Using Insights From Network Science to Enhance Agricultural Entrepreneurship

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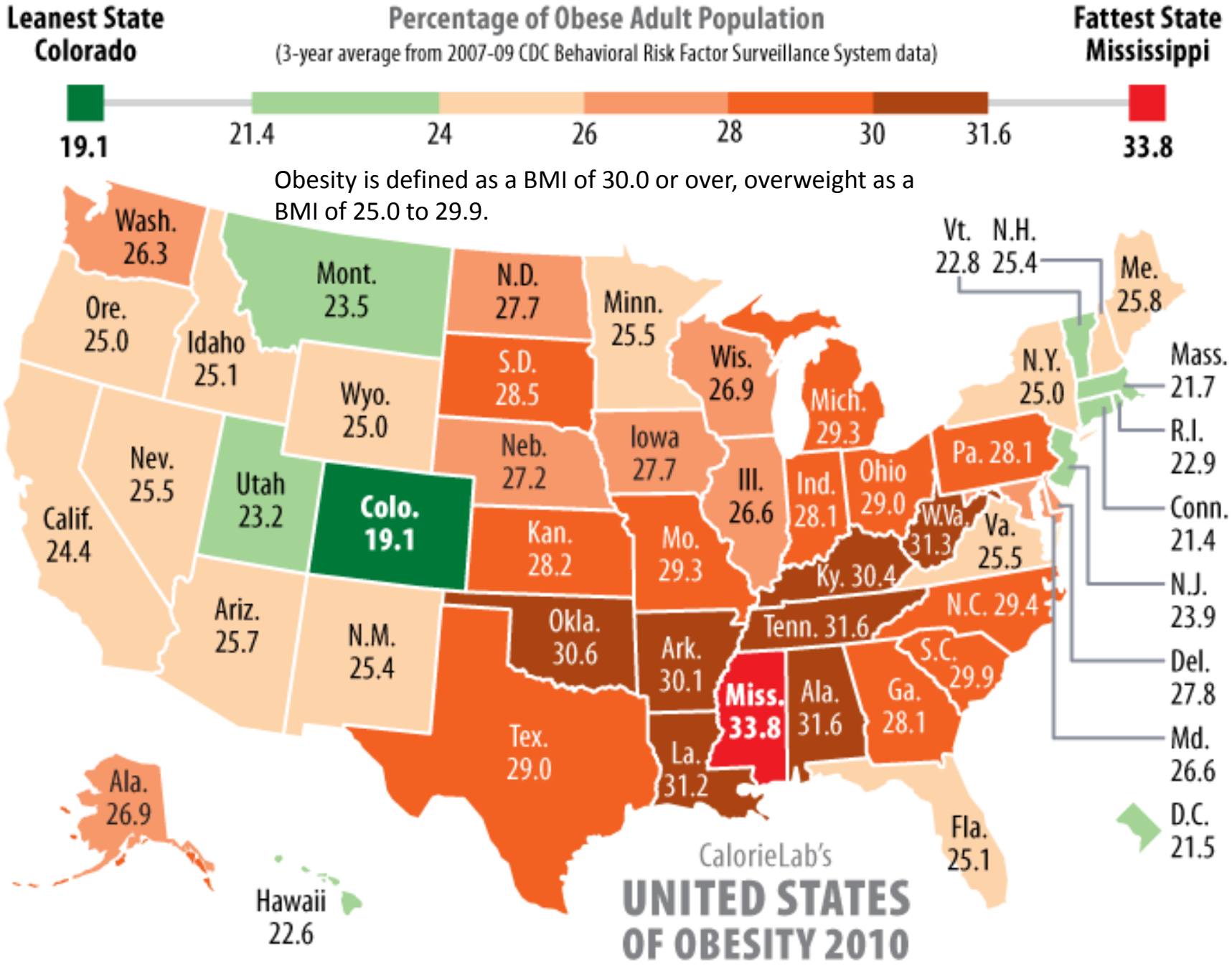
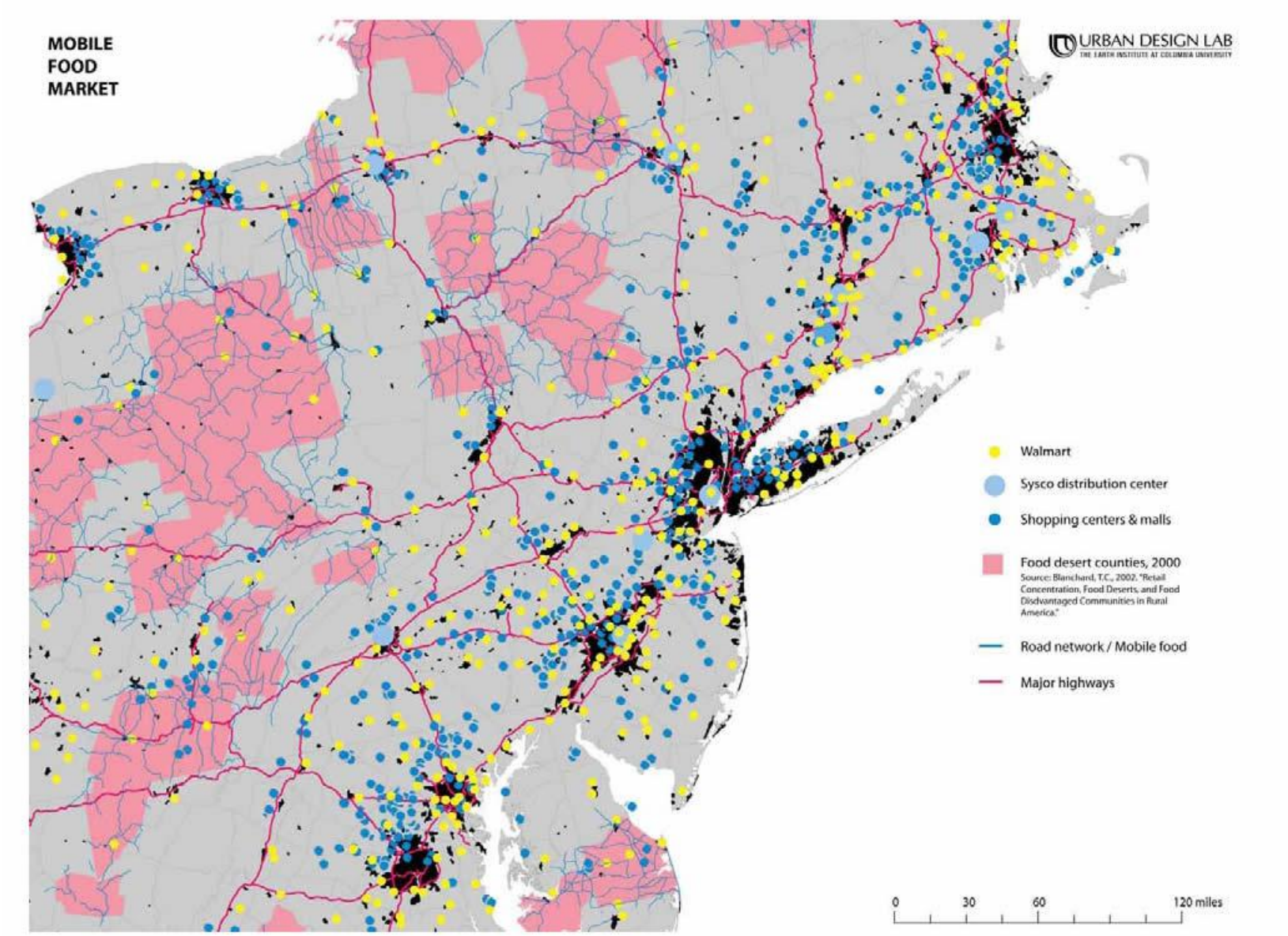
Key trends affecting food and agriculture

- 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



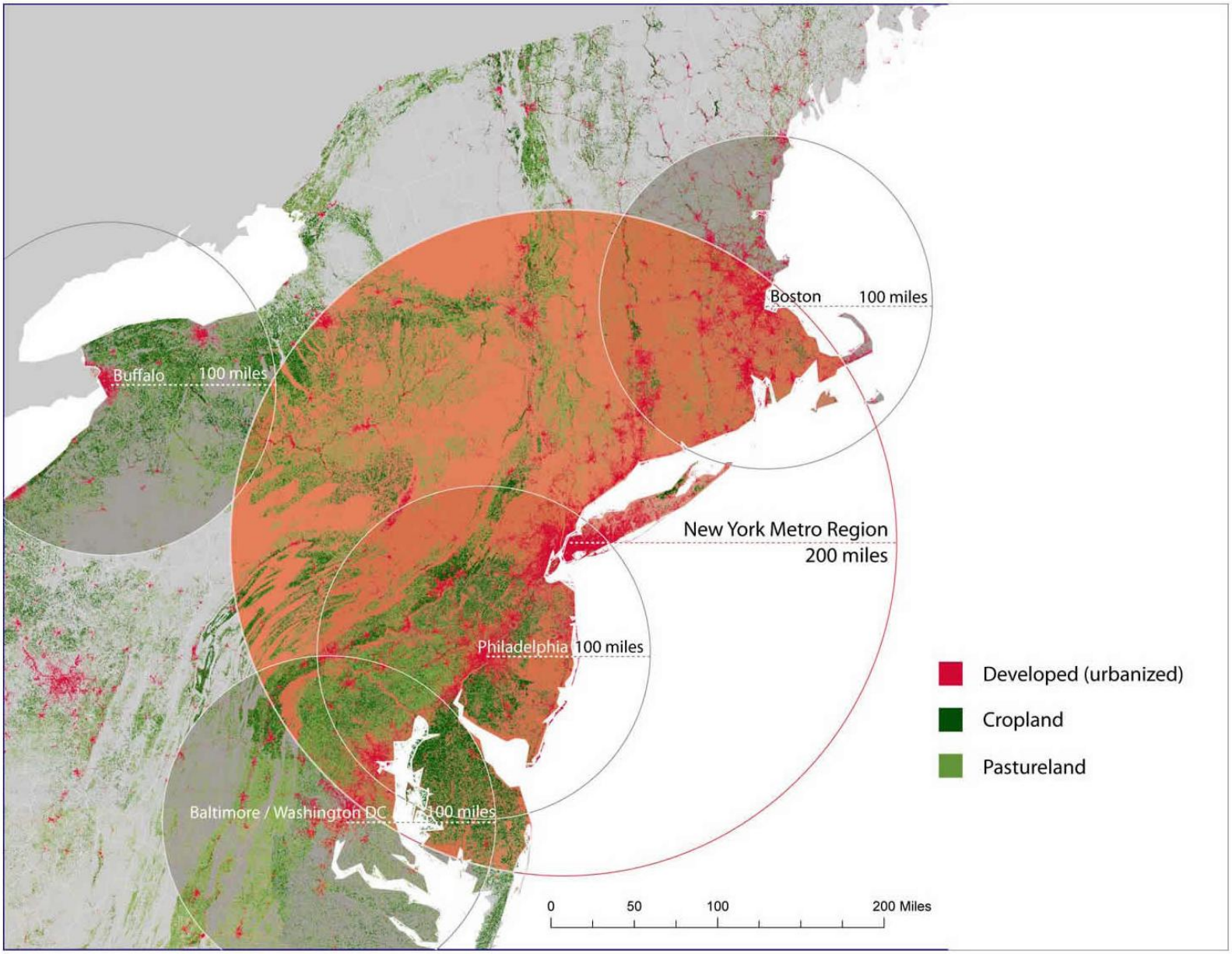
http://calorielab.com/news/wp-images/post-images/fattest-states-2010-big.gif

Can "Mobile Food Markets" serve food deserts?



