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Supply Chain Analysis of Applying Spent Microbial Biomass (SMB) from Bioprocessing Plants as Soil Amendment

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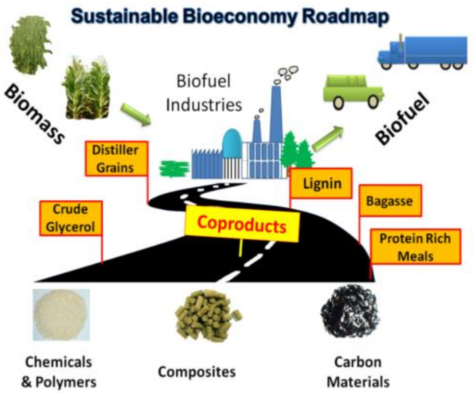
DuPont Tate & Lyle BioProducts

Opportunity

The global interests in expansion of bioeconomy brings opportunities:

- Firms to capitalize on growing consumer demand for products with smaller environmental footprint



- Research on the economic and logistic feasibility of recovering the values of ‘Waste’ or co-products produced by industries that contributes to bioeconomy

Challenge

- Industries contributing to the bioeconomy's sustainability requires research on the economic and logistic feasibility of up-scaled problems

- Most of research on value recovery of these type of biomass are constraint in a lab or pilot stage
    - "Wastes" or co-products are typically in non-discrete form
    - Different physical forms: from solid to sludge

Case Study: East Tennessee

- Bioprocessing plant (DuPont Tate & Lyle (**DTL**)) produces:
  - Main product: BioPDO (140 million lbs per year)
  - By-product: Spent Microbial Biomass (SMB) (12,000 tons per year)
- Farmers can save on fertilizer by using SMB as:
  - Soil amendment
  - Fertilizer substitute
- University of Tennessee (**UT**) BioSystem Engineering and Soil Science (**BESS**) and DTL researchers have conducted years of research with participations of local farmers on:
  - Technical feasibility : application rate , carbon sequestration, machine (spreader)

The Firm's Problem

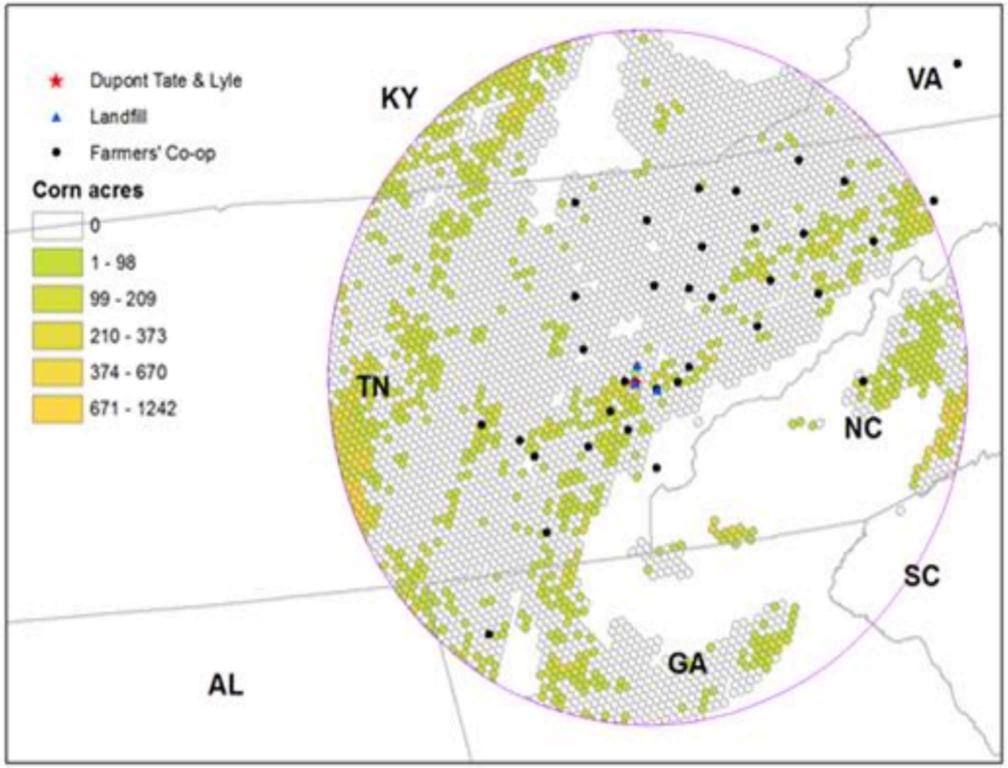
- Question: How can a supply chain network ensure that SMB is properly stored and delivered to farmers at the time needed and maximize the overall value generated?

  - "Just-right" quantity, location, and time
    - Where and how to store SMB?
    - Shipping from where to where?
  - The best physical form
    - What's the optimal moisture content for SMB?

