Taking the devil out of the details: reducing uncertainty in bioenergy production

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What is the best type of bioenergy?

The large-scale replacement of conventional petroleum-based fuels with fuels derived from biomass feedstocks has become an area of increasing interest in the United States due to its potential to ameliorate both dependency on foreign oil and the climate impact of fossil fuel combustion. However, the biofuels industry is still in its infancy, and many questions remain regarding the best use of biomass as well as the types of bioenergy production systems that maximize energy, economic, and environmental benefits. This is further complicated by the numerous types of bioenergy feedstocks currently being explored, including waste wood, corn stover, perennial grasses, starchy grains, oilseeds, and many others.

The best approach to answer these questions is full-system analysis of potential bioenergy production schemes (Figure 1). However, the informative value of such full-system analyses is limited by numerous uncertainties arising from the complexity, diversity, and nascent nature of such systems, as well as spatial heterogeneity with regard to feedstock procurement and coproduct markets. At CSU we are working to identify and address key areas of uncertainty in bioenergy production systems in order to inform future industry development.

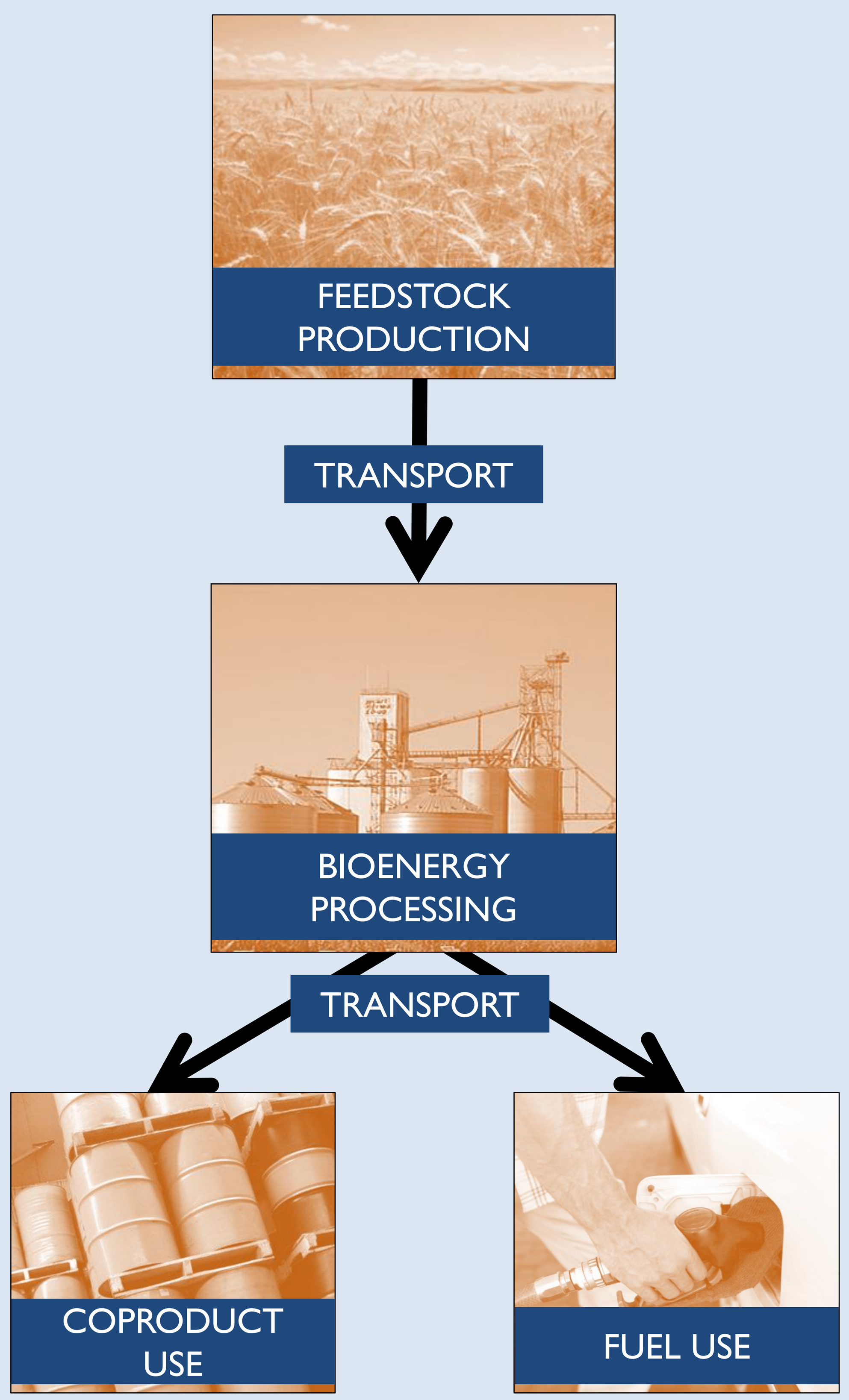
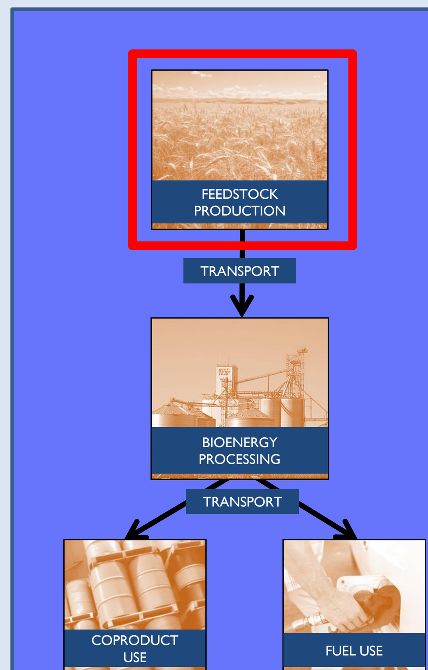