Source: Columbia Univ., Urban Design Lab

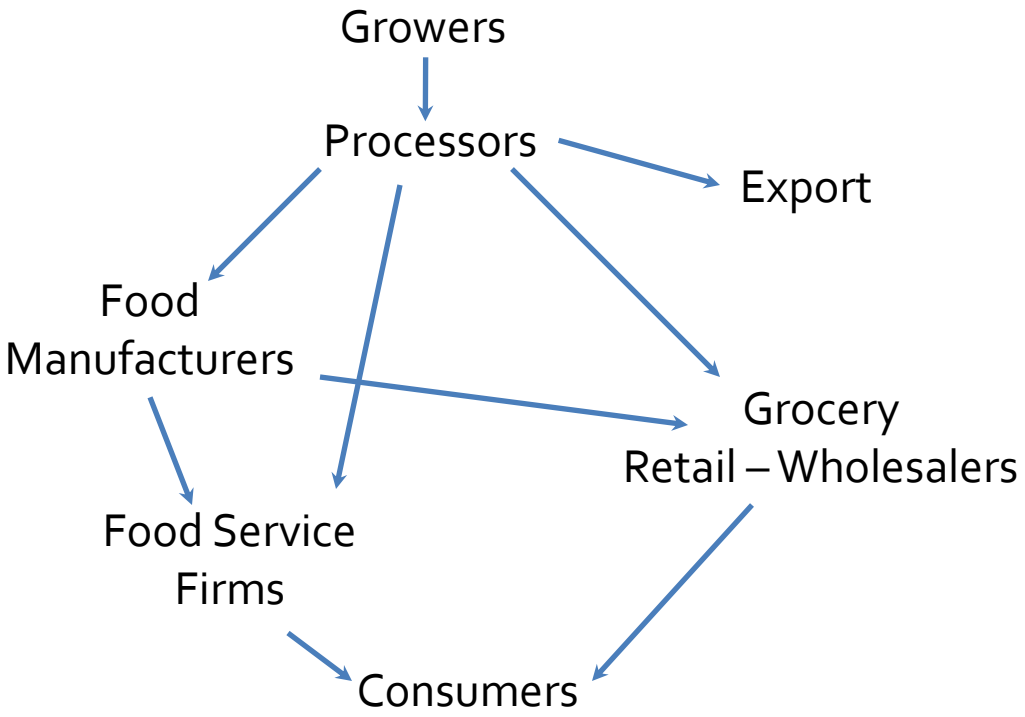
New York City Regional Foodshed Initiative



Source: Columbia Univ., Urban Design Lab

Food System (value chain) idea is not new

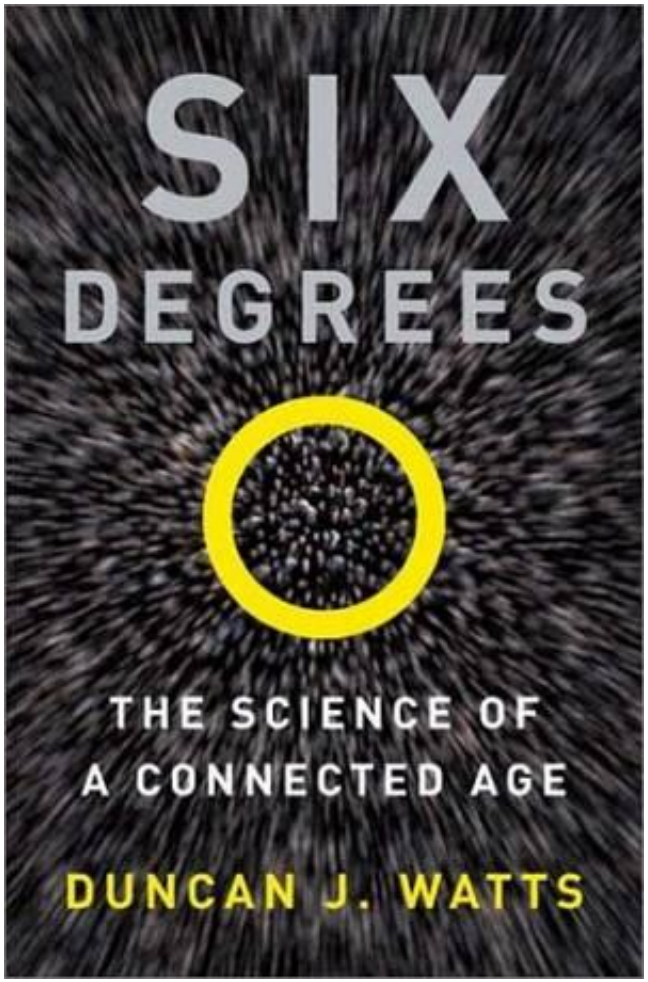
Tart Cherry Marketing Channels (or Sub Sector)



Source: Bruce W. Marion and NC 117 Committee, *The Organization and Performance of the U.S. Food System*, Lexington Books, Mass. 1986 (p.180)

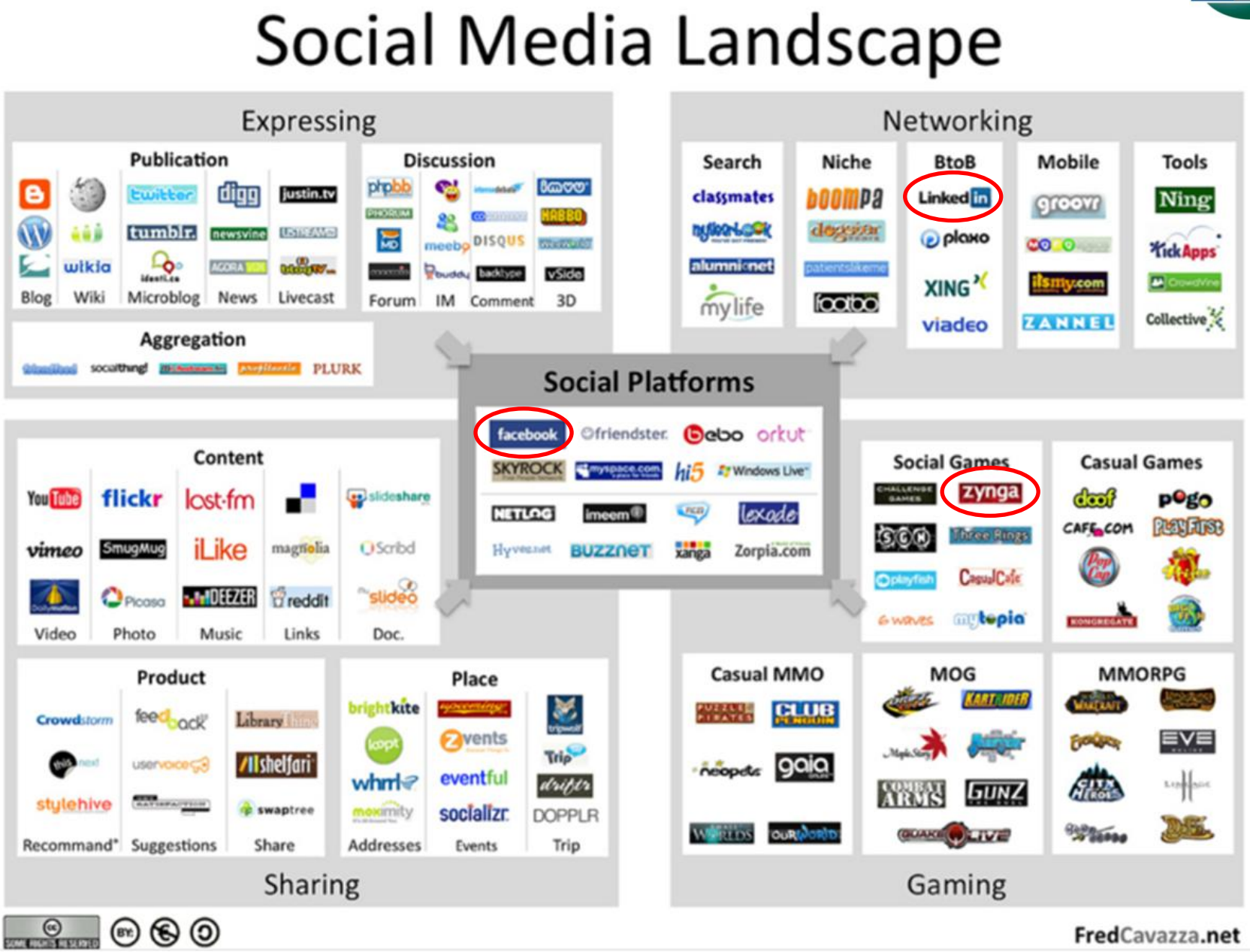
What can we learn from network science to enhance food supply chains extending into New York City?
Or Chicago?

The Rise of Social Networks and Virtual Worlds

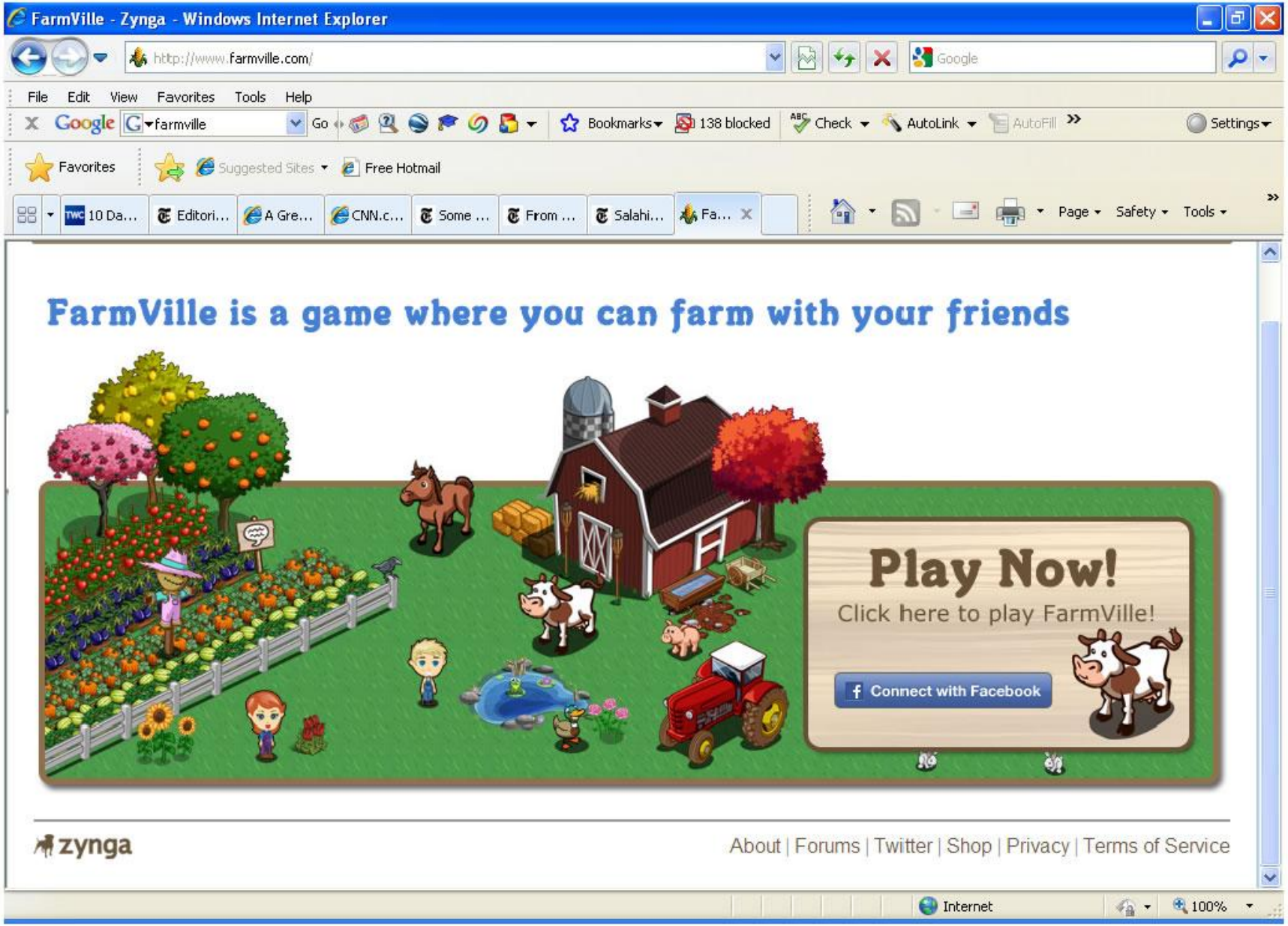


YAHOO! RESEARCH

Social Media Landscape



Zynga (Farmville)

