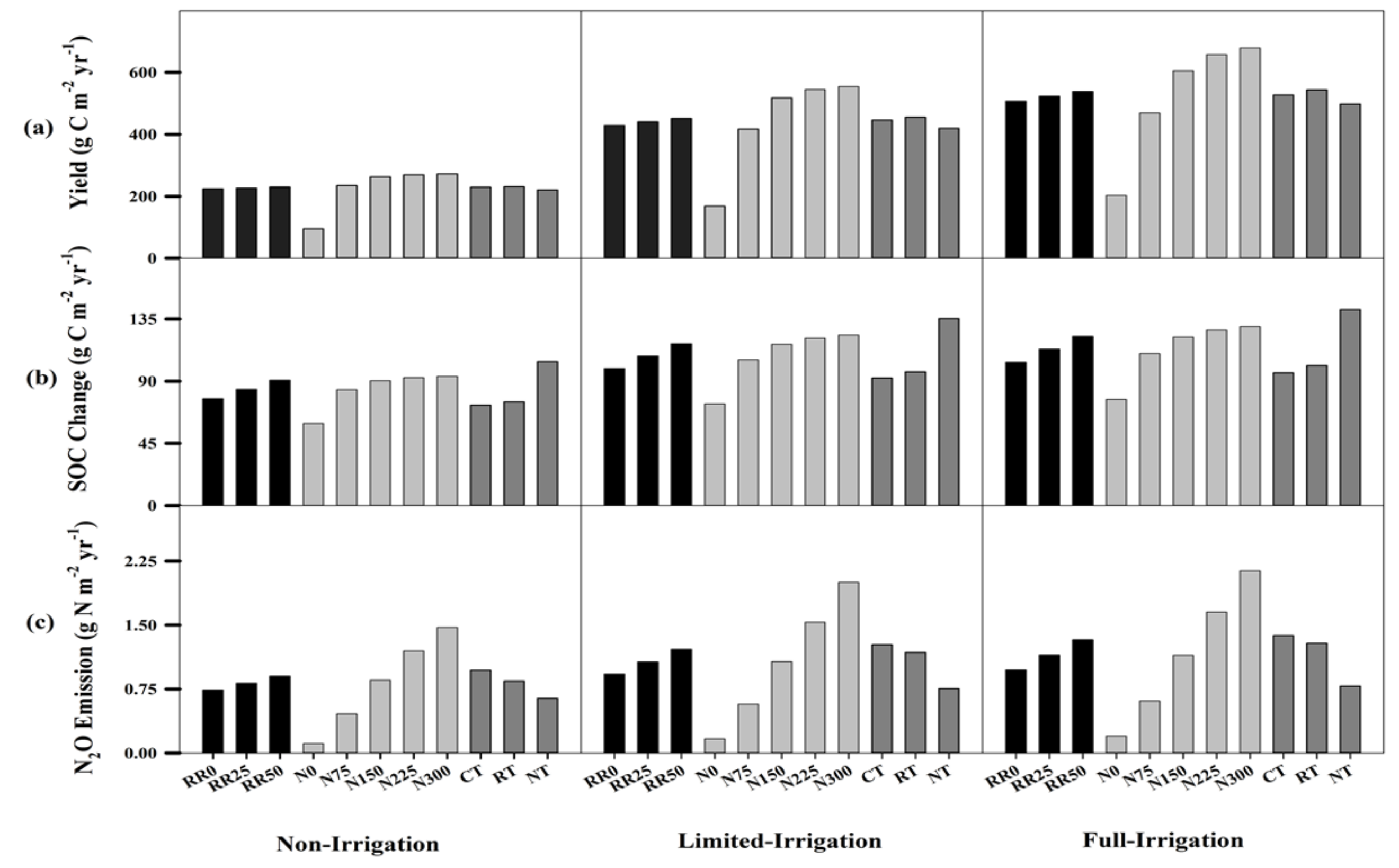

Fig. 4. Average annual aboveground biomass C (a), SOC change (b), and N_2O emission (c) under different residue return, N fertilization, and tillage intensity under three irrigation systems in 2016-2050