Objectives

- Identify optimal SMB supply chain network configurations that will maximize the overall generated value

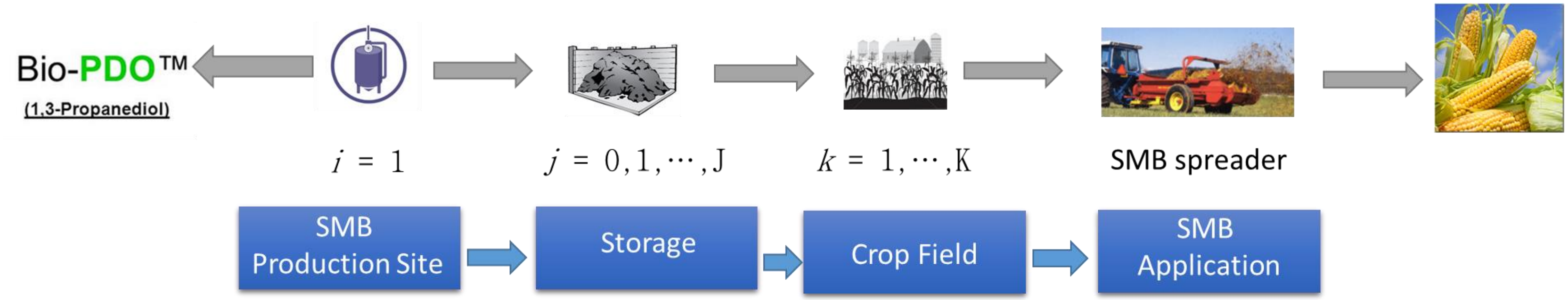
Study Region and Decision Units

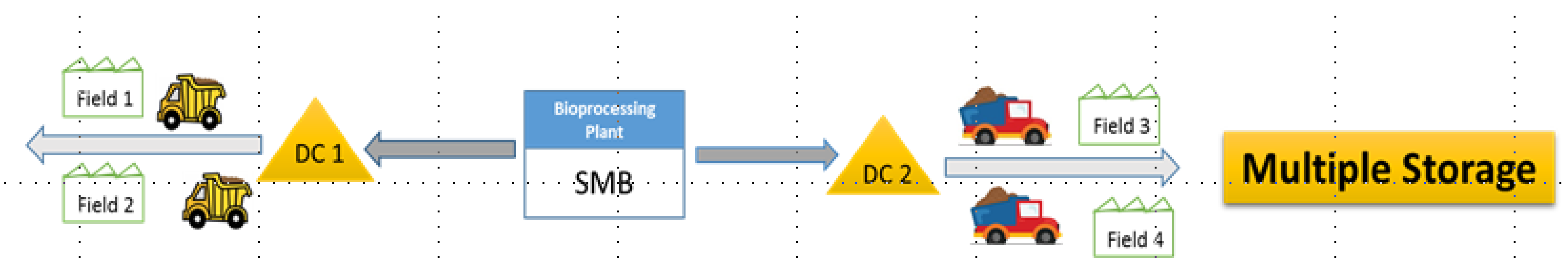


Define supply chain system

- The production of SMB is constant at a daily base
- The application of SMB on crop production occurs in spring (before planning) or fall (after harvesting)
- To use SMB at full capacity, a storage system is needed
- Crop production is distributed across the study region, multiple storage facilities may be needed

Supply Chain System





Supply Chain Network Optimization (MILP)- Objective

Maximize $RVE - CP - CN - CT - CS$

corn revenue	$RVE = \sum_{k=1}^{K} X_k \cdot Y_k \cdot P$
corn production cost other than nitrogen costs	$CP = \sum_{k=1}^{K} X_k \cdot (VC + FE)$
remaining nitrogen cost after applying SMB	$CN = NP \cdot \left(\sum_{k=1}^{K} r \cdot X_k - \sum_{j=1}^{J} \sum_{k=1}^{K} V_{j,k} \cdot (1-\beta) \cdot \gamma\right)$
SMB transport costs	$CTF = \sum_{j=1}^{J} \sum_{k=1}^{K} V'_{j,k} \cdot \left[CL \cdot (LT + ULT + 2 \cdot \frac{D'_{j,k}}{SPL}\right] / LW$ + $CTS = \sum_{i=1}^{1} \sum_{j=1}^{J} V_{i,j} \cdot \left[CL \cdot (LT + ULT + 2 \cdot \frac{D_{i,j}}{SPL})\right] / LW$
SMB storage cost	$SC = \sum_{j=1}^{J} \sum_{s=1}^{S} B_{j,s} \cdot H_s$

