

Article

The Small World of the Alternative Food Network

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Received: 19 June 2018; Accepted: 15 August 2018; Published: 17 August 2018



Abstract: This research offers the first use of graph theory mathematics in social network analysis to explore relationships built through an alternative food network. The local food system is visualized using geo-social data from 110 farms and 224 markets around Baltimore County, Maryland, with 699 connections between them. Network behavior is explored through policy document review and interviews. The findings revealed a small-world architecture, with system resiliency built-in by diversified marketing practices at central nodes. This robust network design helps to explain the long-term survival of local food systems despite the meteoric rise of global industrial food supply chains. Modern alternative food networks are an example of a movement that seeks to reorient economic power structures in response to a variety of food system-related issues not limited to consumer health but including environmental impacts. Uncovering the underlying network architecture of this sustainability-oriented social movement helps reveal how it weaves systemic change more broadly. The methods used in this study demonstrate how social values, social networks, markets, and governance systems embed to transform both physical landscapes and human bodies. Network actors crafted informal policy reports, which were directly incorporated in state and local official land-use and economic planning documents. Community governance over land-use policy suggests a powerful mechanism for further localizing food systems.

Keywords: social network analysis; social change; supply chain management; complex systems; traceability

1. Introduction: How Alternative Is a Local Food System Network?

A growing body of literature and practice draws ties between local food systems and building sustainable futures for human health [1–4], education [5], land management [6,7], and economies [4,8,9]. This research posits that alternative food networks (AFNs) structurally differ from their globally-reaching counterparts (Figure 1). A better understanding of AFN architecture could provide insights into its development, growth, and resiliency for meeting the above sustainability goals. More broadly, the food system is often conceptualized as a network of nodes represented by producers, processors, distributors, and consumers. Connections between the nodes are referred to as ‘edges’ (for a review of network analysis and graph theory, models, and study see [10]). AFNs are characterized by transparent, often direct marketing of food [11–14]. In AFNs, transparent edges between producers and consumers are emphasized as important to tighten feedback loops between diets, consumer demand, land management, and economic investment in sustainable practices, as trust is re-discovered between producers and consumers [15–17]. The proclaimed benefits to future generations are manifold, from healthy diets impacting epigenetics over several generations [2,3,5,12,15] to land-use that guides compact urban development while protecting long-term soil health with more agroecological farming practices [6,7,12].

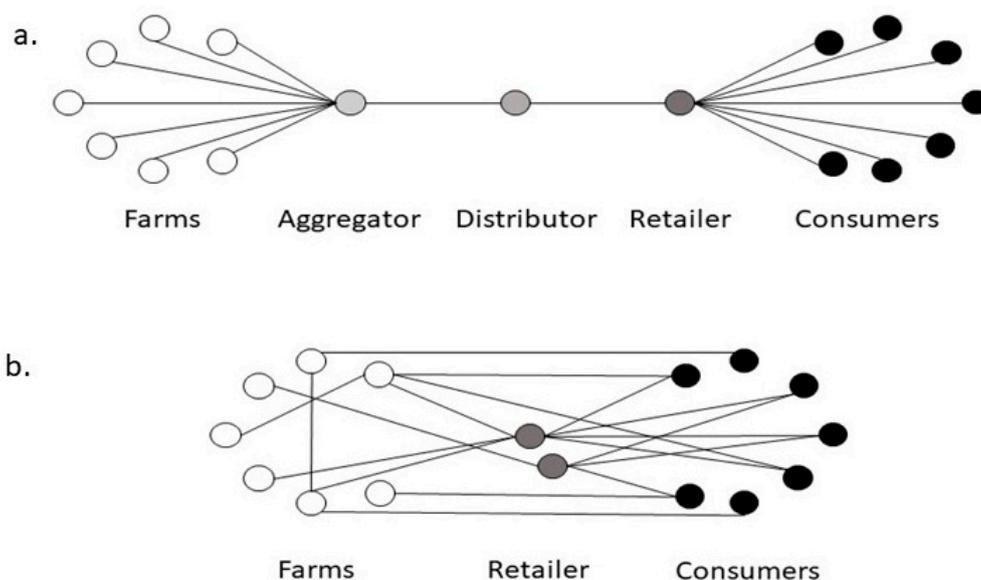


Figure 1. Author's archetypes for a centralized food distribution network as typified by the global supply chain (a), in comparison with alternative food networks (b).

Conversely, the networks of nodes and edges involved in growing, processing, storing, and distributing food in the global system are well hidden. To uncover edges, researchers must tease out networks through recalls, mergers, and court cases [18–20]. The spatially far-flung global markets provide avocados grown in Mexico to the other side of the world, for example. But, global food supply chains are highly centralized and fragile, as evidenced by large-scale food contamination outbreaks, such as the 2006 spinach *E. coli* outbreak which spread to 26 states and saw over 200 individuals infected, with half hospitalized and nearly 20% experiencing kidney failure [21,22]. A review of studies in supply chain management [23] shows that the discipline leverages a large body of research on system architecture to further understandings of policy influence and network behavior to shocks and market controls. Empirical studies in supply chain management reveal global supply chains that are definitely not 'small world' but hourglass-shaped long-chains with many suppliers concentrating delivery to a few processors under centralized management before sending product further to distributors [18–21] (Figure 1). Understanding this architecture helps supply chain engineers trace outbreaks and redesign pathways to build resiliency. Efforts to understand the AFN system architecture may similarly aid scholarship and practice.

This research posits that AFNs exhibit 'small-world' network architecture. A network that would be less vulnerable to disruption is one wherein the loss of any one node or edge does not drastically affect communication across the entire system. In short, resiliency to disturbance is built into the architecture, because multiple redundant edges between other nodes allow alternate pathways (Figure 1b).

Such a network is exemplified by Stanley Milgram's groundbreaking 1967 small-world experiment [24]. There, he hypothesized that social networks follow mathematical, scalar rules such that through relatively few 'weak links' or friend-of-a-friend contacts [25], a message can rapidly cross from one side of the network to the other. He found that through 'six degrees of separation' [26], any one person could pass a letter to any other person in the world without knowing the final letter receiver personally.

An important feature revealed in Milgram's small-world experiment is that people intuitively knew how to navigate the network without knowing exactly how every node or edge was connected [27]. In contrast to global supply networks, direct marketing farms often proudly list their marketing outlets with 'you can find our food at the following markets ...' signage. This

research posits that the transparency of the AFN facilitates similar small-world navigation. Such a feature is handy especially because small-world networks are often constantly evolving as new connections are made and others dropped.