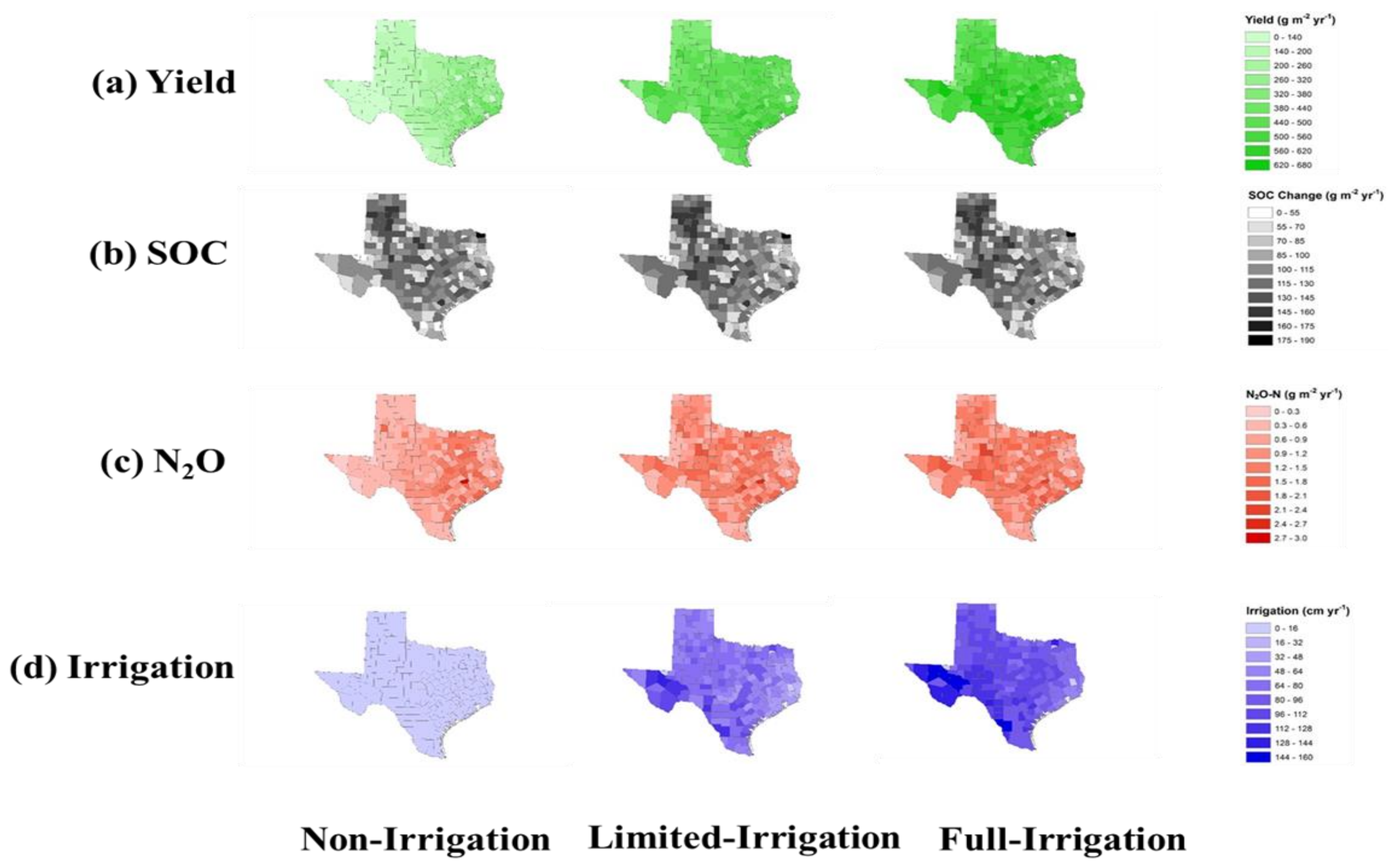

Fig. 5. Average annual aboveground biomass C (a), SOC change (b), N_2O emission (c), and irrigation amount **per unit area** (d) under different residue return, N fertilization, and tillage intensity under three irrigation systems in 2016-2050

