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# A MULTI-AGENT SIMULATION OF REGIONAL FOOD HUB SUPPLIER MANAGEMENT

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## ABSTRACT

Over the past decade, consumer interest in regionally-produced food has grown significantly. Small- and medium-scale food producers, which lack the necessary scale to satisfy large-scale distributor volume and price point requirements, can benefit by selling to regional customers through food hubs. One of the many challenges that food hubs face is determining appropriate policies for supplier management. To assess the effects of different policies on regional food system outcomes, we have developed a multi-agent simulation model of a theoretical regional food system in which farmer agents and a food hub agent iteratively negotiate, trade, evaluate outcomes, and adapt their strategies based on these outcomes. The model captures individual and system performance measures and illustrates tradeoffs associated with each policy.

## 1 INTRODUCTION

Over the past decade, consumer interest in regionally-produced food has grown significantly. Proponents of regionalized food systems value the perceived quality and safety of local products, the transparency and availability of information about the producers and their production methods, and the satisfaction of supporting regional businesses. Small- and medium-scale food producers, which often lack the necessary scale to satisfy large-scale mainline distributor volume and price point requirements, can benefit greatly by selling to regional customers. Most of these producers market their products to consumers directly (e.g., through farmers' markets). However, farmers' markets are an inefficient market channel for larger-scale institutional customers (e.g., restaurants, grocery stores, schools), and until recently there have been no mechanisms to connect these customers with regional producers. As a result, the producers are unable to access a significant economic opportunity, and institutional customers are unable to meet the demands of their customers for regionally-produced food.

To address this problem, there have been recent efforts to develop new farm-to-institution marketing and distribution channels, such as regional food hubs. Food hubs act as regional aggregation points between producers and institutional buyers, for both physical products and information. Food hubs allow institutional buyers to gain access to regionally-produced food without overwhelming transaction costs, and provide small- and medium-scale producers with access to a market with consistent demand and adequate prices. In contrast with conventional food distributors, regional food hubs are typically motivated not only by traditional supply chain metrics (i.e., maximizing profits), but also by social concerns (e.g., supporting regional employment). This concern for overall social welfare of regional producers is typically rooted in personal values, a desire to maintain a strong and diverse regional supply base, and/or government incentives in support of regional economic development. One of the many challenges that food hubs face is determining appropriate policies for supplier management that balance these two (often conflicting) objectives. For example, food hub managers would like to know how to determine the ideal number of producers they should work with for each product type to minimize risk, provide customers with sufficient selection, and provide sufficient revenues for the producers. These managers also have

concerns about developing and managing quality assurance policies that satisfy their customers but are not overly burdensome to the producers.

To determine the types of policies for effective food hub supplier management that support economic and social sustainability of a regional food system, we have developed a multi-agent simulation (MAS) model of a theoretical regional food system using NetLogo. MAS is particularly well-suited to modeling this type of system, allowing us to capture the dynamic interactions and adaptations of autonomous and heterogeneous actors and to study their effects on overall system outputs and outcomes over time.

## 2 METHODOLOGY

The model contains two agent types: farmer agents and a regional food hub agent. There are 100 farmer agents of variable farm size, each of which can supply a single crop type to the food hub in each time-step (where one time-step represents one week). Each farmer agent's objective is to prevent his "satisfaction" from falling below a threshold value (where "satisfaction" is based on profit). The food hub agent seeks to satisfy its demand while maintaining low costs and high product quality. In each time-step:

- The food hub's demand is stochastically generated.
- Farmer agents produce food to sell. The quantity and quality of the food is stochastic.
- The food hub invokes its supplier selection policy and iteratively selects farmers to fill demand.
- The food hub and each selected supplier negotiate the terms of their transaction.
- The food hub evaluates each farmer's performance (in terms of pricing and food quality) and records these outcomes in its memory to inform future decision making.
- Each farmer agent evaluates its satisfaction and adapts its marketing strategy accordingly. This determines the quantity, price, and quality of food that it will offer the hub in the next time-step.

Possible supplier selection policies for the food hub include:

- Selecting farmers randomly
- Prioritizing/rewarding top-performing farmers and rejecting farmers that yield poor-quality food
- Prioritizing/rewarding top-performing farmers and penalizing farmers that yield poor-quality food

## 3 RESULTS

For each supplier selection policy, the model was run for 30 replications of 100 time-steps each. The following output metrics were captured at the end of each replication and analyzed statistically:

- Farmer and food hub profitability
- Number of farmers required to satisfy food hub demand
- Size distribution of the farmers selected by the food hub
- Overall quality of food supplied to the food hub

Results indicate the nature of the relationships between food hub policies, individual agent profitability, and overall food system performance. We discuss the tradeoffs between food quality, individual agent satisfaction, and social considerations. This theoretical model will become the basis for a future larger-scale model that will be used to analyze supplier management policy for regional food hubs, using input data from existing regional food systems in Iowa.