Using Insights From Network Science to Enhance Agricultural Entrepreneurship

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Key trends affecting food and agriculture

- Rising obesity rates
  - CDC maps, OECD 2010
  - Food deserts; hunger + obesity
- Interest in local and regional foods
  - Supply chain analyses
  - Consumer supported agriculture
  - Farm to Fork, School, Institution, etc.
- Growth in farm numbers (small, niche)
- Economic Networks and Clusters
Obesity is defined as a BMI of 30.0 or over, overweight as a BMI of 25.0 to 29.9.
Can “Mobile Food Markets” serve food deserts?

Source: Columbia Univ., Urban Design Lab
New York City Regional Foodshed Initiative

Source: Columbia Univ., Urban Design Lab
Food System (value chain) idea is not new

Tart Cherry Marketing Channels (or Sub Sector)

- Growers
- Processors
- Food Manufacturers
- Food Service Firms
- Consumers
- Export
- Grocery Retail – Wholesalers

What can we learn from network science to enhance food supply chains extending into New York City? Or Chicago?
The Rise of Social Networks and Virtual Worlds
Zynga (Farmville)

FarmVille is a game where you can farm with your friends.
The Science of Networks

Nodes

Links
Each node represents a person; each line represents a potential channel for interpersonal communication. The most central node in each network is colored black (darkest).

Network Analysis: “Kite Diagram”

Measures:
1. Degrees – number of direct connections
2. Betweenness – quality of direct connections
3. Closeness – degrees of separation (lengths of communication paths)

Source: After Krackhardt (2008)
**Actor degree centrality**

\[ C_D(n_i) = d(n_i) = x_{i+} = \sum_j x_{ij} = \sum_j x_{ji} \]

\( n = \text{node} \)
\( x = \text{tie (link)} \)
\( i, j = \text{individual} \)

Standardization measures are independent of \( g \) and can be compared across networks of different sizes:

\[ C'_D(n_i) = \frac{d(n_i)}{g - 1} \]

Group degree centralization:

\[ C_D = \frac{\sum_{i=1}^{g} [C_D(n^*) - C_D(n_i)]}{\max \sum_{i=1}^{g} [C_D(n^*) - C_D(n_i)]} \]

*Source: After Wasserman and Strauss (2006)*
**Actor betweenness centrality**

\[ C_B(n_i) = \sum_{j<k} g_{jk}(n_i) / g_{jk} \]

Group betweenness centralization

\[ C_B = \frac{2\sum_{i=1}^{g} [C_B(n^*) - C_B(n_i)]}{[(g - 1)^2 (g - 2)]} \]

**Actor closeness centrality**

\[ C_C(n_i) = \left[ \sum_{j=1}^{g} d(n_i, n_j) \right]^{-1} \]

The sum of distances from actor \( i \) to all the other actors. Index of group closeness:

\[ C_C = \frac{\sum_{i=1}^{g} [C_C'(n^*) - C_C'(n_i)]}{[(g - 2)(g - 1)/(2g - 3)]} \]
Network Analysis: Measures of Centrality

Source: After Krackhardt (2008)
A Network of Connectors Linked by Weak Ties

Based on: R. Ogle (2007), *Smart World: Breakthrough Creativity and the New Science of Ideas*
For a given network, $P(k)$ is the fraction of nodes that have $k$ links. $P(k)$ is a connectivity distribution or probability that a randomly chosen node in a network has $k$ links.
Topological phase transitions of networks

After Csermely (2009)
Real-World Applications
Map of the Internet, colored by IP addresses, by William R. Cheswick

Source: Albert (2010)
2009 Northeast Local Foods Conference (LFC): Pre-Conference Network (N~100)

Total number of ties: 629

“Isolates”, made new connections at the event

The total number of ties increased from 629 to 1,429

Suppose there are at least two distinct sub-groups or “affinity” networks.

If these two groups can learn from one another, how can they be linked?

Local Foods Conference:

A few have many connections, many have few

The number of other participants with whom the respondent had worked or “connected” prior to the conference

Source: K Brasier and S Goetz, LFC Technical Report, 2010
Local Foods Conference: 

The Law of Preferential Attachment: 
The rich get richer

Prior connections and new connections made at the conference.

Source: K Brasier and S Goetz, LFC Technical Report, 2010
Another example of the potential to use networks...

Photo courtesy of: ces.ca.uky.edu/Lee/AgNaturalResources

Basic Idea: Columbia Urban Design Lab
versus...