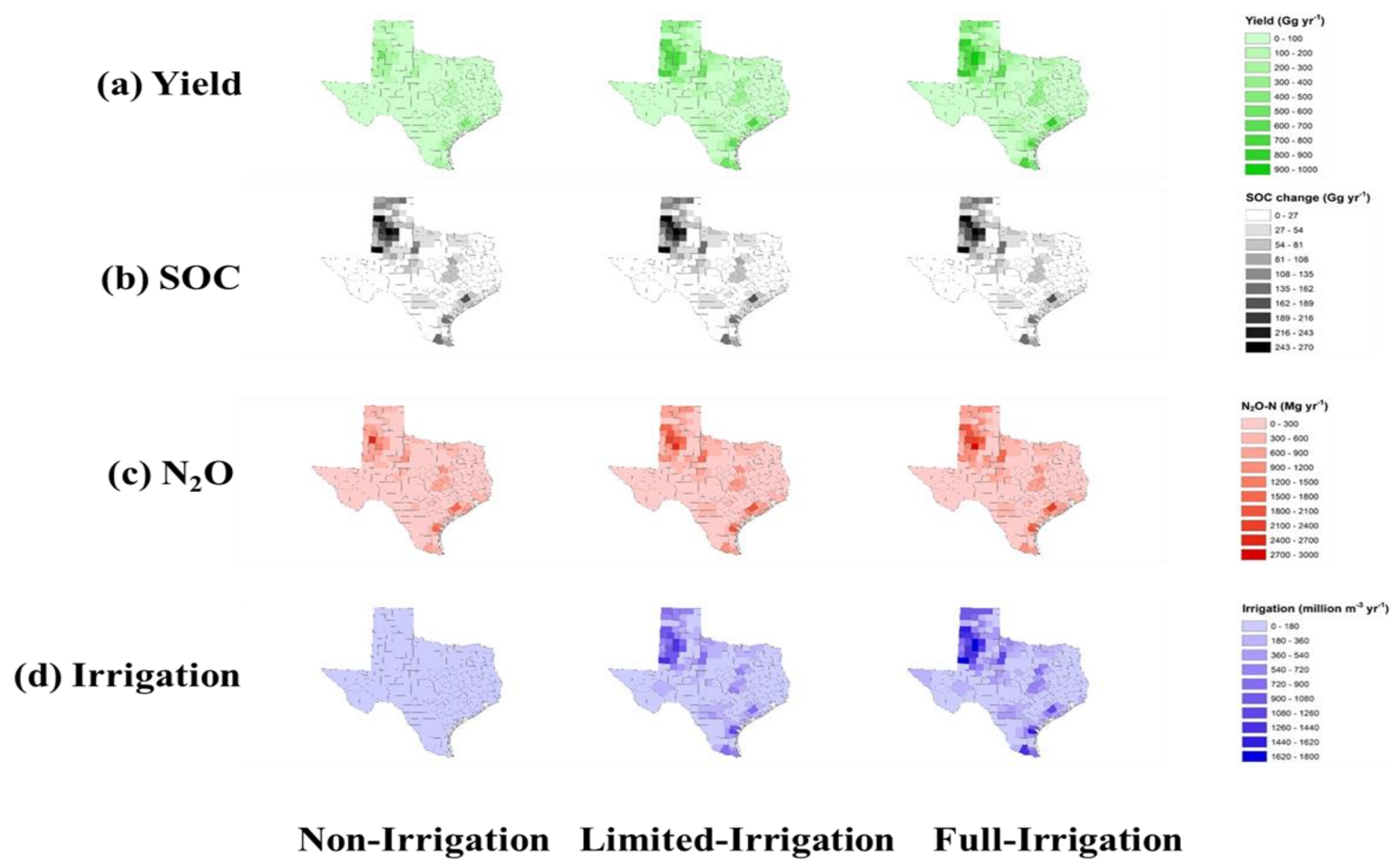

Fig. 6. Average annual aboveground biomass C (a), SOC change (b), N_2O emission (c), and irrigation amount **per county** (d) under different residue return, N fertilization, and tillage intensity under three irrigation systems in 2016-2050