Figure 1. Basic schematic for a bioenergy production system.

Reducing uncertainty through targeted research:

FEEDSTOCK PRODUCTION



Key uncertainty for corn stover: How much biomass can be harvested?

Introduction: Corn is a major U.S. crop. Corn stover, the material remaining after corn grain harvest, is a feedstock of interest for bioenergy because of the scale at which it is already produced. However corn stover is also an important soil amendment, contributing carbon (C) that maintains soil fertility, and the quantity that can be sustainably removed varies between systems.

Method: We used the DayCent ecosystem model[1] to analyze the soil C impacts of variable levels of corn stover removal, with and without nitrogen fertilizer in Rosemount, MN.

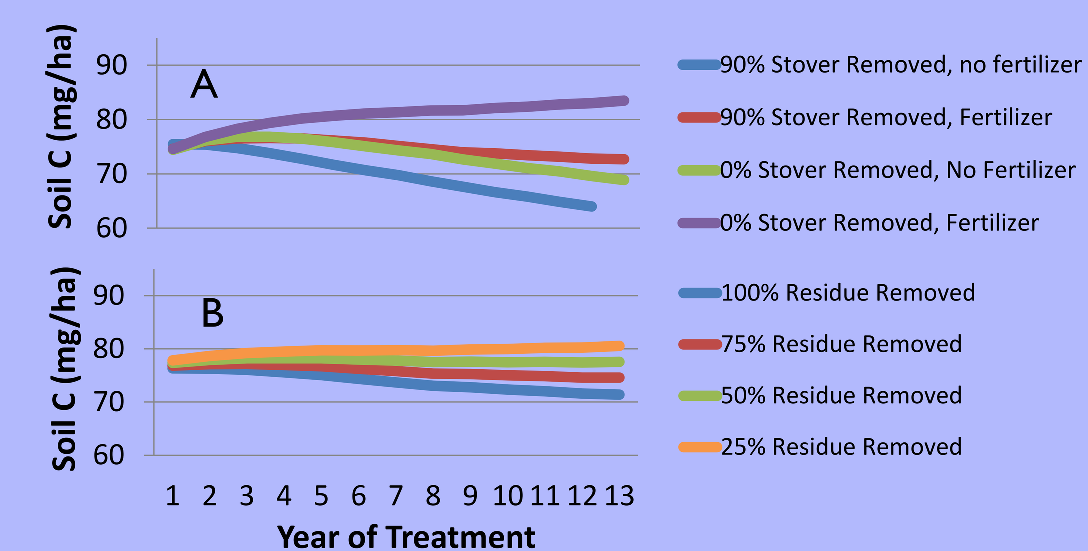
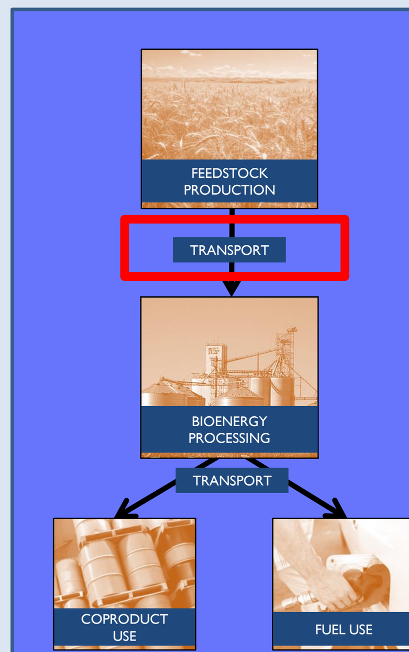