Since Milgram's experiment, other mathematical properties of small-world graphs have been explored through empirical studies in mathematics, sociology, and complex systems. Small-world network structures are often characteristic of collective action-oriented social movements [28], where small clusters of semi-independent actors work together in 'affinity groups' to motivate broader changes within the larger network in which they are nested [29]. In a rather complicated fashion, AFNs are often thought of as being part of many different social movements concerning diet, economics, lifestyle, and the environment [30]. This research posits that AFNs may show similar characteristics of affinity clustering. This self-organizing component belies cooperation amongst competitors. As a result, small-world structures have been shown to enhance the system's overall economic and resource efficiency [29,31,32] while concurrently balancing antagonistic tendencies for segregation and integration in structuring processes, analogous to market competition and simultaneous cooperation. This dichotomy of competition and cooperation is often needed for a small-world network's parallel and yet, synthetic performance, allowing its sum to be more than an addition of parts. Such high performance is in part due to how rapidly affinity groups can disseminate new information and innovate. Recognition of this small-world property has promoted calls from industrial supply chain architects to not only optimize for technological and commerce features but to build 'small-world networks' that facilitate trust and enable innovations to easily diffuse across the network [23,33]. Supply chain management may have something to learn from the alternative food movement.

Understanding the social networks created through food supply chains is also important to understanding how they might interface with a variety of civic social processes, such as sustainable land management. Sociologists have long noted that social values are embedded in economic markets [34,35]. This research acknowledges that social networks formed through supply chains can shape the geographic and economic futures at either end by influencing land-use. For example, scholars argue that local food systems help forge social networks of shared values with a focus on keeping land in agriculture, supporting agroecological growing practices, promoting equity of access to healthy food, and sustaining inclusive, local economies [15–17,36,37]. The equation below summarizes the embedded nature of food systems as byproducts of *and* influences upon the landscape and social values. Likely, geography governs how various network nodes, edges, and clusters are spatially and socially oriented, an area of inquiry in this research and one that is not yet well understood in broader network studies [10,38]. In turn, this research offers theoretical insights into the pathways that social values, social networks, markets, and governance systems align to transform physical landscapes and human bodies.

$$\text{Food systems} \xleftrightarrow{\text{reciprocal}} \text{Land – use planning} + \text{Social networks} \quad (1)$$

Representing the interplay between food systems and geography and social systems, this equation uses dynamic cause–effect symbology to note how each system and its governing structures push and pull one another.

In America, most land-use control is exerted at the jurisdictional level of counties and cities through general plans. Local actors have incredible power to shape land designation for production and consumption by serving on advisory committees, participating in charrettes, and giving public comment. By levying local land-use control instruments, such as zoning and the public participation process, communities can act on their preferences and shape the food environment to welcome or refuse new supermarkets [39] or farmers markets [37]. On the food production side, protection of farmland is key to local food systems [6]. Beyond economic market mechanisms that allow AFN farmers to stay competitive against housing markets, general plans help designate which lands stay in agriculture

through zoning, tax-based incentives, and permanent conservation through easements. The degree to which local values for land-use and food systems are aligned is explored with this research.

2. Literature Review of Alternative Food Networks

What is now labelled as an alternative food network (AFN) is frequently traced back to social movements in the 1960s that sought to re-localize food production and consumption, often with the intentionality of counteracting the global industrial food system [30]. While the food movements of the 1960s have popularized AFNs in research and the vernacular language, the direct market has a long history. Local food systems were planned as early as the Law of the Indies in the sixteenth century [40,41] and have historically played a large role in food security for war-torn Berlin [42] and the economic dislocation in Russia [43–45] when global supply chains were disrupted. Indeed, many countries explicitly acknowledged the importance of local self-reliance in food production through national agendas during and after world wars [43] while infusing urban areas with small-scale allotment and urban gardens [46,47]. A review of food systems planning [43] shows that the global food supply chain architecture at top of Figure 1 is a relatively recent feature, dating within the past 150 years. Before this time, most cities drew from within their local foodshed. As such, the AFN movement is often seen as a return to the past, with updated contributions to future sustainability bestowed on both members of the movement, communities within the network, and affiliated future generations.

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The modern notion of AFNs connects diets, local economies and environmentally-friendly land-use. A review of AFNs reveals their role in shifting consumers to plant-based, seasonal, and healthful diets [3,4,15,16,48]. Findings, however, are often complicated by omission of socioeconomic control variables in most studies on food and diet [1,2]. Nonetheless, in this shift to local consumption, local economies are supported with farmers receiving higher profit margins per acre [49] as a result of both price premiums for local, organic, and value-added agroecological products, as well as more efficient growing practices that sustain long-term soil health and productivity. Food sold directly from producer to consumer fetches roughly twice the market price [49]. In turn, higher values from production allow farmers to out-compete housing markets, resulting in higher density developments. Doubling the value produced per hectare results in a 26% decline in land conversion to urban uses according to an international study of urban expansion [50]. In addition, new social alliances are wrought in AFNs, tightening the civic armature that guides land-use controls [4,6,7,14–17]. In sum, AFNs align more sustainable diets with localized economies and sustainable development practices (Equation (1)).

AFNs are growing, as evidenced by data from the global north. About 7% of United States (U.S.) farms direct marketed to consumers in 2012, twice as many as in 2004 [51–53]. This growth has promoted a suite of new agricultural survey and census questions, with results released in 2016 [53]. Providing only an estimated 1.5% of the total U.S. agricultural production value [53], the promise of

social change is still largely nascent. Surveys also reveal spatial patterns. The majority of community support agriculture sales and farmers markets in the U.S. are in the northeast and west coast, near major metropolitan areas [51–53]. The extent of a local food system’s reach from farm-to-fork, directionality, and magnitude are yet unknown. It has been nearly 20 years since Jarozs [6] called for the combined use of network theory and supply chain management theory to understand regional agri-food systems. A better understanding of the network structure may help elucidate opportunities and the extent of the total AFN growth.

Previous research has made tenuous connections between AFN structure and civic systems. For example, Dufour et al. [54] showed how direct marketing farms in three regions in France form spatially- and socially-based affinity groups that influence branding and agricultural policy. And from a case study based in Barcelona, Paül and McKenzie [55] noted that supportive land-use regulations, such as farmland preservation, are necessary components for local food networks to thrive. Scholars are also employing social network mapping in understanding AFN connections between farms, processors, and distributors. Sonnino [36] traced the rise of saffron markets, finding that social and economic networks embed to form new relationships and commitments to the land. Chester County, Pennsylvania, hosted the first study to connect the social networks formed through AFNs to their specific geographies and land-use governance, revealing that where social values emphasize food security as a core value, land-use planning documents encouraged donations and volunteering at the local food bank [37]. The foodbank was also a central hub in the local food system network [37]. This research uses similar methods to understand the network properties of a local food system.