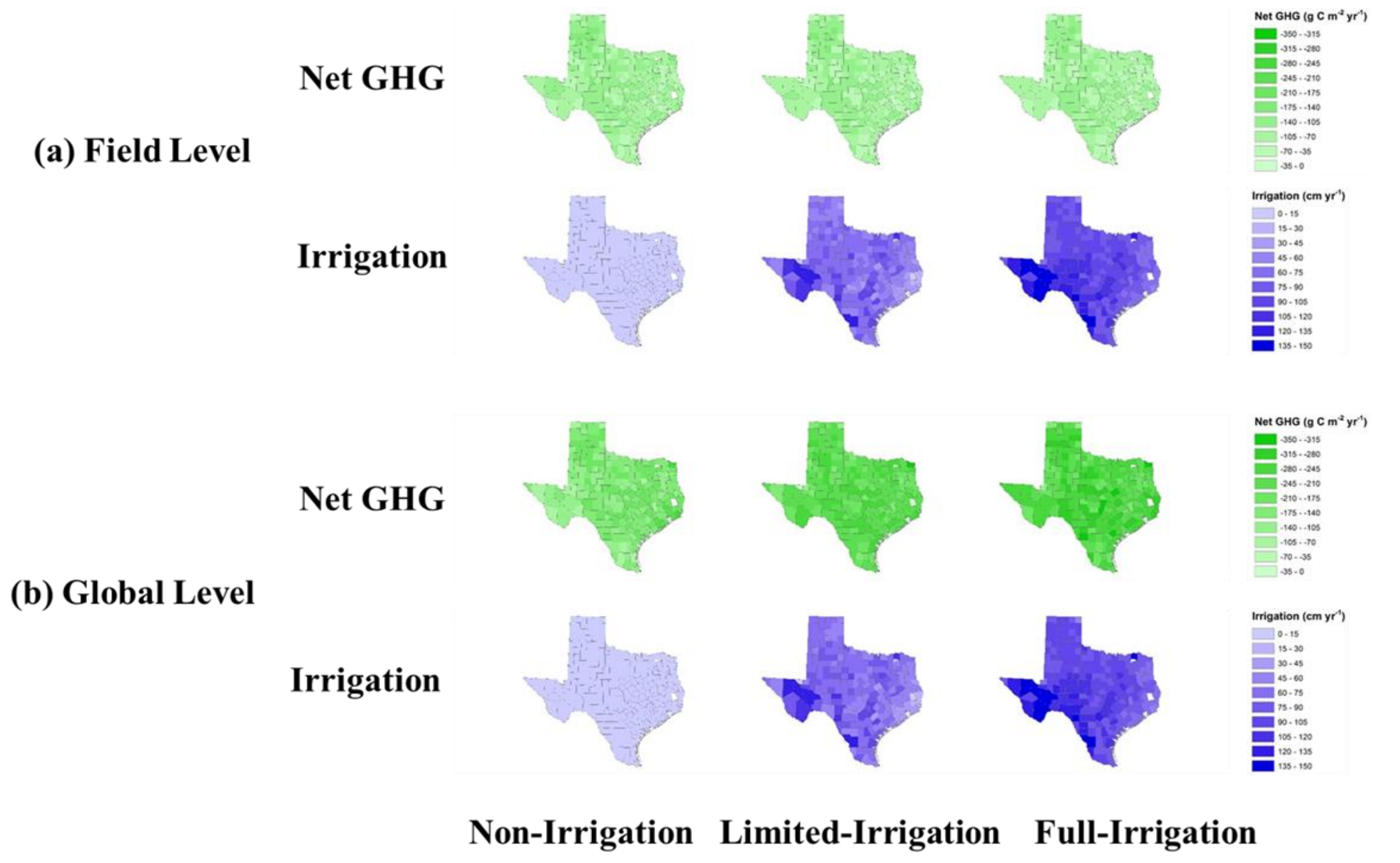

Fig. 7. Average annual net GHG emissions and irrigation amounts when accounting for C mitigation with harvested biomass conversion (global level) and without (field level) **per unit area** under best residue return, N fertilization, and tillage intensity combinations under three irrigation systems in 2016-2050