Figure 2. Changes in soil C with and without residue removal and fertilizer addition (A), and with fertilizer addition and variable levels of removal (B).

Results: Corn stover removal without fertilizer addition leads to a decrease in soil C. However, corn stover removal with fertilizer addition maintains a higher level of soil C, comparable to leaving corn stover on the ground without fertilizer (A). With fertilizer addition, residue removal of 25 – 50% will maintain soil C. These simulations were based on a site in Rosemount, MN with high soil C. These trends may be different in sites with low soil C.

FEEDSTOCK TRANSPORT



Key uncertainty for biomass crops: Where should biomass be cultivated?

Introduction: The greenhouse gas (GHG) footprint of bioenergy feedstock crop cultivation shows a wide degree of spatial variability in response environmental factors such as climate and soil type[2]. However, the exploitation of this heterogeneity may be limited by the need to minimize field-biorefinery transport emissions.

Method: We used the GREET LCA model[3] and the DayCent model to estimate emissions from the cultivation and transport of switchgrass along a main supply route (US 65) for a planned cellulosic biorefinery site in southwest Kansas.

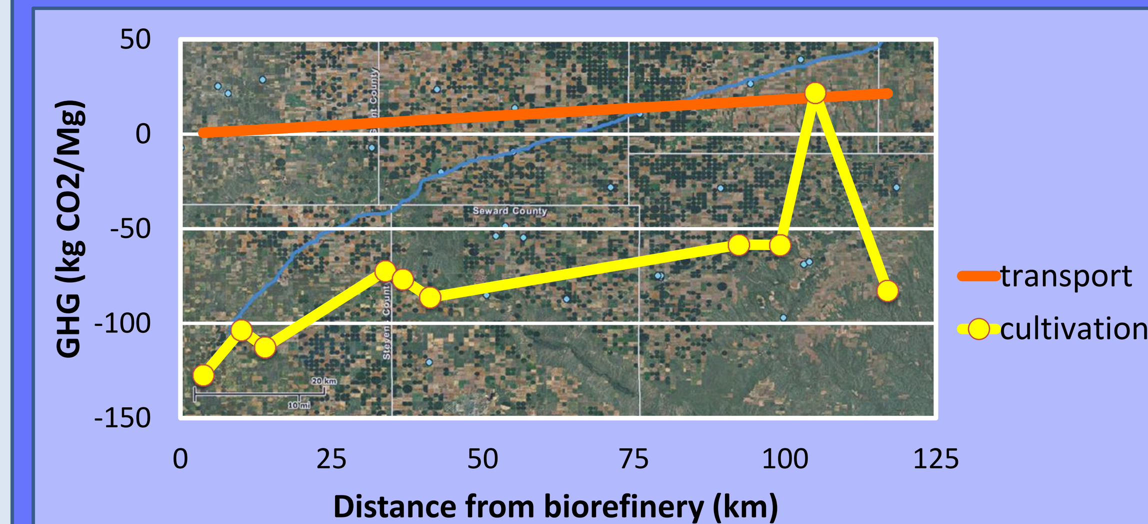
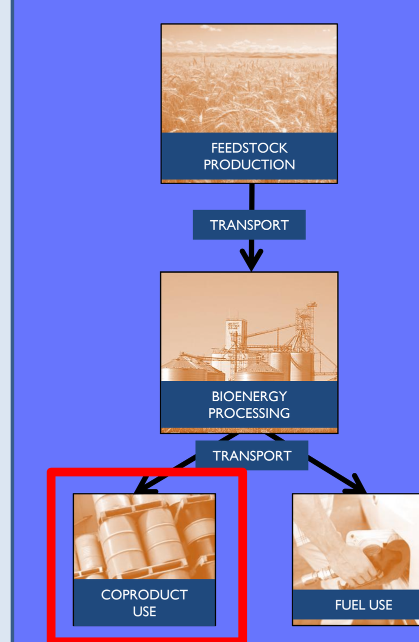