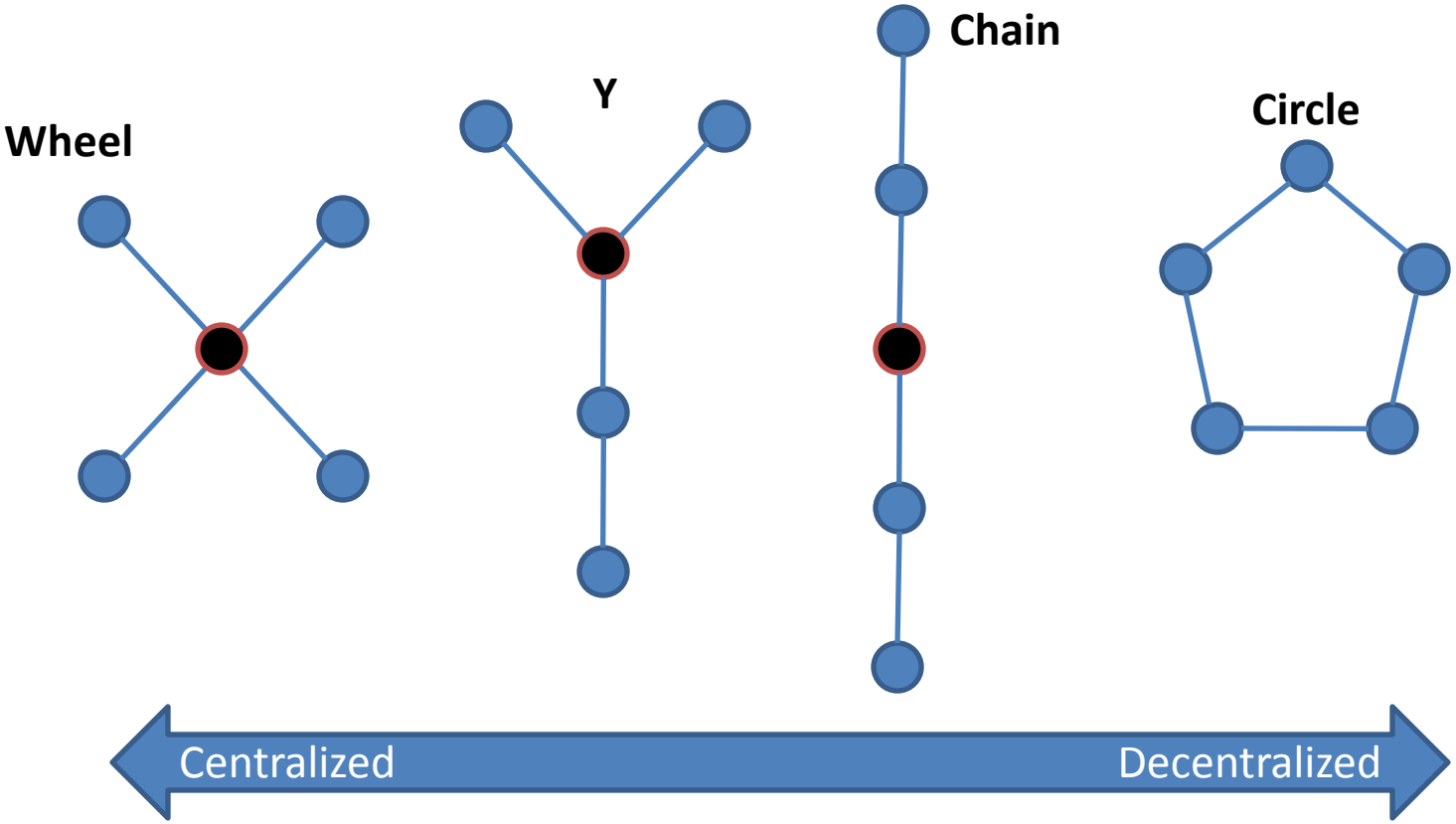


The Science of Networks

Nodes

Links

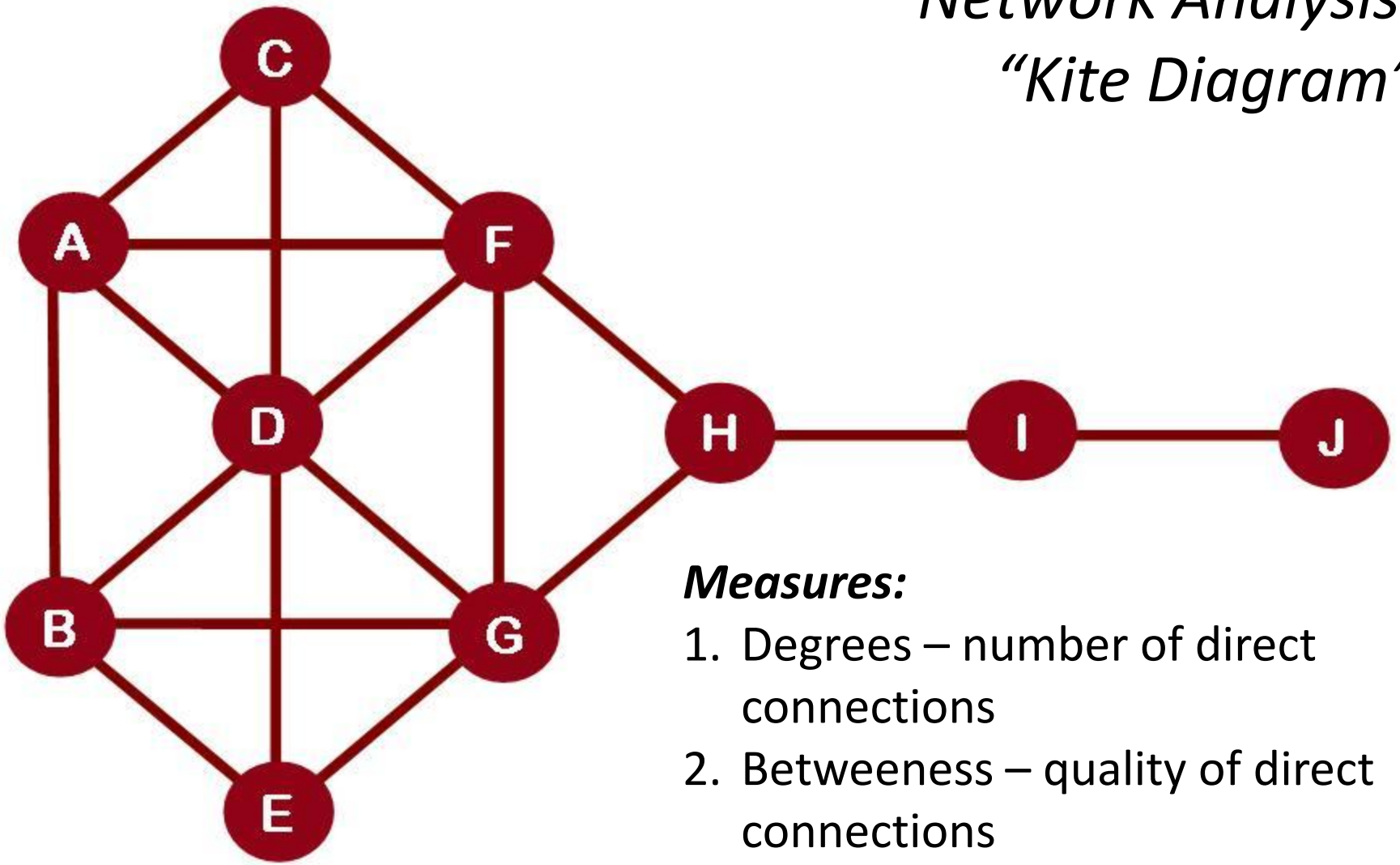
Alternative Structures of Networks (Value Chains)



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).

Source: Borgatti et al., "Network Analysis in the Social Sciences," *Science*, 13. Feb. 2009, Vol. 323, pp. 892-5.

Network Analysis: "Kite Diagram"



Measures:

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

Source: After Krackhardt (2008)

Actor degree centrality

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

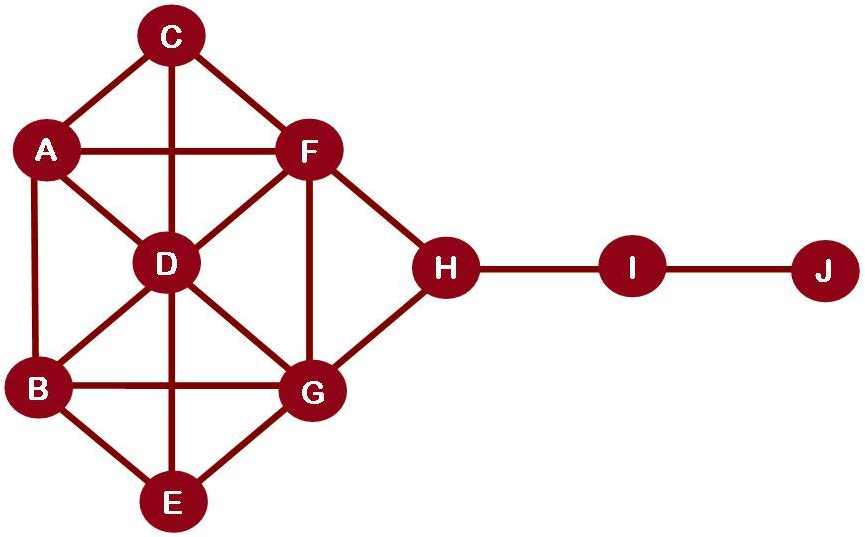
n = node
x = tie (link)
i, j = individual

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:

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



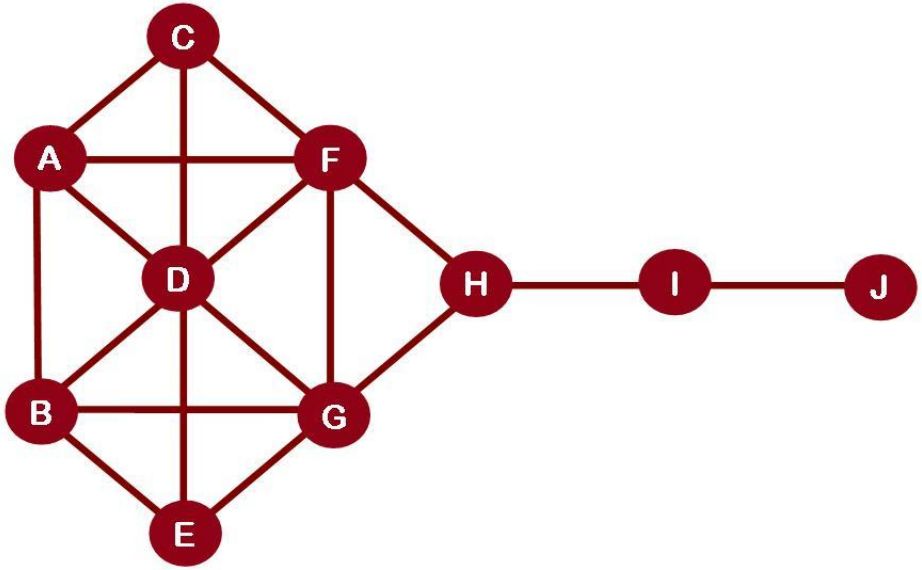
Source: After Wasserman and Strauss (2006)