3. Methods

In understanding the spatial and social components, a geo-social network analysis is conducted on Baltimore County, Maryland’s AFN. This research combines social network analysis, interviews, and document review. The historical and social components are investigated through document review of plans and policies related to agricultural lands and markets. This information is triangulated in interviews for extra-network actors and actors at central hubs in the local food marketing network in order to verify findings. Interviews also help elucidate where each network is aligned in interests and actors and where there are tensions or gaps (Figure 2). Combined, this research employs a multi-layer social network analysis [56] approach wherein the extent and orientation of local food networks are constrained by another layer of network actors who govern land-use and public health (Equation (1)).

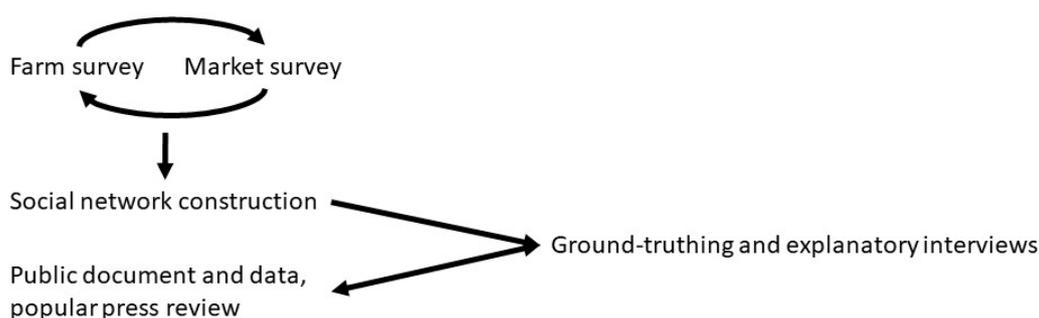


Figure 2. Schematic overview of methods.

Methods are described by [37] and include gathering farm and market data from google searches, county agricultural data, and internet listings. To verify farm and market locations, products, and connections, email and phone surveys were conducted for 1000 farms and their first point of sale or donation entering, within, or leaving Baltimore County, Maryland. The surveys were conducted in 2012. This research focused on fresh, raw, unprocessed food products, emphasizing the immediacy of network edges in moving time-sensitive, perishable food products. Both the first point of sale and donations for unprocessed edible products were included in network edges. Value-added and

processed products, such as jams, were not included. The geographical coordinates of nodes were captured and viewed in Google Street View to verify farm or market location. Network edges were coded a priori, resulting in the following edge relationships: sales through community supported agricultures (CSAs), farms selling at farmers markets, farm sales to restaurants, farm sales directly to wholesale grocers, farm sales directly to wholesale groceries with restaurants, farm-to-farm sales, and farm sales through institutional purchases, foodbank donations, and by product recycling (edible products purchased for animal feeding).

A double-verified snowball sampling technique was used, such that both the farm and the first point of sale/donation must validate an edge connection to be included in the network (Figure 2, top). This method yielded a network of 334 nodes and 699 edges.

The social network analysis was conducted in Gephi software using a custom-built plugin to calculate the magnitude and directionality of directed edges. The network diameter, a measure of the longest path distance between the nodes in the network, was used to calculate small worldliness. Connected nodes have a graph distance of one. Network diameter measures the distance between the most distant nodes. Betweenness centrality, a measure of how central a node is in network paths, was used to calculate centrality using a linear spline. Clustering coefficients and modularity [57] were used to identify affinity groups of communities.

Six in-depth interviews with key actors at network hubs were solicited. Because the formation of an AFN is the result of multiple, often uncoordinated efforts, expertise was sought from coordinating and supporting actors outside the network, such as agricultural extension agents to overcome this shortcoming. Further document review of news articles, court cases, reports, public datasets such as the agricultural census and American Community Survey, and local government documents was conducted prior to interviews to inform content on how AFN values might align with governance. The interviewees were queried by phone using open-ended interviews on the history, barriers, and potential growth of AFNs. Document review and social network analysis results were presented for verification to clarify the researcher's understanding and solicit additional context and insight. The interviews lasted from 30 min to an hour and were transcribed.

4. Findings

First, the document review findings provided a case description of Baltimore County, located in the northern part of Maryland, just north of the City of Baltimore (Figure 3). A review of spatial crop data, population census information, and agricultural census information showed that the county is typical of other counties in America's northeast corridor in that it is heavily involved in direct marketing, close to major urban areas, and farming comprises diverse production practices with a long history of direct marketing to cities. The majority of land in agricultural production is in grain and livestock production. In 2012, there were 640 farms comprising 44,000 acres (16% of the total land area) in Baltimore County. The average farm size was 110 acres, and 66% of farms had sales less than \$10,000 (420 farms), 27% had sales from \$10,000–\$249,000 (173 farms), and 8% had sales over \$250,000 (51 farms; USDA, 2012).

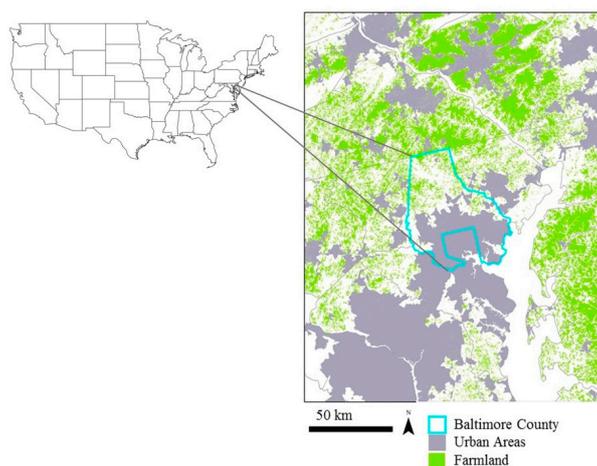


Figure 3. Baltimore County urban areas (gray) and agricultural land (green) according to 2012 National Agricultural Statistics Service and 2010 United States (U.S.) Census data. The county boundary is outlined in blue.

The Baltimore AFN is likely representative of national local food systems by virtue of its location in the northeast corridor and composition of marketing practices. The United States Department of Agriculture (USDA) released its first Local Food Marketing Practices Survey in 2016, concluding that farms selling to wholesalers and institutions made up the largest percentage of total sales (\$3.4 billion) when compared with direct-to-consumer sales (\$3 billion), a category made up largely by farmers markets and on-farm stores [49]. The survey also found that more than 80% of all direct market food sales occurred within 100 miles of the farm, with the majority of farms selling to consumers who were less than 20 miles away [49]. While not expressed in terms of economic generation, Baltimore’s network composition is similar with the largest categories being in wholesale, restaurants, and institutions (53% combined) compared with direct-to-consumer farmers market and CSA sales (31% combined) and average reach under 100 miles (Table 1).