Figure 3. Magnitude of transport and cultivation emissions per tonne of switchgrass feedstock produced. Negative cultivation emission values indicate carbon sequestration in soil that exceed nitrous oxide emissions.

Results: Cultivation emissions due to nitrous oxide formation and soil carbon changes show significant variability from site to site along the transect, usually much greater in magnitude than the associated transport emissions. This result suggests that the optimal GHG-mitigating system design involves the targeting of low-cultivation-emission sites for feedstock farming, since the associated emissions savings outweighs the additional transport emissions incurred.

COPRODUCT USE



Key uncertainty for biochar: What factors drive the biochar market?

Introduction: The economic value of coproducts is essential to the viability of the bioenergy industry. Biochar is one potential coproduct, derived from the pyrolysis of biomass in a low or no-oxygen environment. Biochar has value as a soil amendment in some areas though the science underlying its effects is not fully understood, hence markets are still in development and future pricing remains uncertain.

Method: We analyzed the drivers of the existing biochar market in the United States to better understand viable future directions for economic development.

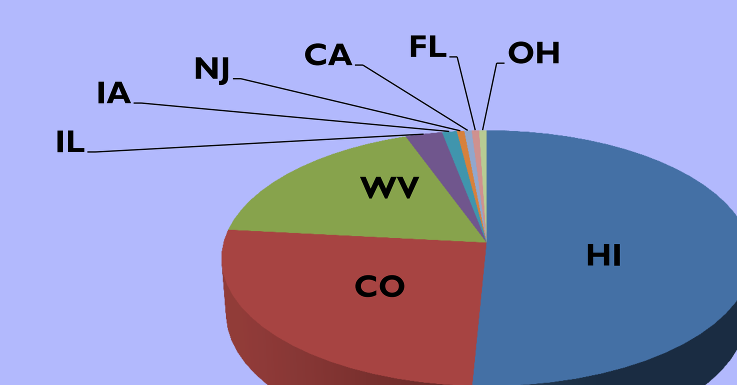


Figure 4. Current U.S. biochar production market shares by state

Results: The current biochar market is dominated by Hawaii, Colorado, and West Virginia[4]. In HI, the biochar market is driven by *use as an amendment* for the highly weathered acidic soils. In CO, the market is driven by *research and mine reclamation projects, in conjunction with disposal needs* for large amounts of forest waste[5]. In WV, the market is driven by *research needs and limited retail*. These drivers are highly variable by region, and some drivers are likely short-term.

Regional specificity reduces uncertainty and maximizes benefits

Variability due to spatial heterogeneity in environmental factors and coproduct markets are major sources of uncertainty in the analysis of environmental and economic outcomes for bioenergy production systems. While full-system analysis has historically been performed at the national or global level in order to draw generalized conclusions about broad technologies, the detailed design of successful systems will require that such methods be applied at finer scales. Optimizing environmental outcome requires modeling at fine spatial scales to identify areas of maximum sustainable residue removal or most favorable energy crop cultivation. Likewise, maximizing system profitability is dependent upon a regionally-specific analysis of coproduct markets in order to target the most profitable production scenarios.

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References:

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