

Integrated Spatially Explicit Optimization of Biofuel Supply Chains and Landscape Design Considering Biomass Supply Uncertainty

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Project Goals: To develop a generalized spatially explicit biofuel supply chain stochastic optimization model that accounts for biomass supply uncertainty.

The overall environmental and economic performance of biofuel supply chains (SC) is highly sensitive to the spatial distribution of available land for biomass production. Because large quantities of dedicated bioenergy crops have yet to be planted, there is an opportunity to use mathematical programming techniques to optimize the biofuel supply chain network design. We modeled the supply chain network design problem as a two stage stochastic mixed integer linear program which takes into account the uncertainty in biomass supply as a set of discrete scenarios with known probability. Given (i) the spatially explicit available land, (ii) biomass yield potential at each site, (iii) potential biorefinery and preprocessing depot locations, (iv) potential preprocessing and conversion technologies, (v) cost parameters and greenhouse gas (GHG) emission parameters. The model finds the optimal (i) biorefinery and depot locations, (ii) technology, (iii) capacity, (iv) transportation, production, and inventory planning, (v) crop establishment locations, (vi) and land management; the combination of which minimizes the total annualized cost of the supply chain. Model complexity is sensitive to the number of uncertainty scenarios, the size of the study area, and the number of supply chain nodes considered. As model complexity increases, approximations that sacrifice model accuracy for computational tractability are introduced to solve larger problems. A case study is performed in southern Michigan. Our results show that by adjusting the cost of carbon (\$/MgCO₂e), decision makers can decide how much to value reductions in GHG emissions with respect to SC costs. Also, by considering uncertainty, the performance of optimal supply chain configurations is more robust to the realization of uncertain biomass yields. We show that when designing biofuel supply systems it is important to consider the environmental and economic tradeoffs between land management, supply chain operation, and capital decisions and how these decisions guard against system disruptions and uncertainty.

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