Actor betweeness centrality

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

Group betweeness centralization

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



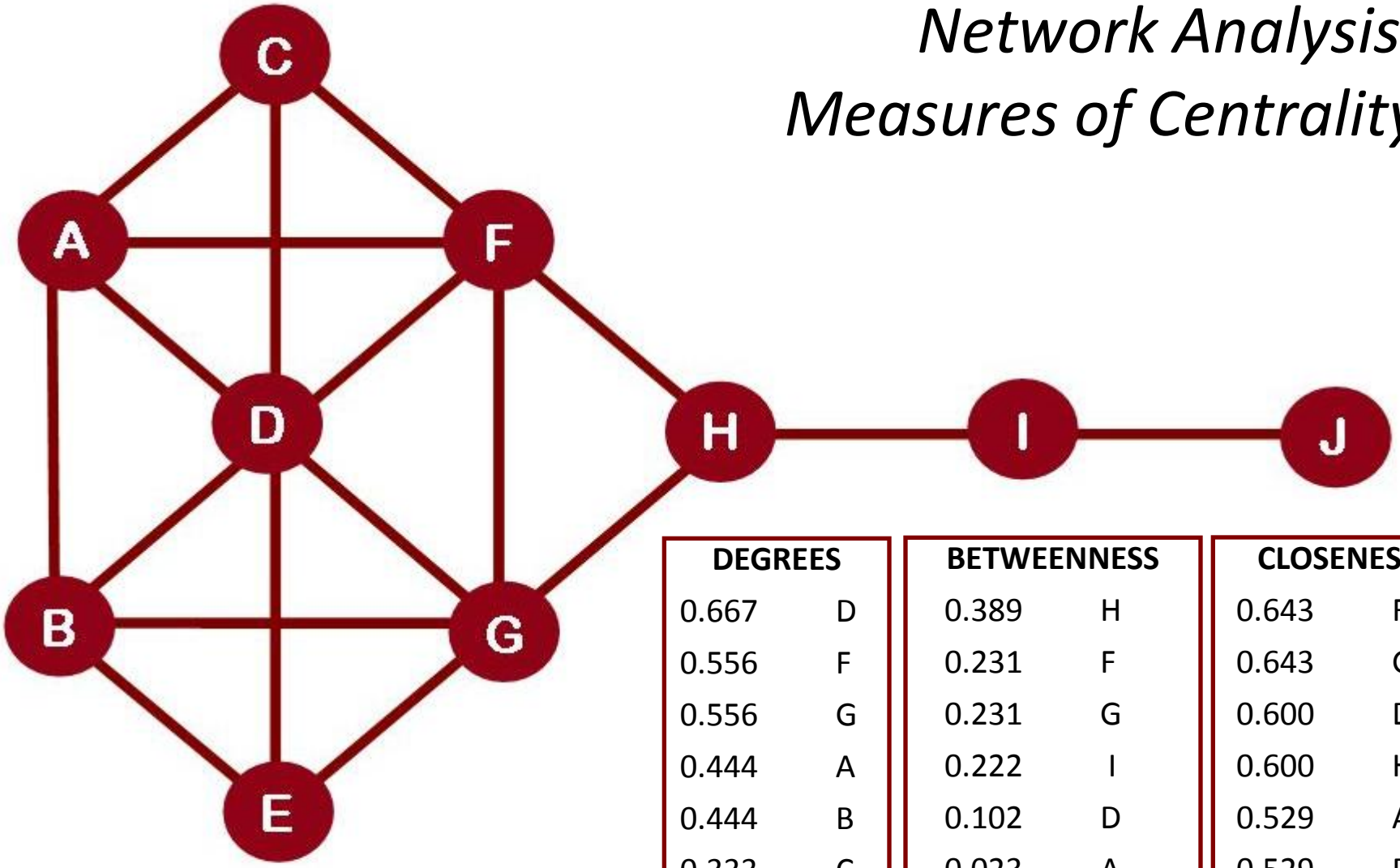
Actor closeness centrality

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

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

$$C_C = \frac{\sum_{i=1}^{g}[C_C'(n^*) - C_C'(n_i)]}{[(g-2)(g-1)/(2g-3)]}$$

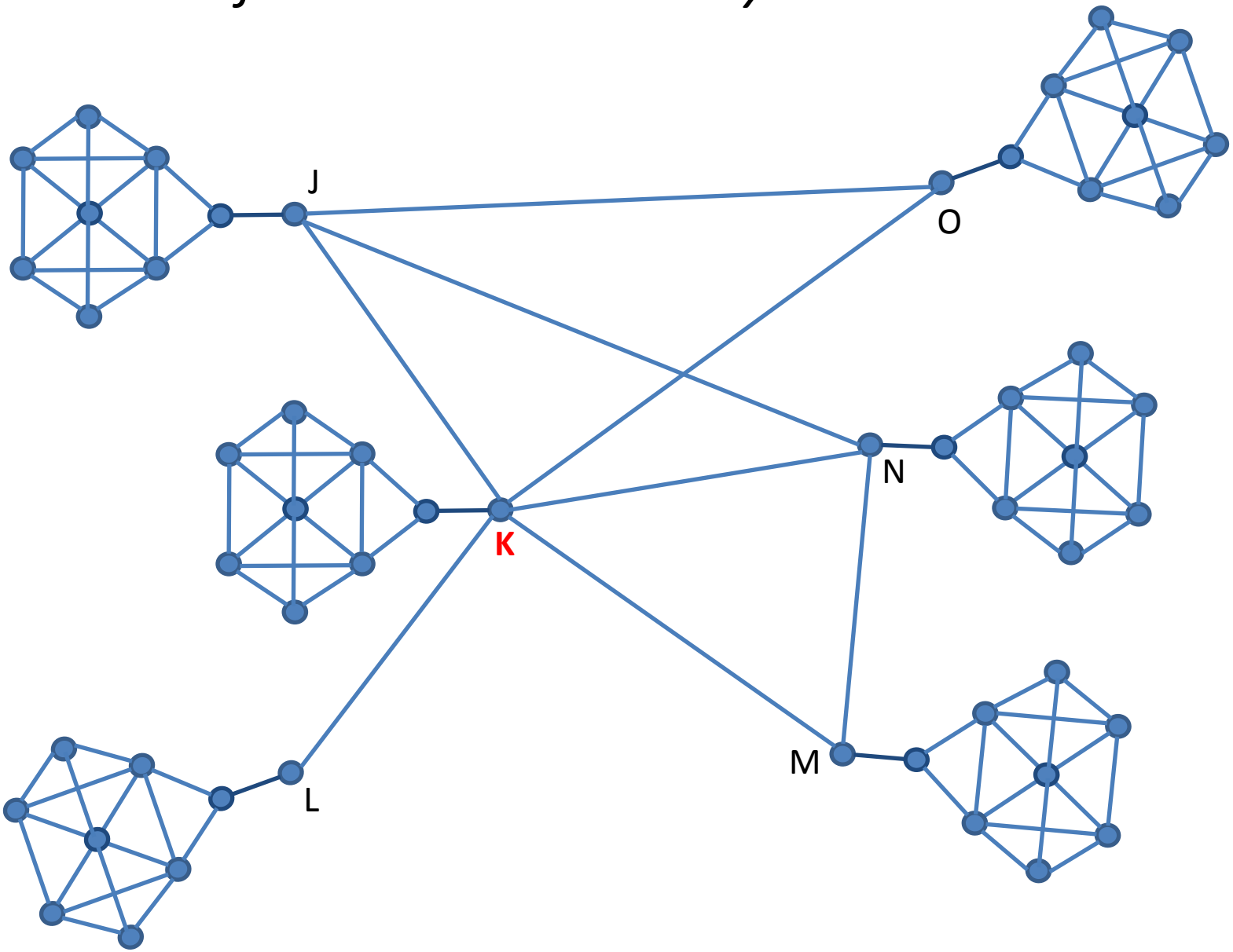
Network Analysis: Measures of Centrality



DEGREES		BETWEENNESS		CLOSENESS	
0.667	D	0.389	H	0.643	F
0.556	F	0.231	F	0.643	G
0.556	G	0.231	G	0.600	D
0.444	A	0.222	I	0.600	H
0.444	B	0.102	D	0.529	A
0.333	C	0.023	A	0.529	B
0.333	E	0.023	B	0.500	C
0.333	H	0.000	C	0.500	E
0.222	I	0.000	E	0.429	I
0.111	J	0.000	J	0.310	J

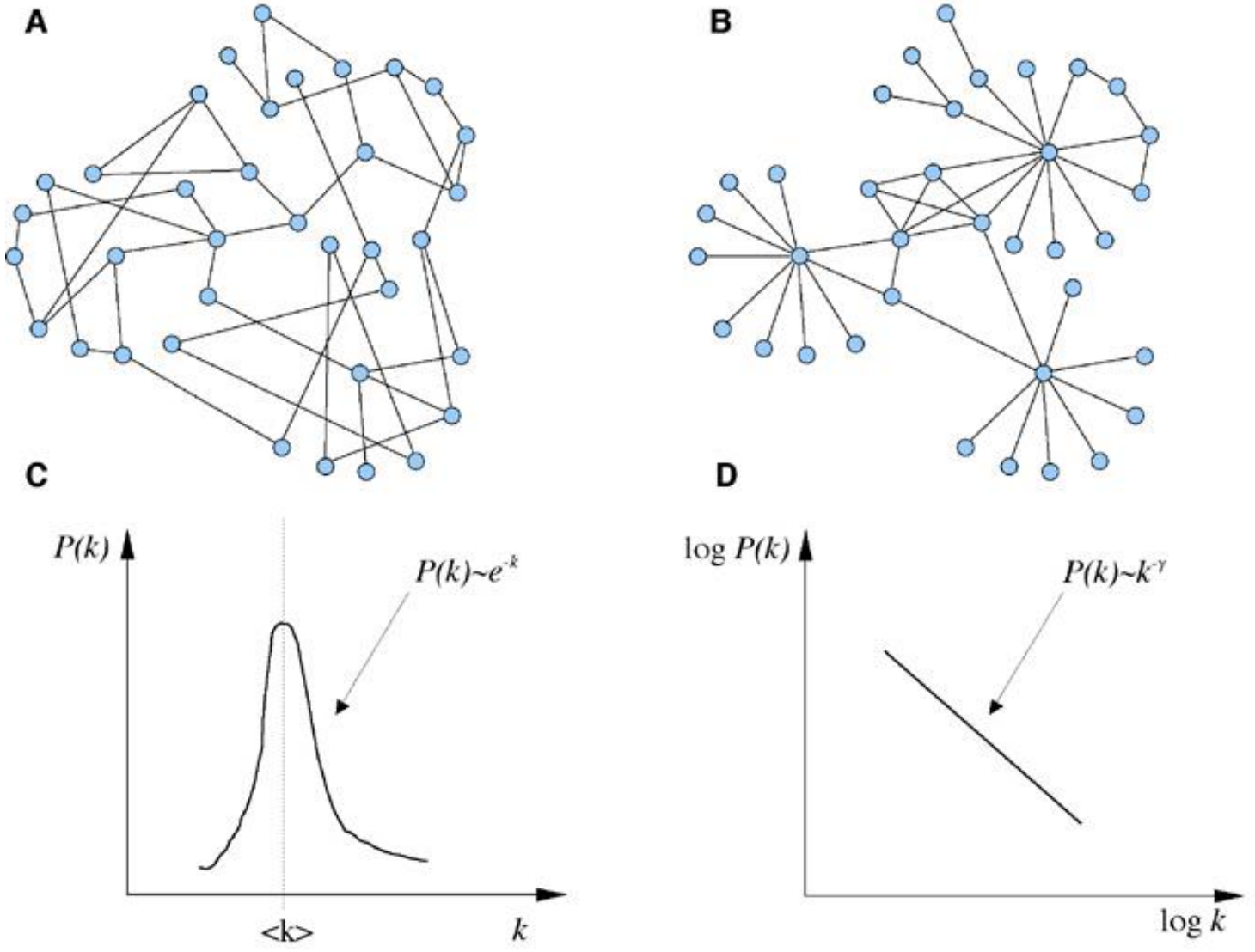
Source: After Krackhardt (2008)

A Network of Connectors Linked by Weak Ties



Based on: R. Ogle (2007), *Smart World: Breakthrough Creativity and the New Science of Ideas*