Table 1. Network Edge Characteristics. Magnitude is expressed in cardinal directions, S: South, NNE: North-by-north-east.

Edge Type	Percentage of Network	Average Distance (km)	Magnitude
Farmer’s Market	27%	33	1501.48 km S
Restaurant	22%	36	1484.39 km, NNE
Restaurant-Wholesale	16%	74	6007 km, NNE
Wholesale	12%	44	1846.79 km, NNE
Institution	9%	92	1663.86, N
Farm-to-farm	4%	28	159.47, NNE
CSA	4%	19	30.37 km, SSW
Byproduct recycling	3%	21	413.43 km, S
Donation	2%	9	59.04 km, NNE

5. Social Network Analysis Findings

Research methods uncovered an AFN containing 334 nodes. One-third (110) are farms, and 52 farms are in Baltimore County. A total of 25 farms in the network sell directly to retailers, accounting for nearly half of all farms engaged in this practice according to U.S. Agricultural Census data ($n = 53$; USDA, 2012). This network captures nine of the 19 farms engaged in CSA sales (50%, USDA, 2007). In sum, the network analyzed in this study represents half of Baltimore County’s AFN. It should be noted that total network representation is also limited by requiring both farm and market to verify their relationship and excluding unprocessed food and non-food sales, such as Christmas tree farms. In total,

the network represents 8% of the total number of farms according to the USDA 2012 Agricultural Census. According to National Agriculture Statistics Service cropscape data in 2012 [58], the largest agricultural land-uses as a percentage of land cover in Baltimore County are grass/pasture (5%, 20,700 acres), corn (4.5%, 17,500 acres), alfalfa (4.5%, 17,600 acres), and soybeans (2%, 8500 acres), all products not likely to be sold through local markets.

Figure 4 shows the complete AFN represented spatially to scale with Baltimore County. This spatial layout demonstrates the extent of the network and its tight focus on and around Baltimore County despite outlying relationships with farms marketing to Philadelphia and Washington, D.C., (Figure 4). This spatial layout in Figure 4 also demonstrates that the AFN does not neatly follow county or state jurisdictional boundaries. Figure 5 provides a view of the AFN without spatiality. The Fruchterman Reingold layout allows nodes to be evenly spread so that viewers can see the centrality weighting of the nodes in relation to the diversity of edges and affinity clusters within the AFN.

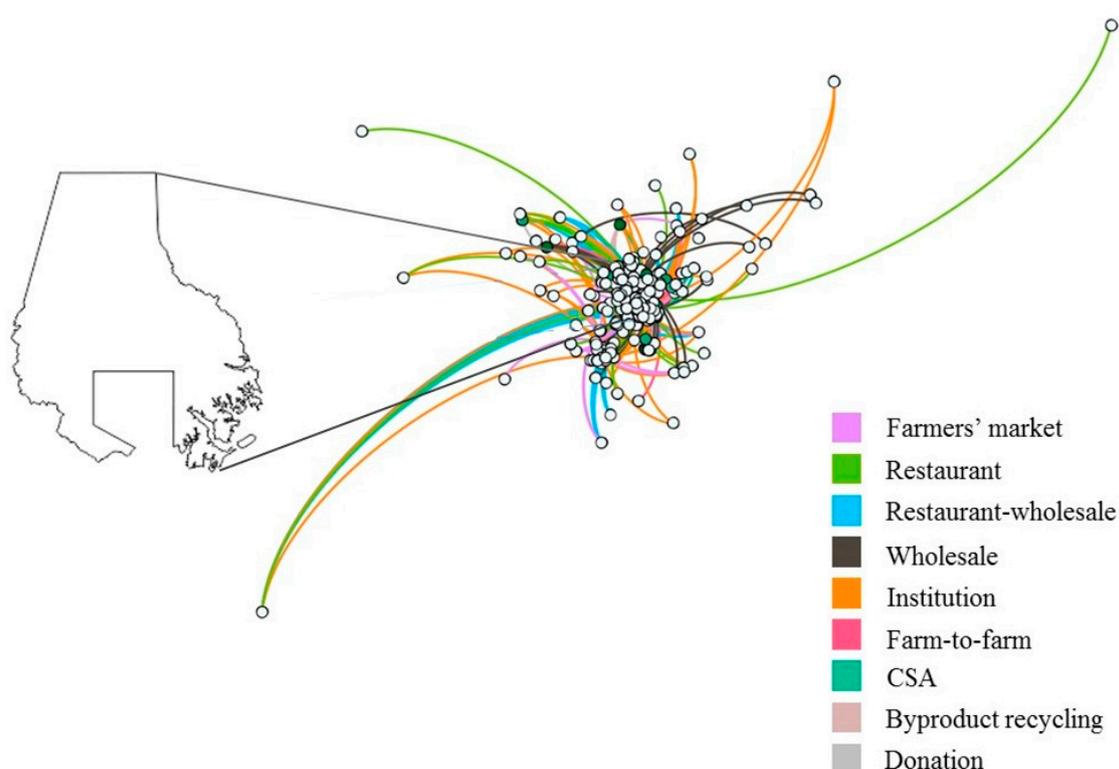


Figure 4. Geo-Social Layout. The far southern node reaches to Washington, D.C., while the far north-eastern node is located in Philadelphia, Pennsylvania. An outline of the County of Baltimore (left) is provided in order to give scale to the network. Nodes with higher network centrality are shaded a darker green.

Baltimore's AFN is connected through 699 edges (Figures 4 and 5). The network diameter is six, indicating a small-world effect with six degrees of separation, such that in six connections any node is connected to any other node. Most nodes do not cluster (average clustering coefficient = 0.032). This finding is perhaps not a surprise when one thinks of the effort in marketing food. It is rare that a farm would sell to restaurants, CSA members, farmers markets, institutions, *and* wholesalers (Figure 5). Many farms, especially large-scale operations, specialize in a particular marketing practice (Figures 4 and 5) and farm to a contract. Nonetheless, Figure 5 shows a prominent hub of farms selling to farmers markets and wholesale operations with restaurants attached.

This prominent hub comprises nodes from three of the four largest affinity groups. Modularity (0.553) shows 17 different affinity groups or communities within the network. While AFN literature has

extensive focus on farmers markets as central to food movements, Baltimore County's affinity groups demonstrate a diversity of edge relationships within each affinity group, indicating that farms selling to grocers, institutions, and restaurants may be of equal importance for influencing total network dynamics and social change. For example, the largest affinity group comprises 18% of the network edges and is comprised of farms selling to farms, inns, restaurants, farmers markets, a school, a catering company, a cooperative natural food grocery store, and a hospital. Indeed, farm-to-farm sales also prove important for knowledge sharing [37], according to interview data, and may influence other 'weak ties' [25] with consumers. The relationship between affinity groups and nodes of high centrality is explored further below.