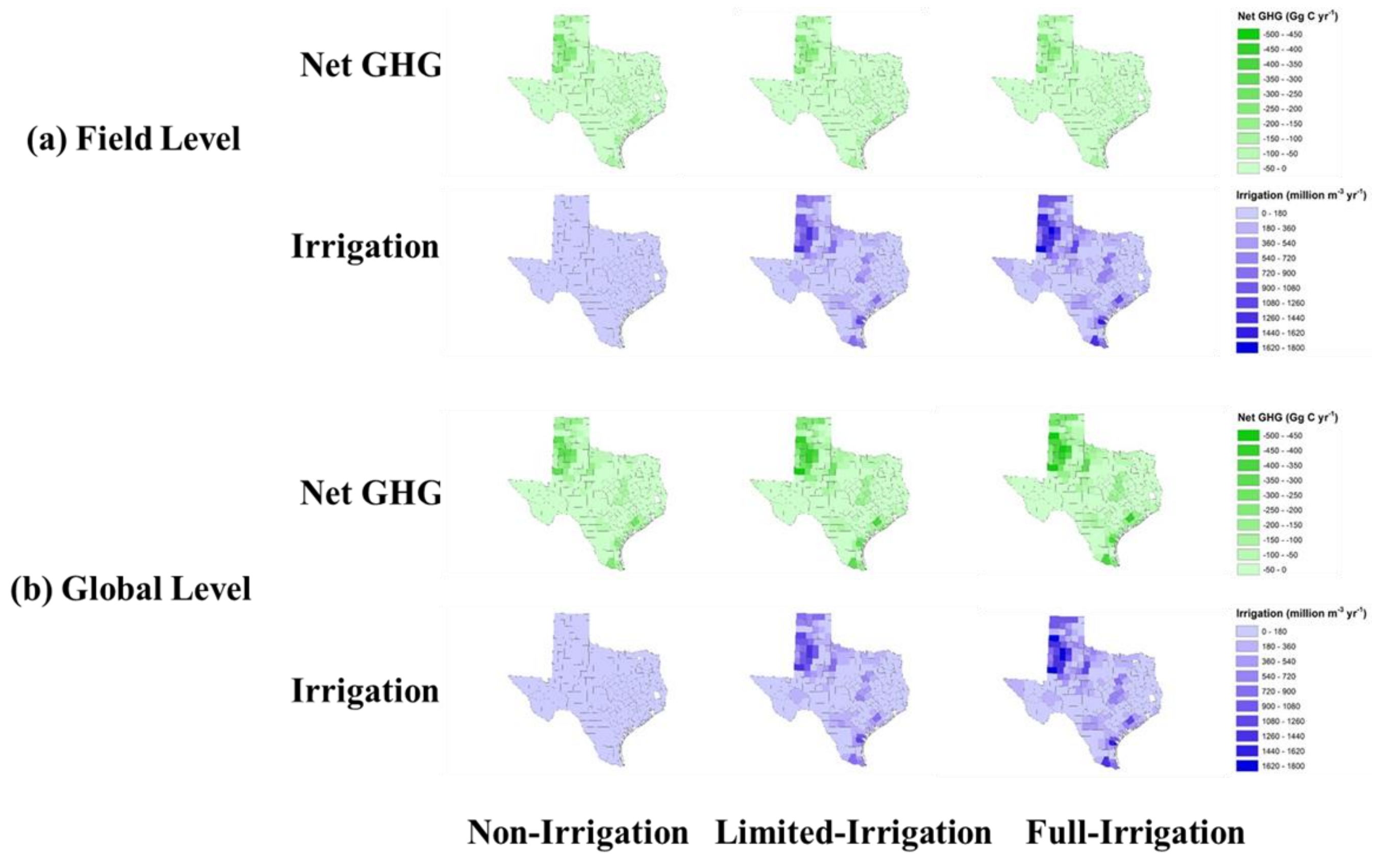

Fig. 8. Average annual net GHG emissions and irrigation amounts when accounting for C mitigation with harvested biomass conversion (global level) and without (field level) **per county** under best residue return, N fertilization, and tillage intensity combinations under three irrigation systems in 2016-2050

Conclusions

- Higher irrigation increased yield, SOC, and N_2O emissions. Limited irrigation seemed to have advantages over non-irrigation and full-irrigation mainly due to its positive effect on sorghum yield without excess water usage.
- For a given irrigation level, higher residue return and N fertilization increased all the selected indices. Lower tillage intensity increased SOC and reduced N_2O emission. Reduced tillage had the highest biomass yield, followed by conventional tillage and no till.
- For statewide arable land in each county, potential biomass yield and N_2O emissions without irrigation were higher in East compared to West Texas due to contrasting annual precipitation amounts in these regions. The difference diminished as irrigation level increased. The distribution pattern of SOC change was consistent with basic SOC distribution, possibly due to interaction of C input from crop residue and C loss by microbial decomposition.
- When accounting for arable land area in each county, biomass yield, SOC sequestration, and N_2O emissions were concentrated in plains and prairie areas such as the High Plains, Rolling Plains, Rio Grande Plains, Blackland Prairie, and Coast Prairie. Correspondingly, total irrigation amounts in these areas were higher than those without much arable land.
- For GHG emission (positive) or mitigation (negative), all irrigation levels were able to mitigate GHG emissions at both field and global levels if best management practices were selected. Because of increased biomass harvest and GHG mitigation potential associated with 0% residue return, no-till, 150 kg ha^{-1} of added N, and limited irrigation, this combination of practices was overall deemed optimal for bioenergy sorghum production in Texas.

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