Examples of A) random and B) scale-free networks

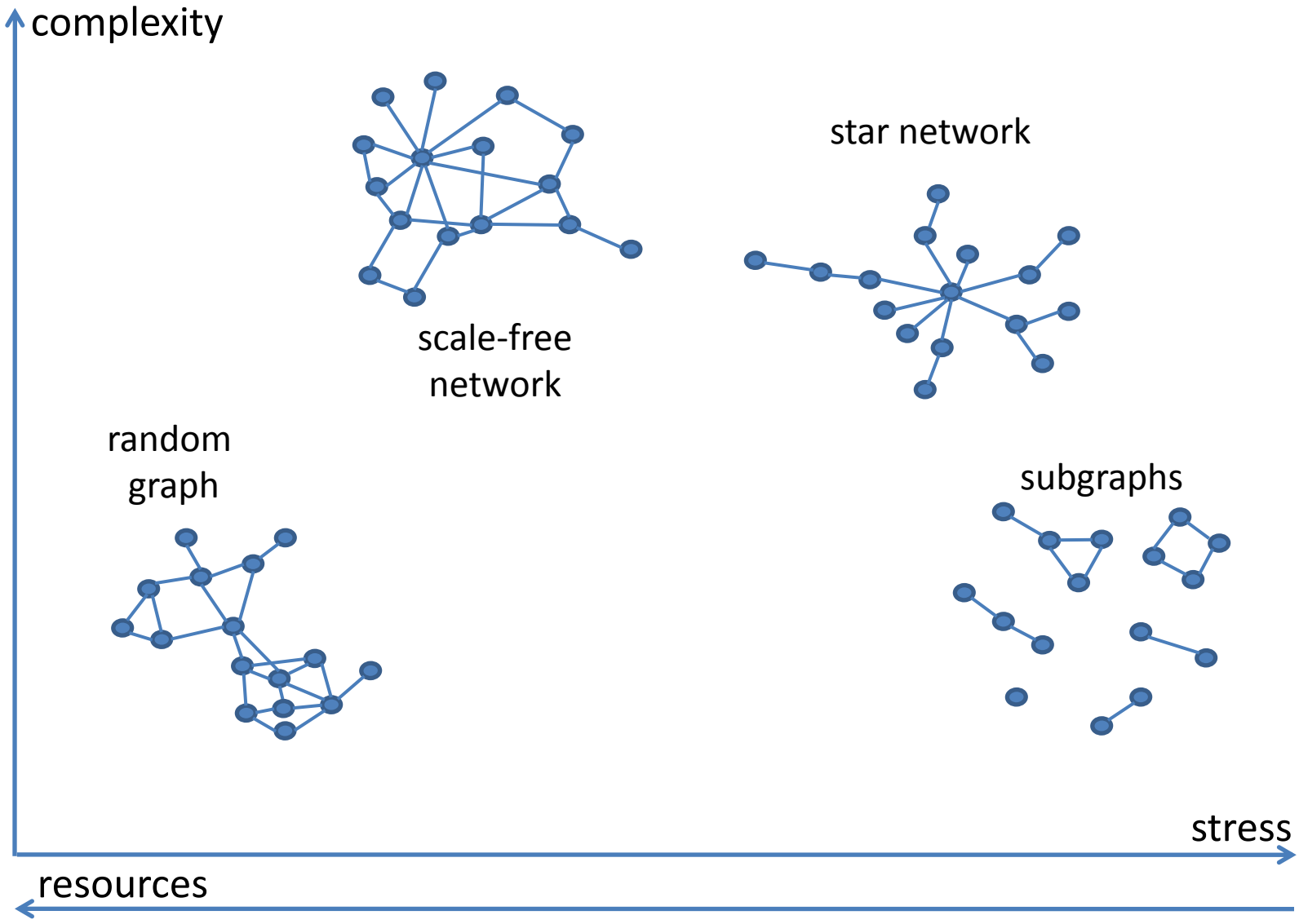


36 nodes
44 links

For a given network, *P(k)* is the fraction of nodes that have *k* links.

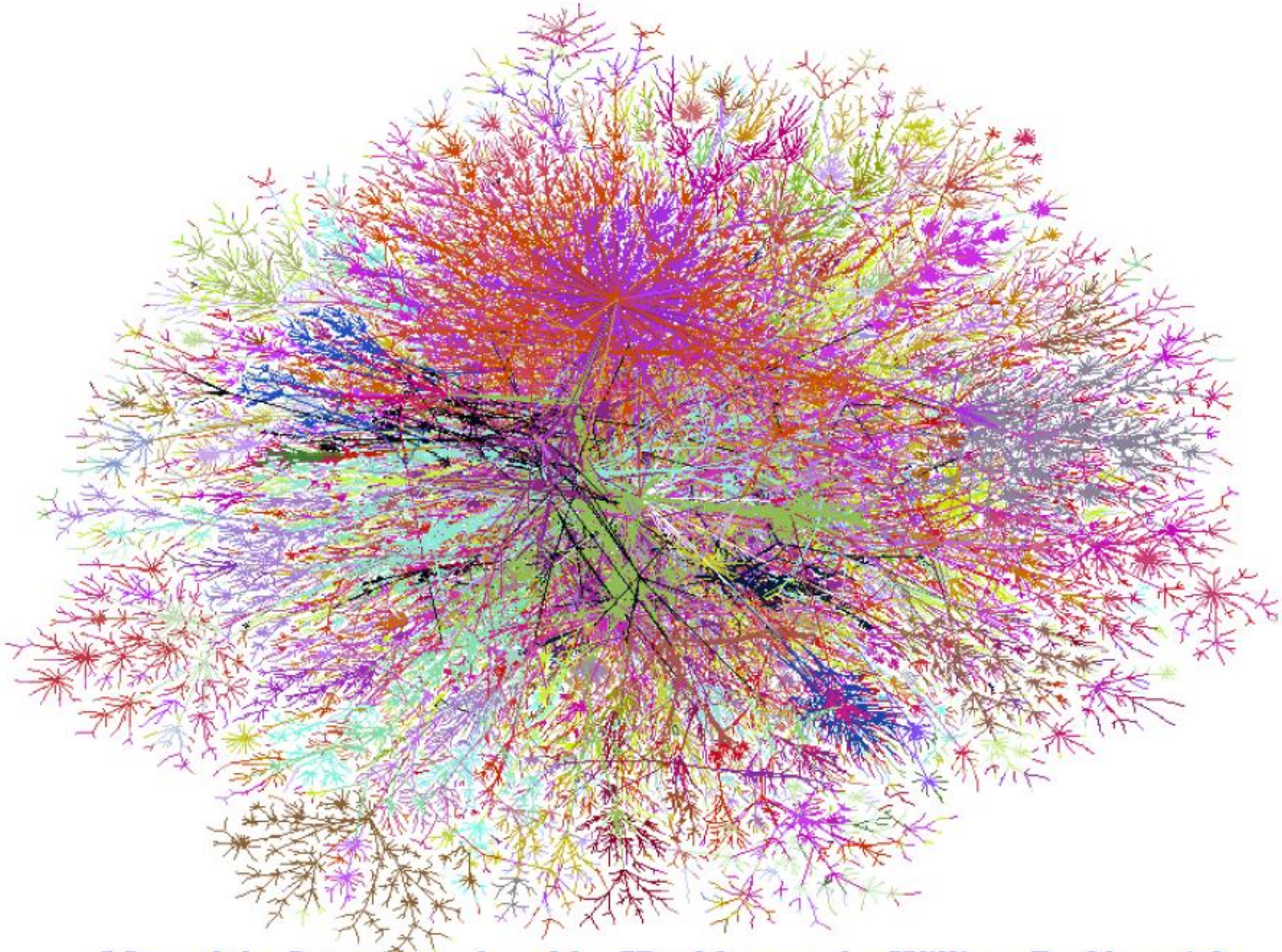
P(k) is a connectivity distribution or probability that a randomly chosen node in a network has *k* links.

Topological phase transitions of networks



After Csermely (2009)

Real-World Applications

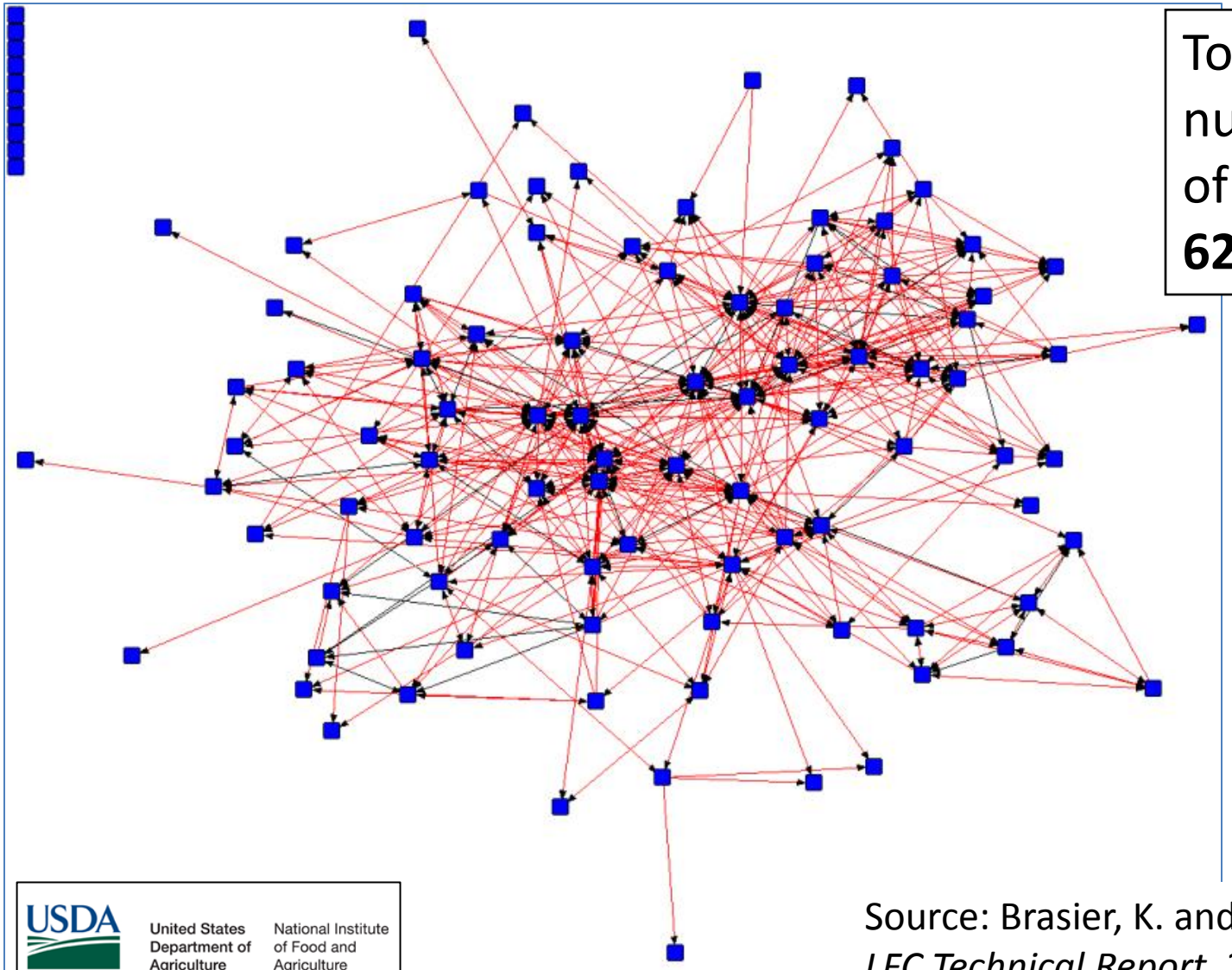


Map of the Internet, colored by IP addresses, by William R. Cheswick

Source: Albert (2010)

2009 Northeast Local Foods Conference (LFC):

Pre-Conference Network (N~100)



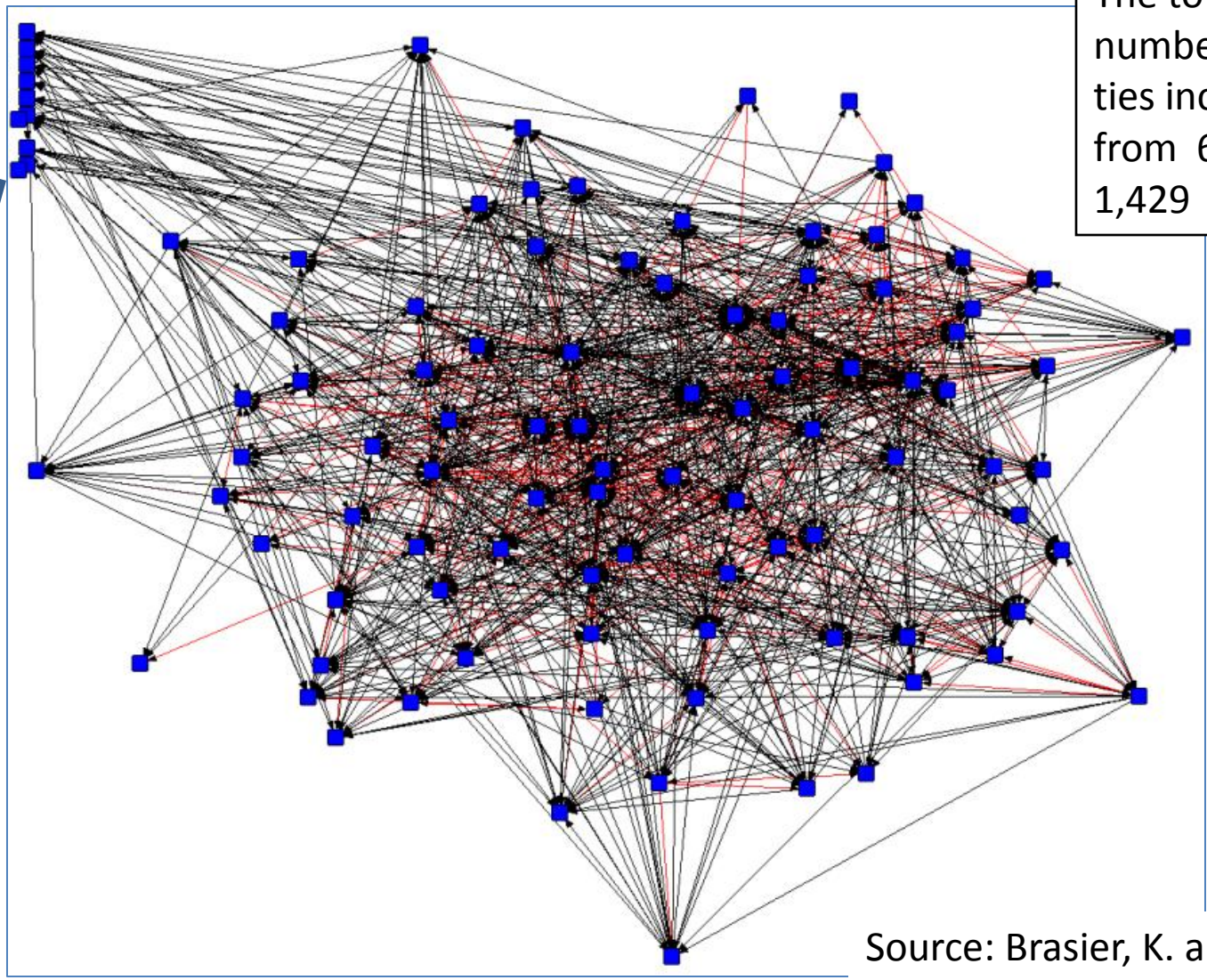
Total number of ties: **629**

Source: Brasier, K. and S. Goetz, *LFC Technical Report*, 2010

NE RCRD

USDA United States Department of Agriculture National Institute of Food and Agriculture