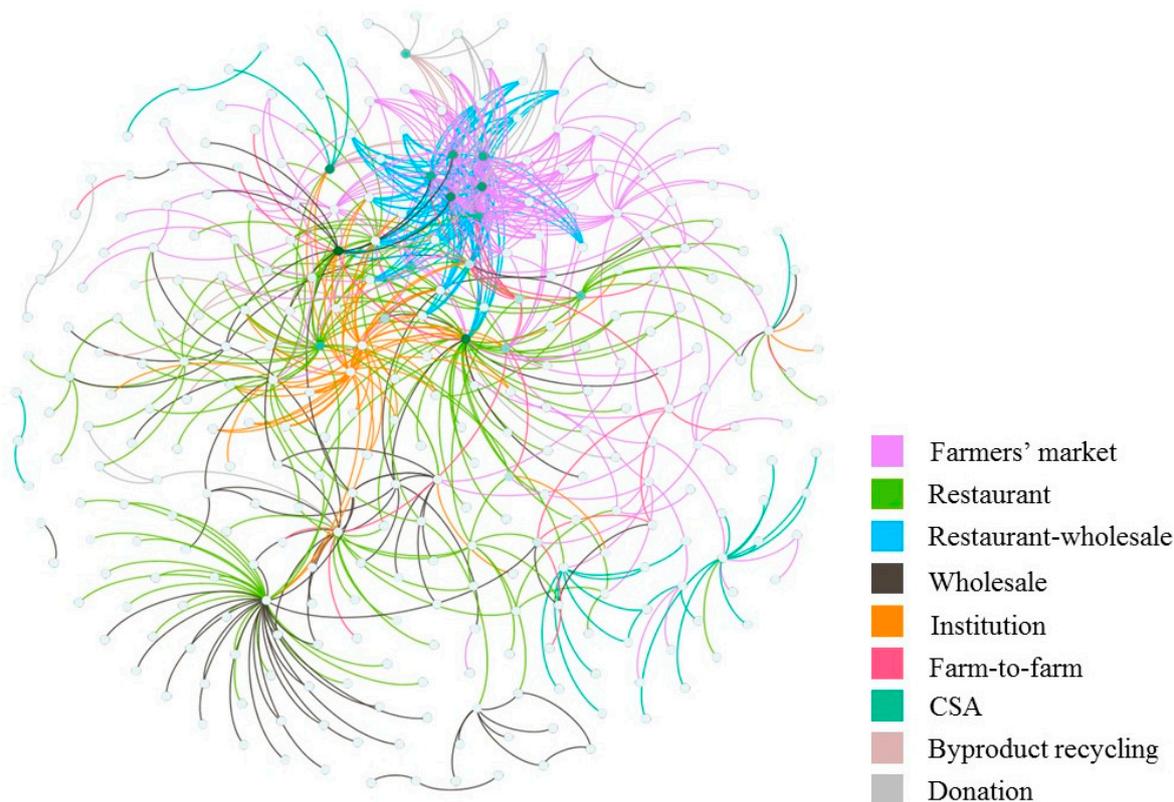


Figure 5. Fruchterman Reingold layout of Baltimore County's alternative food network (AFN). Nodes with higher network centrality are shaded a darker green.

The average distance between a farm and the first point of sale for the entire market was 35.42 km (Table 1). The most proximate connections were food donations followed by CSA sales and byproduct recycling (Table 1). This finding speaks to the potential importance of physical proximity in engendering networks associated with bringing consumers to the farm, food security, and tightening feedback loops for byproduct recycling. As Hinrichs [11] has pointed out, there are fundamentally different forms of social connections made when farmers travel long distances (average: 33 km, Table 1) to attend farmers markets as opposed to CSAs (19 km), where consumers often come to the farm or a nearby location to pick up food. Hinrichs [11] asserts that the socio-spatial differences between CSA and farmers markets likely lead to differently embedded economic and political relationships. A previous study [31] in nearby Chester County, Pennsylvania, supports the notion that CSA sales, byproduct recycling, and food donations are also geographically proximate networks. The small magnitude associated with these variables gives credence to the finding that the product is not pulled in any general direction but is locally focused.

The nodes central to Baltimore County's AFN (shaded darker green) are located in peri-urban regions, and no one food system actor dominates network centrality (Figures 4 and 5). In telecommunications network studies [10], a node with higher betweenness centrality would have more control over the network, because more information will pass through that node. The nodes with the highest betweenness centrality in Baltimore County's network may be similarly critical to the growth and function of the local food system. Further qualifying the spatiality needed for highly connected AFNs to start, grow, and transform, Jeffery Smith, a chef at Chameleon Café for over 10 years, noted that restaurants that are further from farms *and* urban areas will have a harder time getting local food:

[W]ith my restaurant, I had a lot of problems getting farmers to come because I didn't have a lot of refrigeration. I couldn't hold a lot of product. It was hard to get farmers to come out for small orders. And I wasn't around a lot of restaurants. So they would have had to go out of their way for small orders.

Mr. Smith drove out and collected produce from farms, creating direct buying relationships that, despite an unfavorable location, made his café a better-than-average connected node in the network (weighted degree of 3 compared to a network average weighted degree of 2.194; a member of the 11th largest affinity group, comprising 3% of the total network edges). Mr. Smith's comment also suggests that farm-to-restaurant AFNs are geographically bounded not only by distance but by surrounding land-use type and network magnitude. Thus, high centrality in an AFN may be indicative of social will combined with an endemic spatiality of opportunities. In the case of Baltimore County, these critical nodes of high centrality are diversified in terms of marketing typology, further described below (Figure 5).

Our Springfield Farm in Baltimore County is the node with the highest centrality, with a weighted degree of 60. This farm raises organic, free-range eggs and meats on a certified natural pasture, selling them to a variety of restaurants, grocery stores, and farmers markets in Maryland. This farm is the central node in the second largest affinity group, comprising 14% of the total network edges. The farm has been operated by the same family since the 1700s. In 2000, the United States Department of Agriculture Natural Resource Conservation Services recognized the farm as "an Alternative Farm Enterprise–Agritourism Success Story" for its direct marketing efforts ([59], p. 17). The success story is highlighted in the Maryland State Food System Plan ([59], p. 17), underscoring the policy embeddedness of this central node in the AFN. In addition, the farm won the 2012 farm-to-chef prize for best entre in collaboration with Slainte Irish Pub and Restaurant in downtown Baltimore. The annual competition pairs 30 Baltimore County farms with 30 restaurants, and has a sponsor list of 40 local businesses and non-profits. Not incidentally, Slainte is a node (weighted degree 2) within the largest affinity group containing 18% of the network edges and consisting mainly of farms that sell animal products (eggs, milk, cheese, meat) directly to restaurants and grocery stores. The shared prize underscores the innovation power of 'weak ties' across affinity groups in Baltimore's AFN. Yet, despite the celebrated success stories in innovative marketing, Our Springfield Farm has been battling neighbors for seven years over building an on-farm store at the site of a historic barn that was destroyed in 1850 [59]. Though Baltimore County's zoning allows the construction by right, disgruntled neighbors have held up the approval process in court hearings [59]. This case helps illustrate the extra-governmental support for direct and transparent local food purchasing in Baltimore County while drawing attention to the politics of land-use, as farmers negotiate with county planning commissions, local businesses, developers, and residents.