Beyond cooperatives (clusters):
Information sharing/learning
Compete AND cooperate
Regional branding
Influence legislation

Photo courtesy of: ces.ca.uky.edu/Lee/AgNaturalResources
Northeastern Food Supply Chains (examples)

Map prepared by Pamela K. Hileman, The Northeast Regional Center for Rural Development; http://nercrd.psu.edu


- AD-Angello’s Dist.
- AMH-American Mussel Harvesters
- BB-Borealis Breads
- BH-Basis Holdings LLC
- CADE-Center for Agriculture Development and Entrepreneurship, Inc.
- CB-Chenango Bounty
- CF-Chesapeake Fields
- CJH-Celars at Jasper Hill
- COM-Crown O’Maine
- CROPP-Organic Valley Coop. East
- DR-Deep Root Organic Truck Farmers
- EB-Earth Brokers, LTD
- EFC-Evans Farmhouse Creamery and Maple Sugar House
- FC-The Farmers Cow Cooperative
- Fchef-Farm to Chef
- FF-Farm Fresh Connection LLC
- FPC-Fresh Point Connection
- FL-Finger Lakes Organic Grower Coop.
- HVA-Hawthorne Valley Association
- HVT-Hardwick VT Cluster
- IF-Isadore Foods LLC
- OD-Oakhurst Dairy
- PFNM-Pineland Farms Natural Meats
- PVMM-Pioneer Valley Milk Marketing
- RAI-Regional Access, Inc.
- RFMC-Rhody Fresh Milk Cooperative
- RH-Red Hen Baking Company
- RT-Red Tomato, Inc.
- RP-Real Pickles
- RVF-CT River Valley Foods
- SMC-Silvery Moon Creamery
- SRM-South River Miso, Inc.
- TOG-Tuscarora Organic Growers
- WD-White Dog Community Enterprise
- WF-Whole Foods, Inc.
**Distribution Networks of Five Northeast Supply (Value) Chains**

Basic data: Clancy and Ruhf, 2010

Map prepared by David Fleming, The Northeast Regional Center for Rural Development; http://nercrd.psu.edu
Tuscarora Organic Growers
Incorporated 1993
Local. Quality. Integrity.
7 Board Members** (list)

- David Robb* – General manager
- Lee Armstrong – Grower coordinator
- Tony Ricci – Account manager/marketing
- Shawn Rogers – Accounts payable
- Teresa Showalter – Operations manager
- Reina Dudley – Sales
  *replaced Chris Fullerton in 2007

James Crawford, Founder

Parallel Sales (10-20%)

Crop Improvement Meetings

Keystone Development Agency ($)

Processing, loading, sorting, scheduling, marketing, etc.

Tuscarora Organic Growers
Vegetables, herbs, flowers
sold to: Restaurants, Retail, Schools; Wegmans
Farmers sell to one another, supporting roadside stands

TOG Business Network Map

Inputs: Sweet Potatoes, Potting Soil, other

Farmer Members: 22-25 active; Range from 2-60 acres (20-30 avg)

Local labor pools (intern, locals, migrants)

Competition from Whole Foods, Safeway, Giant, etc.

Bus tours, Field days

Department of Agriculture, others

Fingerlakes Organic Growers Oregon Tilth www.tilth.org
Deep Root Organic Coop

CBERP (discontinued)

PASA PCO

“Social sub-groups”

Local building contractors

Violence from Whole Foods, Safeway, Giant, etc.

Processing, loading, sorting, scheduling, marketing, etc.

Commitment charts

Crop Improvement Meetings

Keystone Development Agency ($)

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“Social sub-groups”

Local building contractors
Chesapeake Fields Farmers Cooperative (CFF)
Preservation through Profitability
F. Evans, President

John Hall, Leader

Chesapeake Fields Business Network Map

Parallel Sales
(80-90% of production)

Soy saucers, Bread (artisan), Popcorn

Chesapeake Fields LLC
Joe Bower, President

D. Tompkins – VP
Lansing Williams – CFO
Joseph Goetz – Director of Sales
New business a/c mgr.
Other

Chesapeake Fields Farmers Cooperative (CFF)
Preservation through Profitability
F. Evans, President

Winter meetings w/ farmers

IP protocols

Quality standards, farmer commitments

Corn, wheat, soybeans

Ed Fry
Bill Susan
Bill Cooper
Chris Hagameyer
Roy Crowe

33 Farmers

33 Farmers

Inputs: Seed (wheat, soybeans, corn); Sillinger Seed

Competitive from Frito Lay, snack food cos.

Natto Beans (Japan)

Foreign Visitors, farm visits

Montigue Farms, VA

Department of Ag., Tourism, DBED, other

North Dakota Dr. Neil Doty
Pennsylvania

Univ. of MD, DE; Wash. College

Farmer, consumer, & resident education

Spillover benefits to other farmers

Farm sizes range from 100-500 acres

55 Investors (including non-farmers)

33 Farmers

Input: Seed (wheat, soybeans, corn); Sillinger Seed
Network Graphs

Pennsylvania Women’s Agricultural Network

Chesapeake Fields

TOG

Source: Goetz, Brasier, Raboanarielina and Rangarajan (forthcoming)
Opportunities for entrepreneurs in local and regional foods are huge, and likely to grow.

Making connections within food value chains and discovering new markets is a challenge, but potential payoffs are high.

Requires entrepreneurs who understand the local landscape, plus distant markets.
Mapping and understanding networks of key individuals (hubs) is a starting point.

Network science can provide new insights...

- Importance of weak ties
- Law of preferential attachment (rich get richer)
- Fit get fitter, and richer (more connections)