LFC: *Post-Conference Network*



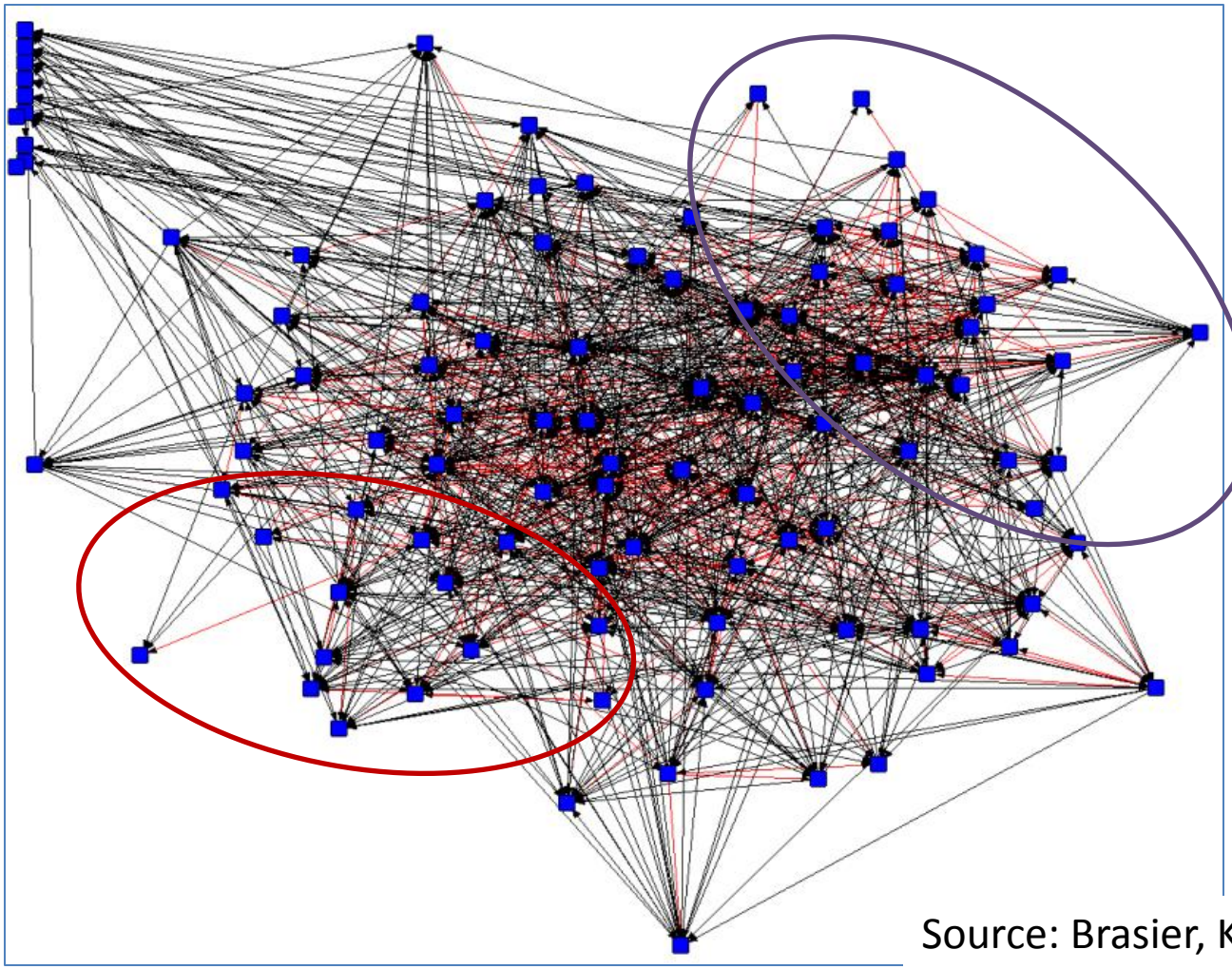
"Isolates", made new connections at the event

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

Source: Brasier, K. and S. Goetz, *LFC Technical Report*, 2010

LFC: Post-Conference Network: ***Homophily***

Suppose there are at least two distinct sub-groups or "affinity" networks

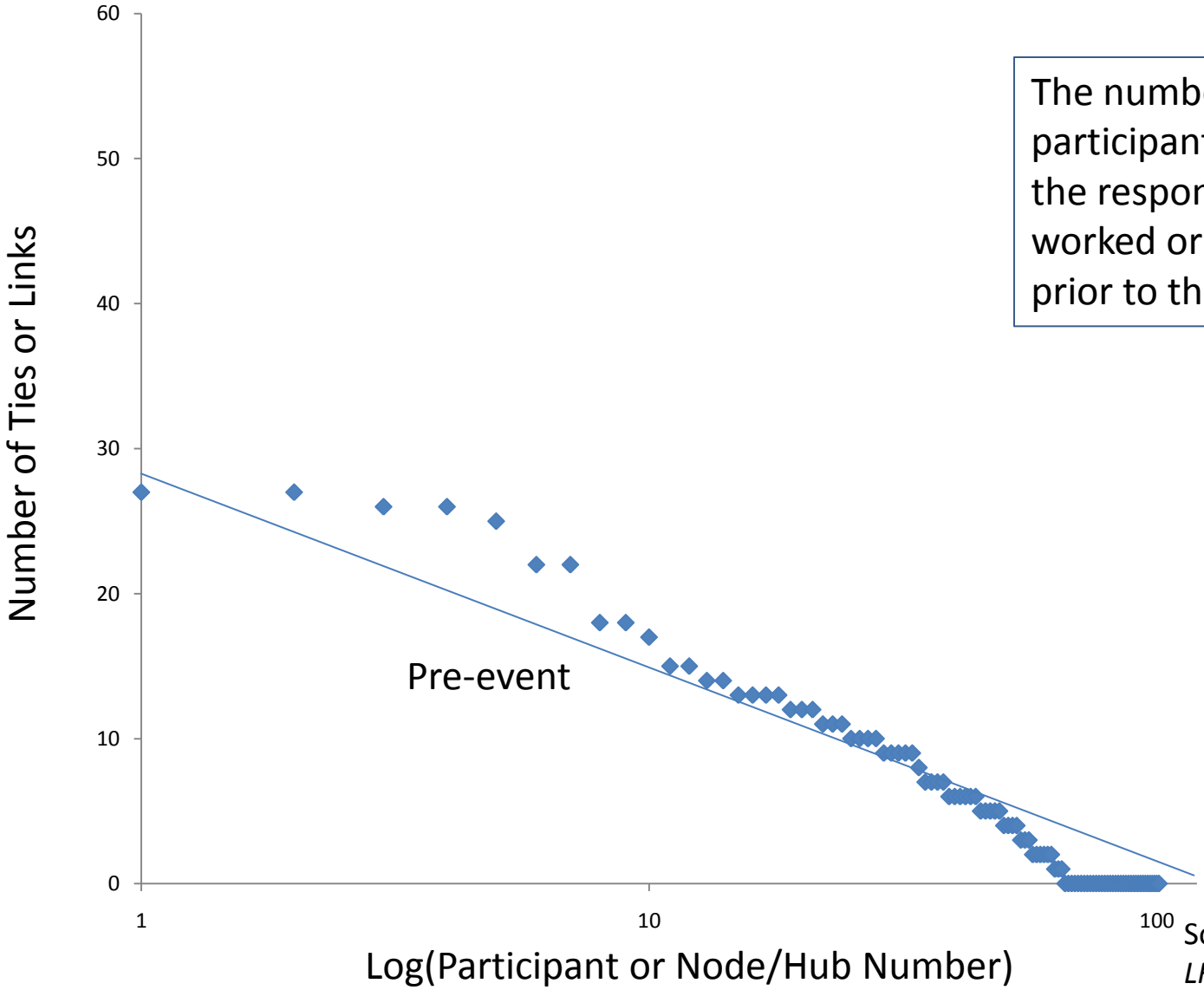


If these two groups can learn from one another, how can they be linked?

Source: Brasier, K. and S. Goetz, *LFC Technical Report*, 2010

Local Foods Conference:

A few have many connections, many have few



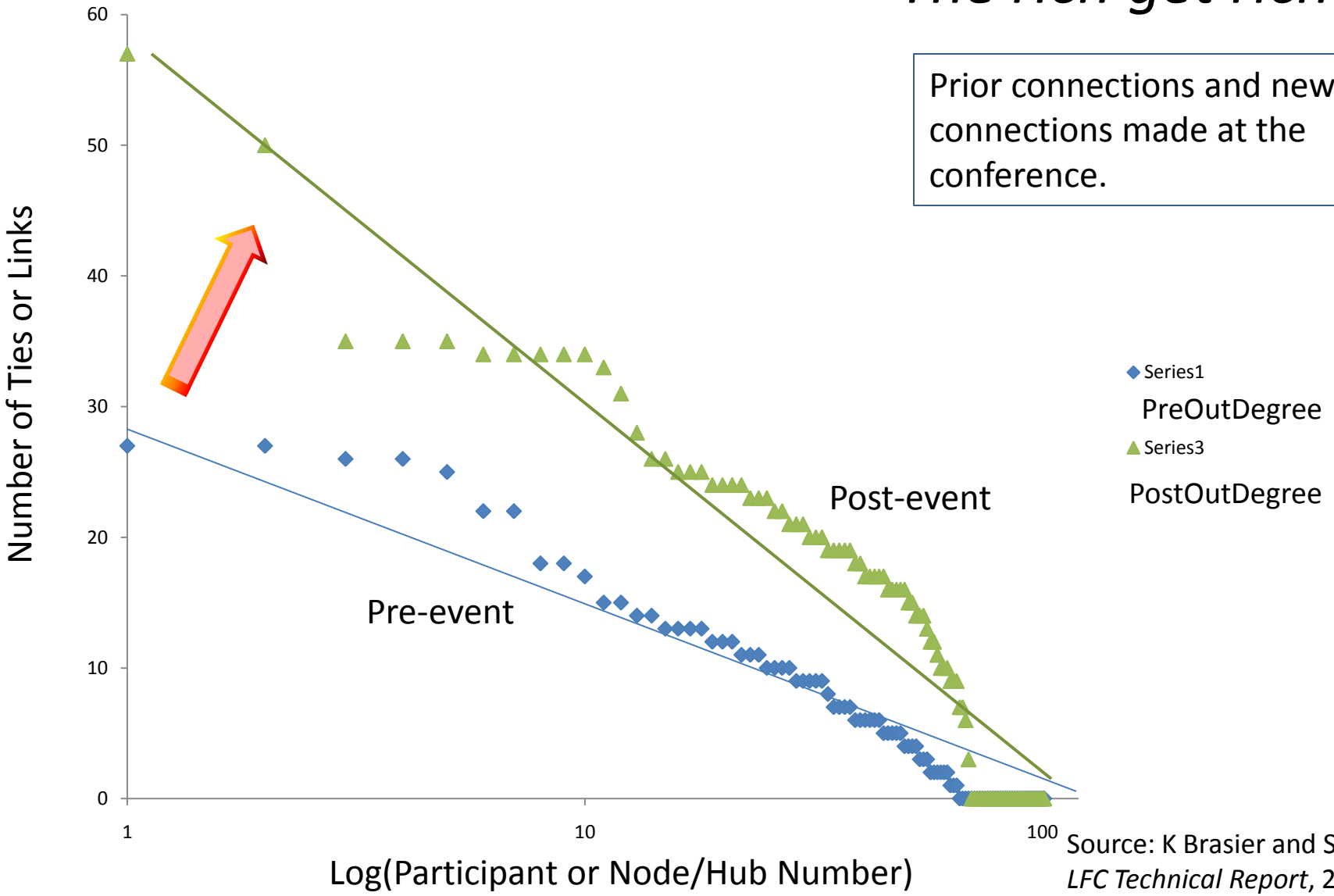
The number of other participants with whom the respondent had worked or "connected" prior to the conference