Supply Chain Network Optimization (MILP) - Constraints

- Subject to:
  - ➢Constraints on total SMB available
  - ➢Constraints on storage capacity
  - ➢Constraints on number of storage in each decision making unit

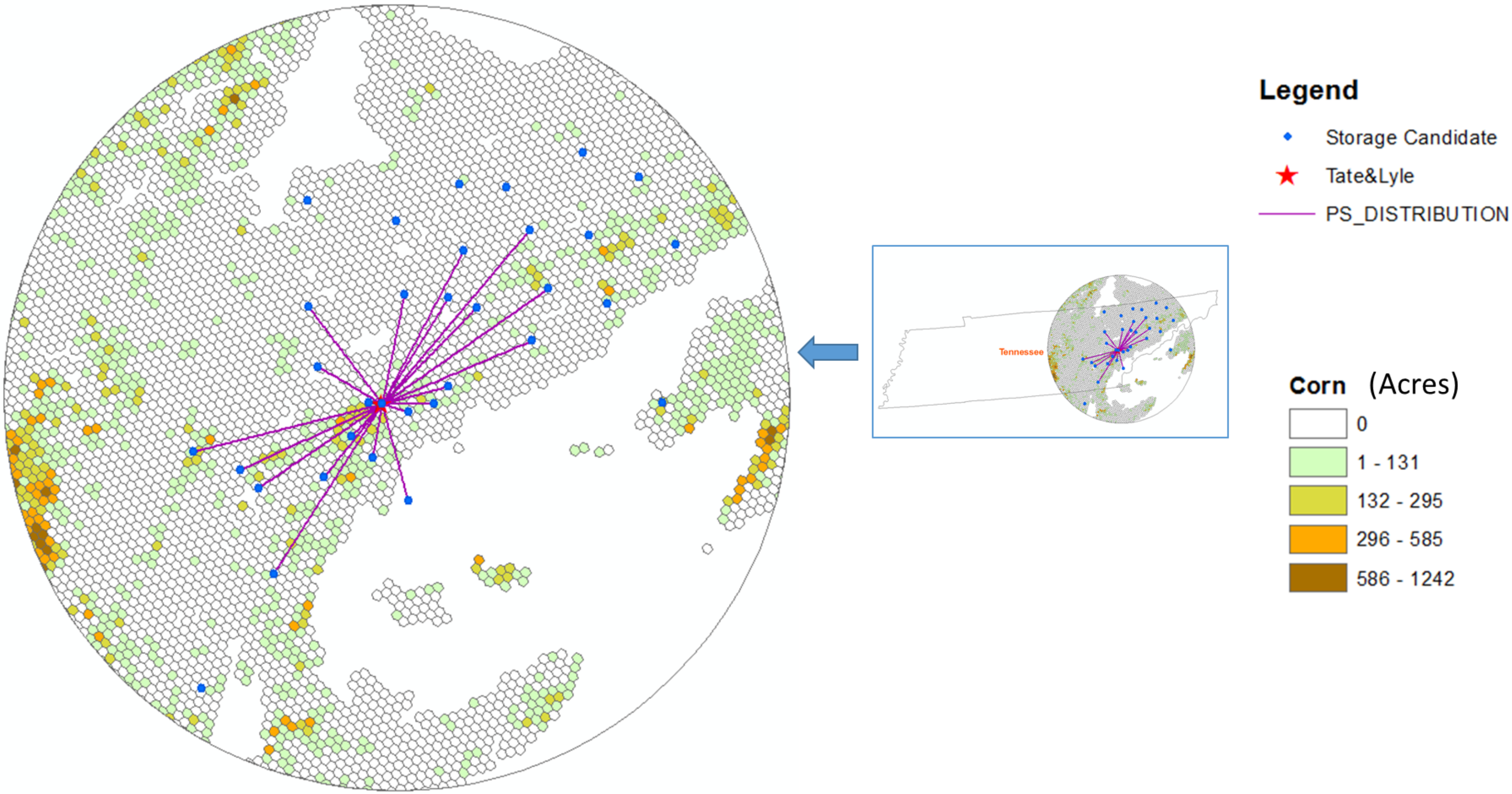
Other Assumptions

- Farmers are willing to apply SMB as (Nitrogen) fertilizer substitute
- The production level of SMB is known and constant every year
- storage candidate sites
  - Farmers CO-OP

Data

- Geographic location of corn production
  - Crop Data Layer generated by USDA's National Agricultural Statistics Service
  - Digitized and superimposed on 5-square miles hexagons
- Geographic location of Farm CO-OP
  - Tennessee Farmers Cooperative
- Distance matrix generated with real road system using ArcGIS
- Corn production budget
  - UT extension (no-till, non-irrigated corn)
- SMB parameters
  - Sullivan et al.2017
  - Personal communication with BESS and DTL

Preliminary Solutions



Preliminary Solutions