Another prominent cluster of nodes in the network are the Atwater's Markets (average weighted degrees of 47), which occupy the third largest affinity group, comprising 13% of all the network edges. Atwater's opened their first market in 2003 with a focus on direct farm sales through vending stalls. Their flagship Belvedere Market in the northern part of the county was a revitalization project. From this initial success, the Atwater's concept has spread to six locations and now manages markets in

Baltimore, Washington, D.C., the Washington, D.C., suburbs, and northern Virginia. Since this study, the Atwater's markets have opened an urban garden in 2016, as well as a processing kitchen, to help farmers make prepared foods for sale through Atwater's restaurants and markets. This case exemplifies the growth of AFNs as a feature of planned local economic development and a 'return' to historic marketing practices and sites with the aid of historic preservation.

Great Kids Farm is another node central to the network (weighted degree: 42) and in the third largest affinity group with Atwater's. This 33-acre non-profit suburban farm was started in 2008 at the site of a religious school and foster home for African-American boys from Baltimore City. It is currently operated by Baltimore City Public Schools. Students grow, harvest, process, and package vegetables that are delivered to Baltimore City Public Schools' cafeterias as part of the district-wide Farm to School Initiative. On the farm side, the program emphasizes professional skill development through work-based learning. The cafeteria side emphasizes education "about healthy eating, sustainable agriculture and the natural sciences" [60]. This case illustrates the innovation of non-profit and institutional partnerships in fostering a local food system, as well as the embedded relationship of AFNs in civic life.

Another node with high centrality is Trickle Springs Creamery in the neighboring state of Pennsylvania (weighted degree of 26; a member of the 8th largest affinity group, accounting for 5% of the network edges). This organic creamery was started in 2001 and sources from several farms with grass-fed, heritage breed cows, which do not use r-BST, a recombinant bovine growth hormone that stimulates milk production. Their creamery offers ready-made food and local food grocery shopping and sources from a variety of dairies and other local growers listed on their website. Trickle Springs also sells their products through the Washington, D.C., Union Market, a historically revitalized indoor farmers market built in 1967. The original outdoor Union Market was first established in 1931 and had over 700 vendors but shut down when city health regulations in 1962 forbade the selling of meat and eggs [61]. The new public health regulation so limited vending that many farms were forced to withdraw from the market, offerings were limited, and customers stopped frequenting the market. Like the revitalization of Belvedere Market, the rebirth of Union Market indicates the reviving of AFNs, as opposed to the synthesis of entirely new foodways. While not directly influencing policy in Baltimore County, Trickle Springs Creamery, like many farms in the network, helps support regional food organizations and festivals, like the Pennsylvania Organic FarmFest, which attracted over 2000 visitors in 2013 and featured a keynote address focused on the connectedness of sustainability efforts across "the natural system, communities and the economy" [62]. This case speaks to the social values promoted in the AFN, the importance of connections between farm-to-farm networks for innovation, historic preservation as an important component to markets, and the powerful repercussions of local public health ordinances.

6. The Embeddedness of Baltimore's AFN in Policy

Comprehensively uncovering the 'weak links' [25] that enabled the food system to exert political influence on land-use decisions via an embedded social network is complex. This section charts the parallel progress of planning documents to include AFN and where network actors are formally embedded in the planning process. Interviews and policy document review provide further insight into the dynamic alignment of Baltimore County's AFN with community values.

Previous studies emphasize the need for farmland preservation [6] to secure space for AFNs. Social values in Baltimore County have emphasized farmland protection more so than most other counties in the United States. Baltimore County has one of the oldest and strictest agricultural zoning ordinances in the country, allowing for agricultural use in all nine of the rural zones that cover nearly 70% of the county. Baltimore County employs a variety of tools for farmland protection, from public ownership and land conservation easements to 40-acre zoning. The 1967 Urban Rural Demarcation Line (URDL) around Baltimore has been successful in containing 90% of the county's population on one-third of the land, with most urban growth occurring within the URDL. The most-used tool for

farmland protection in Baltimore County is farmland preservation through purchase or donation of conservation easements; 70% of all farmland is preserved this way. Overlaid on farmland preservation is agricultural zoning, such that in combination, a total of 94% of the farmland is protected.

Building from this long history, numerous local, non-profit and state level initiatives support AFNs. The embeddedness of AFN actors in planning policy is best exemplified by the collective efforts of the Baltimore County-based non-profit organization North County Preservation, Inc. (Monkton, MD, USA), which commissioned the 'Rural Baltimore County Agricultural Profitability Study and Action Plan' in 2009 [63]. The report was compiled by a multidisciplinary team comprised of many of the farms and markets represented in Baltimore's AFN, including representatives from Atwater's Markets, Prigel Creamery, and Great Kids Farm with the Baltimore City School District. Network actors also contributed financially to the creation of the report [63]. The report includes interviews with farmers and food professionals; the identification of opportunities for improvement (market analysis and identification of priority areas); and recommendations (creation of working subgroups, list of actions, scope, leadership, and top initiatives). Most final recommendations include implementation responsibilities shared between the Baltimore County Economic Development Planning Office and the commissioning consortium of network farmers and market managers. For example, the first focus area is concentrated on agriculture development and has the goal to "collaborate with County and State efforts to develop new sources of capital dedicated to agriculture" [63]. This goal includes an action item for "participation in regional planning efforts" ([63], Focus Area 1, Recommendation 2, p. 25). Another action item includes the need to "improve Right to Farm protections with the creation of a mediation board to review, as a requirement, agricultural nuisance claims to include representatives from the Maryland Cooperative Extension, the farm community, community at large, planning officials, and others as necessary" ([63], Focus Area 3, Recommendation 2, p. 35). This goal has the action item to "appoint a farmer led team, to review county land-use regulations and policy with involvement from elected officials and the community" ([63], Focus Area 3, Recommendation 2, p. 35). The financial and political investment of network actors directly in land-use policy provides further support for the reciprocities between the food system and land governance (Equation (1)).