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…

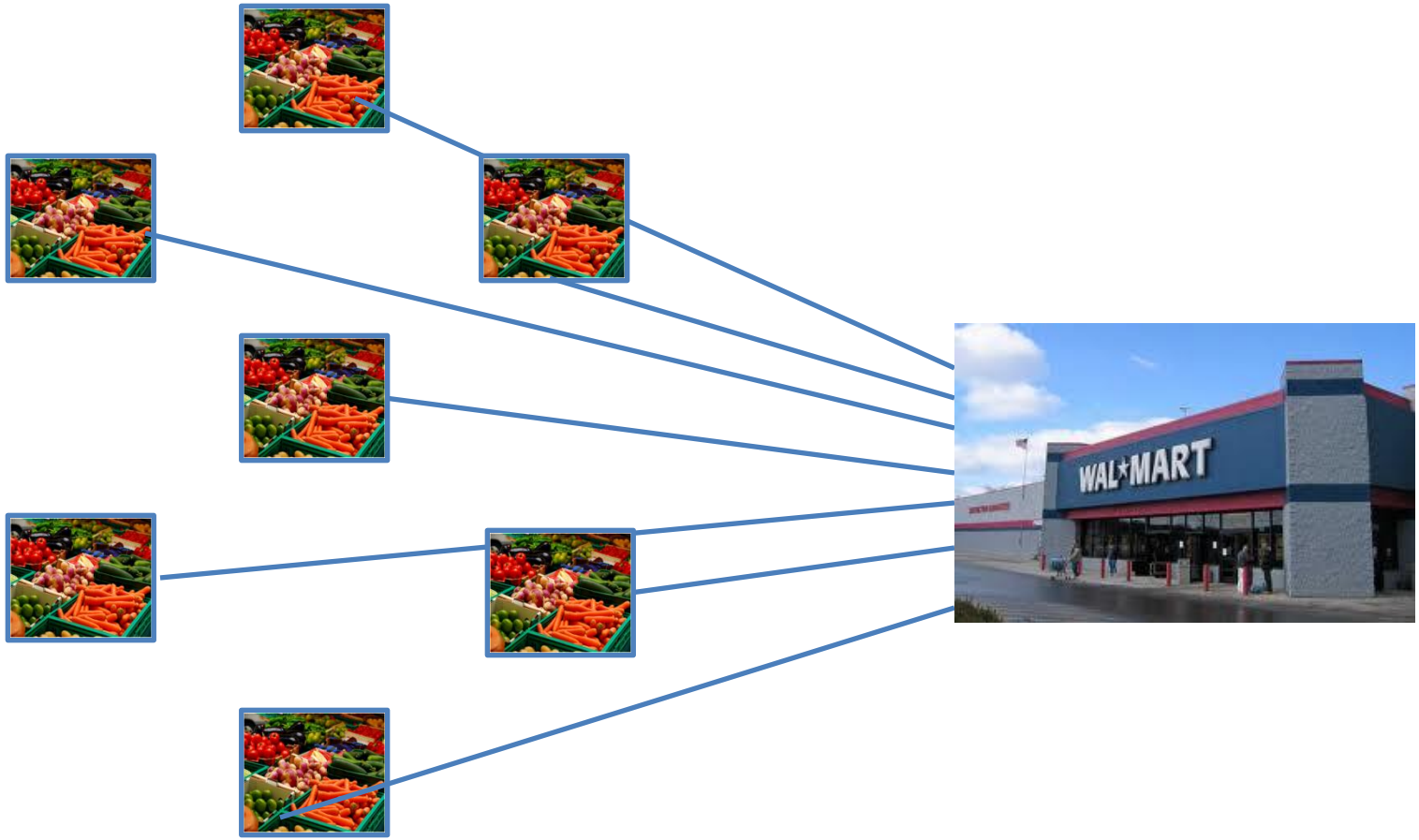
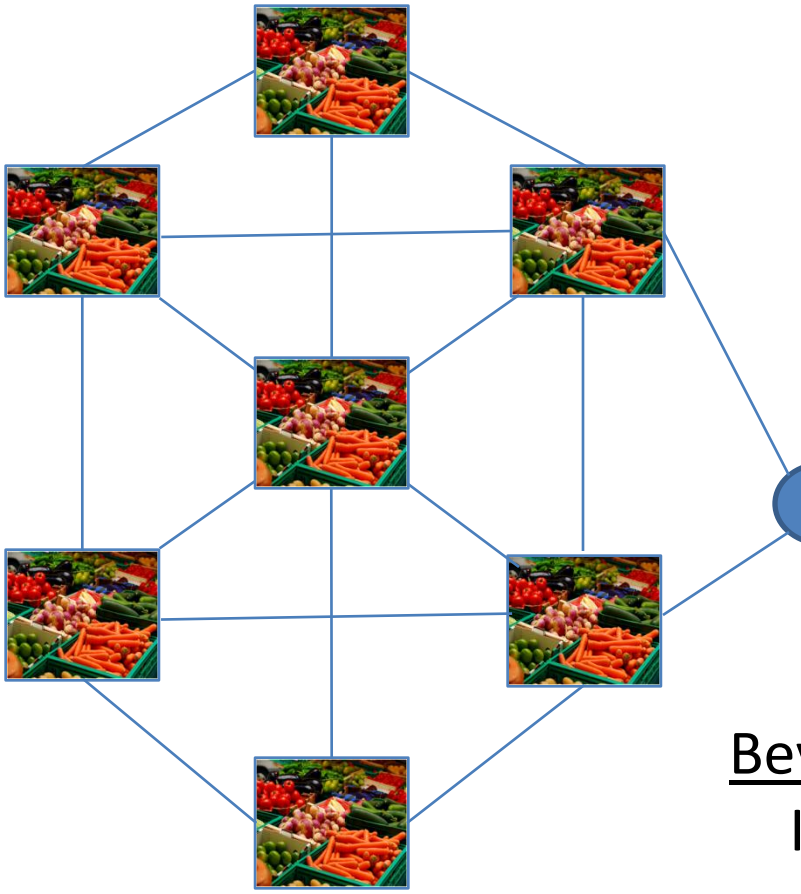


Photo courtesy of: ces.ca.uky.edu/Lee/AgNaturalResources

Basic Idea: Columbia Urban Design Lab

versus…

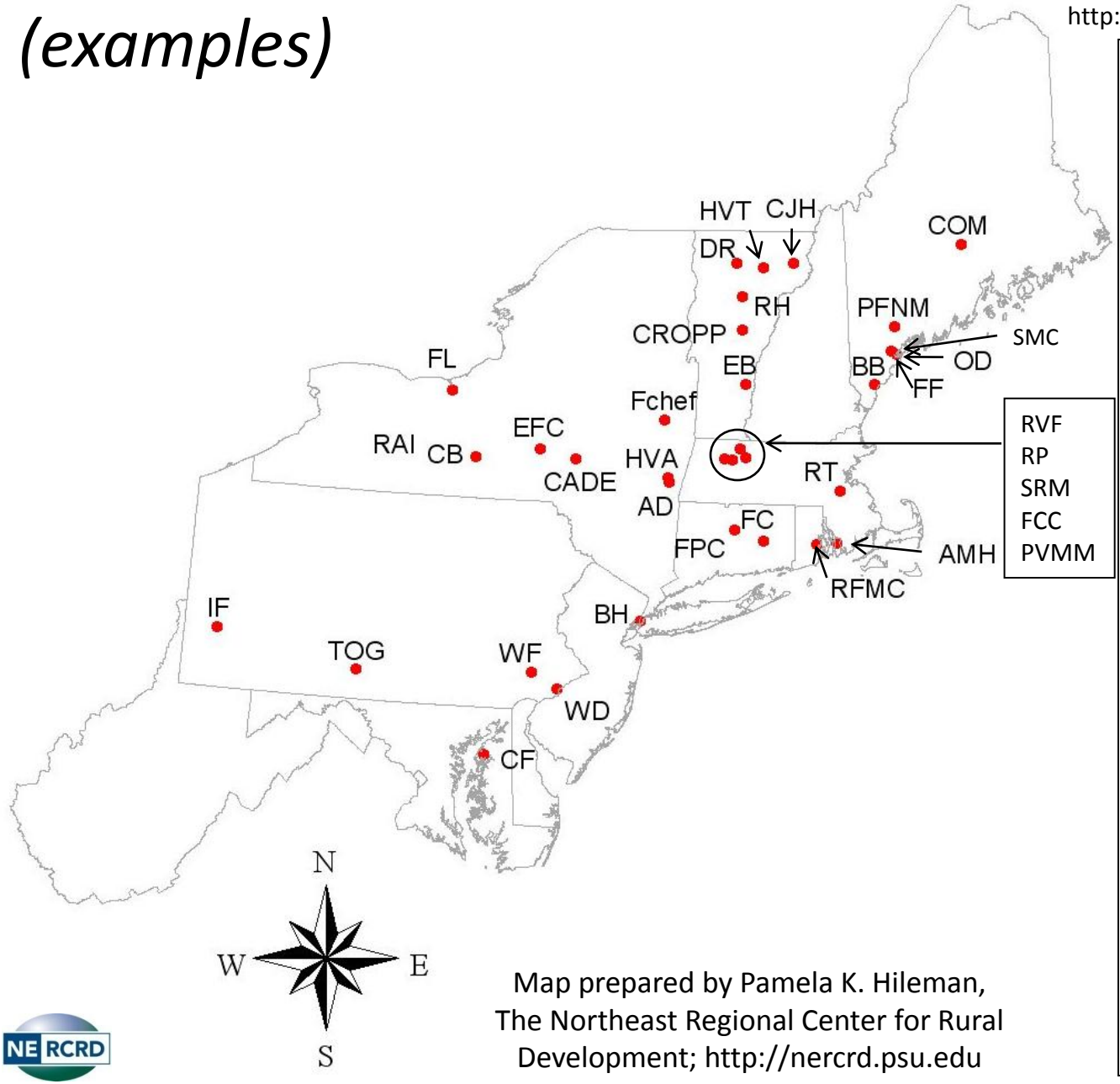


<u>Beyond cooperatives (clusters)</u>:
Information sharing/learning
Compete AND cooperate
Regional branding
Influence legislation

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

Northeastern Food Supply Chains (examples)

K. Clancy and K. Ruhf, 2010, Report on Regional Food Value Chains in the Northeast; available at: http://www.nefood.org/page/publications-1

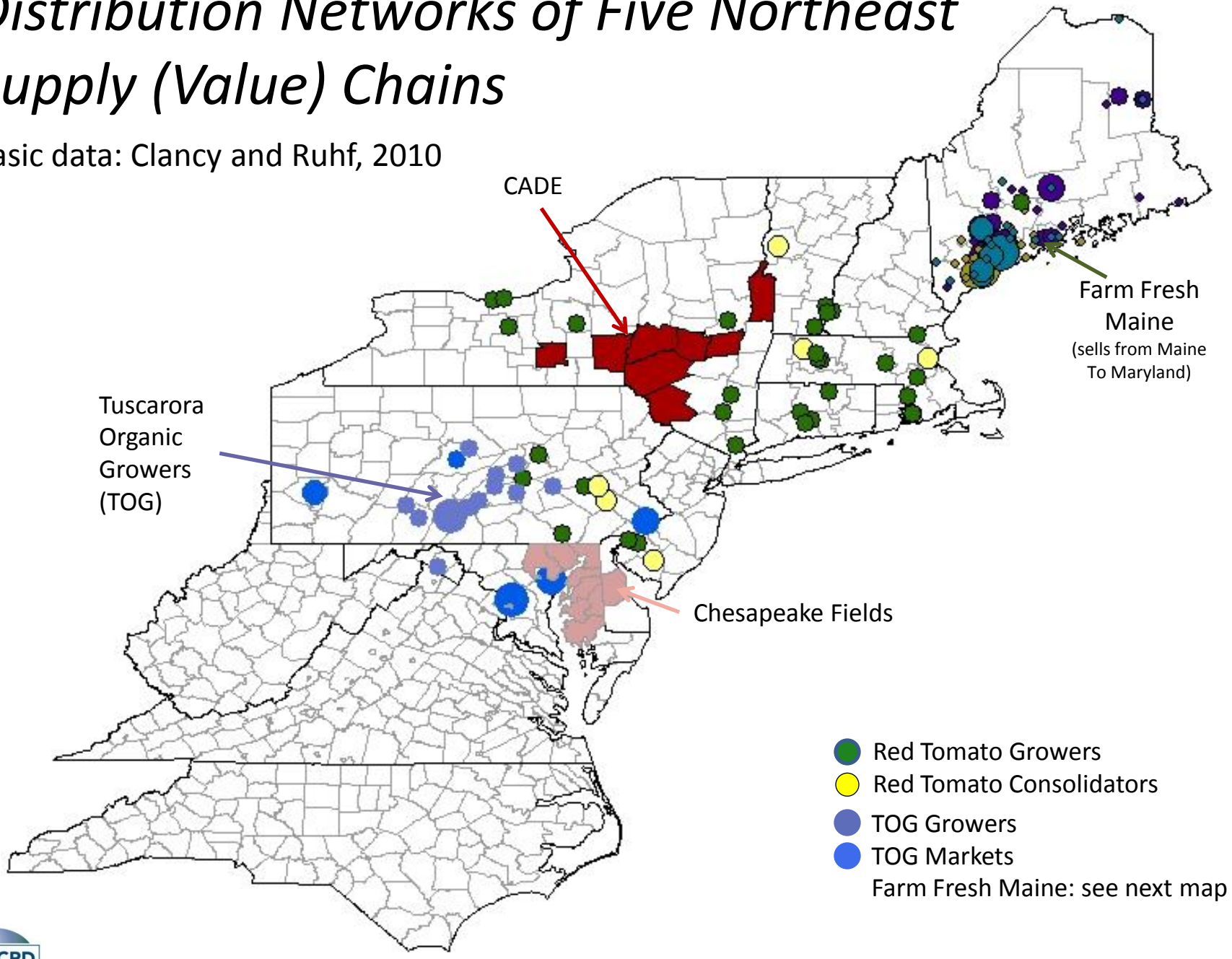


AD-Angello's Dist.
AMH-American Mussel Harvesters
BB-Borealis Breads
BH-Basis Holdings LLC
CADE-Center for Agriculture Development and Entrepreneurship, Inc.
CB-Chenango Bounty
CF-Chesapeake Fields
CJH-Cellars at Jasper Hill
COM-Crown O'Maine
CROPP-Organic Valley Coop. East
DR-Deep Root Organic Truck Farmers
EB-Earth Brokers, LTD
EFC-Evans Farmhouse Creamery and Maple Sugar House
FC-The Farmers Cow Cooperative
FCC-Franklin Community Coop.
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.

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

Distribution Networks of Five Northeast Supply (Value) Chains

Basic data: Clancy and Ruhf, 2010

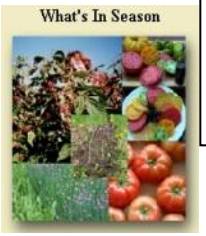


Map prepared by David Fleming, The Northeast Regional Center for Rural Development; http://nercrd.psu.edu

Tuscarora Organic Growers
Family Farms Marketing Cooperatively Since 1988

TOG Business Network Map

Parallel Sales (10-20%)



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

Competition from Whole Foods, Safeway, Giant, etc.

Bus tours, Field days

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

Department of Agriculture, others

Keystone Development Agency ($)

Tuscarora Organic Growers
Incorporated 1993
Local. Quality. Integrity.
7 Board Members** (list)

James Crawford, Founder

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

Crop Improvement Meetings

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

CBERP (discontinued)

PASA PCO

Commitment charts

Quality standards

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

Eric Lichti
Roy Brubaker Village Acres
Mark Stanley Help From Above
Mike Brownback Spiral Path Farm
Tim Durstine Harris Valley
Jim Crawford Early Morning Farm
Tony Ricci
Amish/ Mennonite
"Social sub-groups"

Local labor pools (intern, locals, migrants)

Inputs: Sweet Potatoes, Potting Soil, other

Local building contractors

Chesapeake Fields Business Network Map

Competition from Frito Lay, snack food cos.

Parallel Sales (80-90% of production)

Soy saucers, Bread (artisan), Popcorn

Natto Beans (Japan)

Foreign Visitors, farm visits

Montigue Farms, VA

Department of Ag., Tourism, DBED, other

North Dakota
Dr. Neil Doty
Pennsylvania

Processing, storing, drying, sorting, baking, transporting, scheduling, marketing, etc.

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

John Hall, Leader

Chesapeake Fields Institute (CFI)
J. Hall, Executive Director

Univ. of MD, DE; Wash. College

Winter meetings w/ farmers

IP protocols

Quality standards, farmer commitments

Farmer, consumer, & resident education

Spillover benefits to other farmers

55 Investors (including non-farmers)

Corn, wheat, soybeans

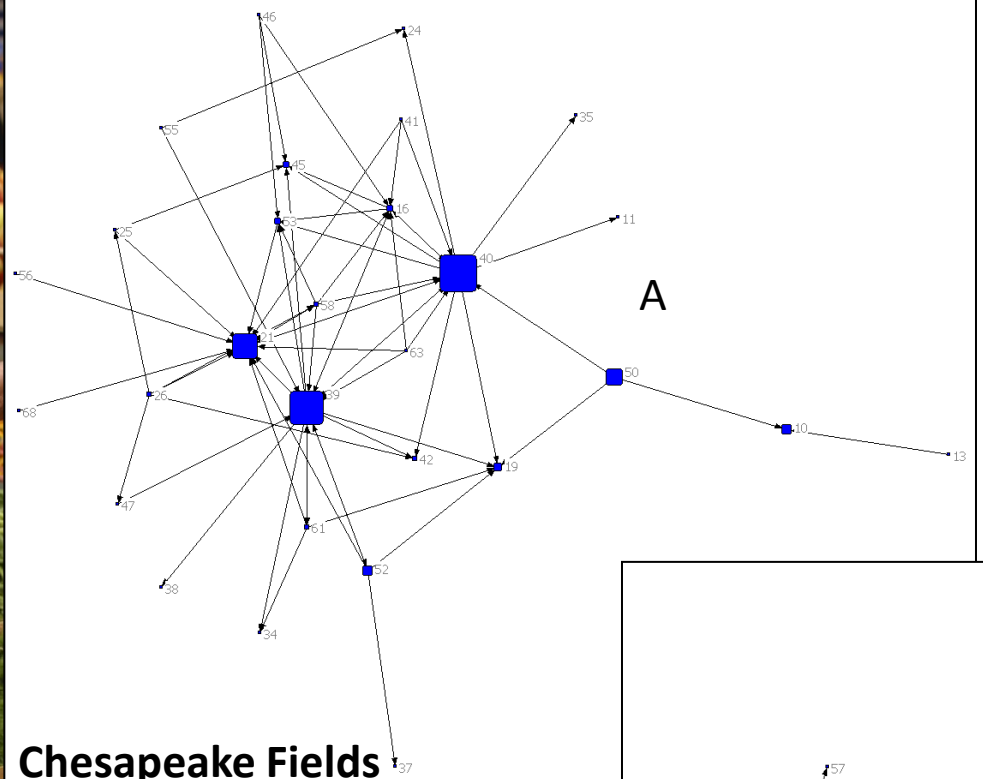
Ed Fry
Bill Susan
Bill Cooper
Chris Hagameyer
Roy Crowe

33 Farmers

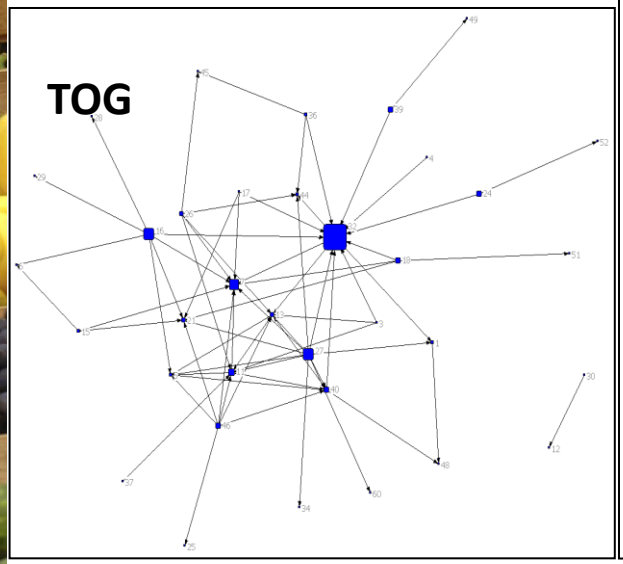
Farm sizes range from 100-500 acres

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

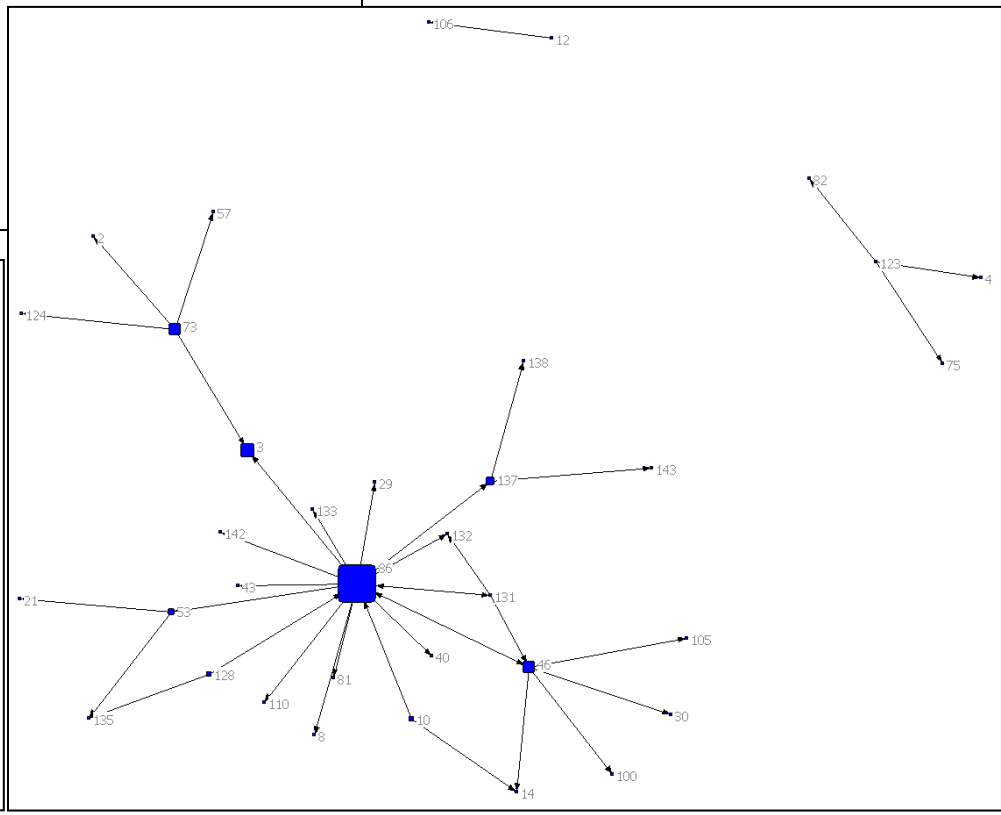
Network Graphs



Chesapeake Fields



Pennsylvania Women's Agricultural Network



Source: Goetz, Brasier, Raboanarielina and Rangarajan (forthcoming)

Final Thoughts (1)

- 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

Final Thoughts (2)

- 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)