Recommendations from this report were ultimately incorporated at the state and county levels in land-use and food system planning documents. The 2011 *PlanMaryland: A Sustainable Growth Plan for the 21st Century* planning document lists Goal 3—to "[e]nsure that a desirable quality of life in Maryland's communities is sustainable"—with the objective to "[i]mprove the access that all residents of Maryland's metropolitan and rural population centers have to locally produced, high quality, nutritious food . . ." [64]. This document prompted the Maryland State Planning Commission to create a 2012 food system plan [59], drawing from the expertise of many farmers and market managers at nodes of high centrality, as well as those from nodes of low centrality. This food system plan highlights the goals and recommendations of the 2009 North County Preservation plan and builds from them. The uptake of AFN network actor efforts into state-level food policy demonstrates the range of embeddedness, as actors influence multiple nested governance systems that touch on economics, land-use, health, and future building.

The effects of the 2009 North County Preservation plan were felt most immediately in Baltimore County planning regulations. The comprehensive plan [65] was amended in 2010 to address a variety of agricultural economic concerns, including a sustainable farming piece in the county plan with emphasis on agritourism, the equine industry, state fair promotion, and large-scale farming supports. These planning supports are explicitly in reaction to the 2009 North County Preservation plan. An action item for the Baltimore County Plan includes to "consult the Rural Baltimore County Agricultural Profitability Study and Action Plan (2009), and implement appropriate actions" ([65], p. 143). The 2009 North County Preservation plan had identified county agricultural regulatory impediments such as limits to on-farm processing and sales, inconsistent application of state-level transportation regulations, varied wildlife management standards, water quality standards, and difficulty in maintaining localized worker housing. Following prompting from the 2009 North County Preservation plan [63], the revised

county comprehensive plan also made renewed commitments to support Farm Bureau educational activities, such as the “Agriculture in the Classroom” program at Hereford Middle and High Schools, a new mobile agricultural classroom, and the branding and marketing of Baltimore County agricultural products ([65], p. 44).

A contributor to the 2009 North County Preservation plan [63], Ginger Myers, the agricultural extension officer for Baltimore County, notes that the limits to AFNs are not spatial or social but regulatory:

[T]he hard part has never been getting the customer to the market, the more difficult part has been regulatory—food safety. . . . whole house regulations, the transport of the product, regulatory requirements, and permitting in different counties. . . . Many counties have their own layer of permitting on top of the state. For instance, if you wanted to sell eggs in five farmers markets in five different counties, you had to get five different egg sales permits, which could be anywhere from \$50–\$150 per county. No one could afford to do that and sell the eggs. We’ve since been able to do away with that—and have one permit to sell in any county. The same with the permits to move frozen food throughout the county. We now have a state one-time license called a mobile farmers market permit which says you can move frozen products to any farmers market in the state.

Ms. Myers also notes that the food safety and transport regulations are stricter for animal products, perhaps a reason why they are the latecomers to local markets: “it’s only been in the last five years that we’ve been able to sell retail cuts. You could sell the whole animal, but you could not sell processed cuts.” The previously mentioned Union Market case also emphasizes the strict health code oversight for eggs, milk, and meat. Indeed, while “food” is mentioned 28 times in the county master plan [65], 18 mentions are directly related to public health regulations. The network also clearly shows that Baltimore’s AFN does not neatly follow county or state jurisdictional boundaries (Figure 4). Cross-jurisdictional differences likely pervert market orientations, along with their affiliated social, economic, and political capital. Correcting for such cross-jurisdictional regulatory impediments was a chief focus of the 2009 North County Preservation plan and is explicitly mentioned as an action item: “[to] build beneficial relationships with neighboring jurisdictions to improve inter-jurisdictional planning efforts to avoid unintended cross-jurisdictional effects such as development spillover, orphaned water and sewer improvements” ([63], Focus Area 3, Recommendation 2, p. 36). Indeed, while planning requires public input, public health regulations do not. Community governance efforts to influence public health policies necessitate expert opinions and subsequently result in regulatory documents that rarely cite community governance efforts, such as the 2009 North County Preservation plan. Nonetheless, Ms. Myers indicates that concerted community governance efforts were able to align public health regulations across jurisdictions.

Ms. Myers also notes that while permissive land-use regulations may have allowed Baltimore County farmers to explore multifunctional agricultural practices, more recently, planners have been hesitant to grant new on-farm permits. When Baltimore County revised the comprehensive plan, local farmers saw the opportunity to pursue on-farm retail and further valorize their holdings. At the same time, landmark court cases in the county have disputed the right of farmers to develop agritourism and value-added processing facilities on farms. The push back is most strongly characterized in the case of Prigel Creamery, an organic dairy on preserved land with neighborhood letters of support and planning permits for the construction of an on-farm bottled milk and ice cream processing plant [66]. This farm is central to Baltimore’s AFN with a weighted degree of 22 and is a member of the largest affinity group (18% of the total network). A community group was upset over the change in viewscape. After several thousand dollars spent on legal fees, the creamery was eventually built. Myers asserts that the repercussions from this court case have made Baltimore County planners increasingly shy of permitting on-farm value-added facilities. Farms that were early to adopt multi-functional on-farm value-added ventures are continuing to expand, but new farms that would like to join have significant

barriers to entry, as also demonstrated in the case studies. As Ms. Myers notes, “the existing facilities are expanding and growing, but the new facilities are having a much harder time getting the permits. The review process is more stringent than it used to be”. In this sense, the strong farm network enjoyed in Baltimore County may stagnate, but only because non-collaborative governance, such as public health ordinances and court cases, constrain the food system (Equation (1)). None of the interviewees mentioned zoning as a restrictive or supporting factor in AFNs despite the obvious role it has played in shaping farming practice and the siting of multifunctional facilities.

In comparison with the social value of farmland preservation, food security was not emphasized in the AFN or planning documents. Baltimore County’s Master Plan 2020 mentions that “resources can provide for the basic needs of all citizens, including local food production . . . ” ([65] p. 6) and the “promotion of local farms can improve the quality and security of the local food supply and play a role in solving other environmental problems.” ([65] p. 166). The local food movement is explored in terms of how it might benefit the environment and farmers, acknowledged in the plan as a very small portion of the population with less than 0.2% of total employment ([65] Chart 17, p. 18). There are no sections in the general plan that link farms and the local food system to aspects of supplemental nutrition programs, area food banks, health equity, or school lunches. This is a contrast with study findings for nearby Chester County [37], where the local food bank was a hub in the AFN and emphasized in planning documents.

In sum, land-use governing documents reflect a long-term emphasis on protecting farmland at the production end of the network and upholding food safety standards at the consumer end to encourage the economic vitality of agricultural land. AFN network actors are deeply embedded in county, cross-jurisdictional, and state land-use governance. Their pioneering growth management and environmental protection policies help shape the types of farming supported in Baltimore County, as well its geographic relationship to dense, urban areas. Yet, governing documents, like the AFN, lack an explicit emphasis on equity in food access and food security.

7. Limitations

The research scope for this inquiry was focused on the direct sale or donation of raw farm-produced products. There are likely many other edges that could signify embedded AFN relationships where farm visits, value-added foods, or non-edible products are exchanged. Future research may broaden these initial findings. In addition, Baltimore County is home to a community of Amish-run farms. The Amish farmers do not use telephones or email. These farmers were unavailable to verify marketing practices, and such farms are not represented in the analysis.

8. Conclusions and Discussion

This research uses the mathematical properties in network architecture and qualitative data to demonstrate that Baltimore County’s AFN is a small world. Namely, this research reveals a network diameter of six degrees of separation and a series of robustness and resiliency measures built into the network by diversified farming and marketing practices. No one node dominates network centrality, and there are 17 communities of affinity groups within the network made up of diverse marketing practices. This small-world network brings producers, processors, distributors and consumers into a shared value system that is directly embedded in civic land governance.

Small-world networks are found ubiquitously in organic and engineered real-world systems [10,29]. Their architecture possesses the advantage of robustness [29] and shows markedly different properties in terms of resiliency to disturbance when compared with networks that are highly centralized and can experience major disruption if a central node is incapacitated. For small-world food systems, if any one farm or market collapses, the entire network is likely to survive because of a design with internal robustness. Supporting evidence is found in Baltimore County’s network longevity and total network survival after market closures and public health regulation changes for

animal products. Future work can test the correlation of small-world food system architecture with its evidenced resiliency.

For local food security, understanding AFNs as small-world networks may help explain why they are often able to rise to the challenge of supplying food when global food supply networks fail [43]. In support, Comfort and Zagorecki [67] showed that first responders are part of small-world social networks made of friends and neighbors. The importance of food aid through local social networks is well documented [68] and may present similar opportunities for disaster management. For those interested in resiliency planning, this finding suggests the inclusion of local food system actors in long-term and short-term disaster preparedness training. Future research could explore the response rate and scale for local food system involvement in comparison with other disaster food aid efforts. Such inquiries are of growing importance given climate change and the need for resiliency planning on multiple fronts, not least of which is food security.

Another resilience mechanism is built into the network by connecting a diverse set of central actors with multiple marketing practices that operate at various distances. Should regulations governing any one type of marketing change, the local food system network has a diverse central cast of actors to help uphold the system. The findings herein help researchers think of how to parse prior findings, such as those from Selfa and Qazi [13] who noted that “local food systems are defined by social relationships that may or may not be geographically proximate, while for others, local food systems are defined by a politically constructed boundary like a county or a bioregion.” In the case of Baltimore County, spatial proximity matters to CSAs, byproduct recycling, and food donations, but other forms of local food marketing are less constricted by distance and more constricted by regulatory variances at jurisdictional boundaries or nearby land-uses. Indeed, such short- and long-range variation in marketing pathways may enable farms to redirect markets when public health regulations or neighborhood-based lawsuits interfere.

The small worldliness of the local food movement is also suggestive of self-organizing systems. For example, many vendors may compete for customers while cooperating for business at a farmers market. In sum, these efforts help brand a movement of shopping local. The prominent cluster of farmers market sales underscores such cooperation amongst competitors in a much broader social movement. Though often unaffiliated at the node level, a few members of high network centrality function as hubs of connectivity, linking the different groups. In the case of Baltimore County’s local food systems, the nodes with high connectivity are in unique positions to coordinate action, influence land-use, and broaden the support for other local food actors. Indeed, many of these actors are involved directly in setting regulatory policies. The degree to which actor agency can shape AFN inclusivity, growth, and evolution alongside broader health and land-use regulation is an area ripe for future studies [6].

To this end, the spatiality of highly connected nodes in Baltimore County’s AFN predominantly occur in the contested peri-urban space at the crossroads of demand for housing development and farming to support global markets. Perhaps because of the AFN’s struggle against both urbanization and agrifood industries, it is the periurban space, not urban or rural, where the most centralized nodes are located (Figure 4). Producers in this space face multiple threats to their business and would seek multiple and alternate marketing and social practices to stay financially viable. A small-world network would help such farmers innovate and share new marketing information rapidly while remaining robust to the loss of nodes in the network, as global food systems or urban land-uses push AFNs actors out.

Importantly, this study provides further evidence of the embeddedness of AFN in policy documents where value systems influence land governance. Where Chester County’s plan emphasized the food bank as central to shared values, so did the AFN [37]. Baltimore County’s values emphasize redundancy through economic planning supports for land that is already preserved through the purchase of agricultural easements, zoning and urban growth restrictions. This research supports findings from other studies [15,55], which note that AFNs require extra protection from development

to grow, but qualifies that the total system growth likely depends on a value system that welcomes multifunctional agriculture and plans for the continued vitality of markets with supportive public health regulations.

Because land-use control is local, the power to shift these networks lies currently with communities. Locales that do not currently have local food systems may have a harder time unifying value systems around farmland protection and direct marketing practices simply because a social and economic network with such objectives has not yet formed. As Baltimore County demonstrates, public health codes at the city and county level, perhaps more so than land-use ordinances, have restricted local food sales and shaped geographies of opportunity. Court cases similarly deter AFN expansion. There is little public input in formulating public health regulations or court decisions. This is unlike the community governance framework of public hearings, charrettes, and collaborative design that goes into shaping county general plans and guiding land-use regulations. While health practitioners may be wont to crowd-source health regulations from the public, they should be mindful of how food safety regulations indirectly influence health by shaping affiliated systems of healthy food access, economic opportunity, urban revitalization, land-use, greenspace, and small-scale entrepreneurship. Indeed, this research revealed several instances where changes in public health ordinances directly dissolved AFNs. Such bonds connecting rural, urban, and peri-urban actors into a unifying small-world network may be more important than previously understood to value systems, civic engagement, governance, land-use, and health.

Funding: This research was funded by the National Science Foundation grant number 1760621.

Acknowledgments: Thank you to Mark Lubell and the broader Complex Systems community at UC Davis for feedback on earlier drafts of this research. As always, collaboration and conversations with (the now newly graduated!) Jaqueline Scarlett Kingsley on related future projects has yielded valuable insights into data analysis and theory. The reviewers have strengthened the work through their thorough reading and helpful feedback, while helping to chart future directions. A firm, yet gentle, nudge by editor Robert Vos moved this manuscript toward a more compelling write-up. I am grateful for the expertise and time granted by the academic community to grow this area of inquiry. All remaining flaws are mine alone.

Conflicts of Interest: The author declares no conflict of interest.

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