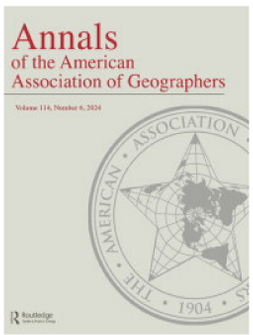

Annals of the American Association of Geographers

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/raag21

Locality, Personal Ties, and Efficiency in a Food Security Network

Jaimie Kelly, Dipto Sarkar & Clio Andris

To cite this article: Jaimie Kelly, Dipto Sarkar & Clio Andris (28 May 2024): Locality, Personal Ties, and Efficiency in a Food Security Network, Annals of the American Association of Geographers, DOI: 10.1080/24694452.2024.2338096

To link to this article: https://doi.org/10.1080/24694452.2024.2338096

ANNALS OF THE AMERICAN ASSOCIATION OF GEOGRAPHERS
https://doi.org/10.1080/24694452.2024.2338096

Locality, Personal Ties, and Efficiency in a Food Security Network

Jaimie Kelly,[a] Dipto Sarkar,[b] and Clio Andris[c]

[a]*Department of Political Science and International Affairs, University of North Georgia, USA;* [b]*Department of Geography and Environmental Studies, Carleton University, Canada;* [c]*School of City & Regional Planning, School of Interactive Computing, Georgia Institute of Technology, USA*

Food sharing and distribution organization systems provide critical resources for local communities and food-insecure households. In this article, we investigate a newly collected data set of the Thrive Network in southwestern Virginia, which links forty food security organizations through fifty-one connections, using a theoretical framework of organization science within geographic space. We first test whether more central and higher degree organizations are toward the geographic center of the network, near convenient points of interest. We then measure whether organizations are likely to form connections based on nearness and logistical effectiveness of moving goods, and where this occurs. Finally, we find "missed connections," defined as sets of organizations that are nearby but highly disconnected in the network. We find that important nodes are not necessarily in the center of the network, but are located on the periphery, and that relatively few organizations are connected to their nearby neighbors. We find that important nodes are not necessarily in the center of the network, but are located on the periphery, and that relatively few organizations are connected to their nearby neighbors. As such, this system could be predicated on bottom-up personal relationships rather than a hub-and-spoke supply chain configuration, and new ties might make the system more effective. We use our findings to help the Thrive Network build a more resilient food-sharing system and better serve vulnerable clients. *Key Words: cooperation networks, food security, geographic network analysis, spatial social networks, Thrive Network.*

Food sharing and distribution systems provide critical resources for local communities that are food insecure; that is, lacking adequate food due to limited funds or resources (Coleman-Jensen et al. 2019). Food-sharing networks rely on the transfer of physical goods such as canned foods, cereals, and produce, thus engaging geographic concepts of both relationships and logistics. These systems can best serve communities when they are connected to the right partners for service delivery, transfer of goods, and client referrals. Yet it is difficult to capture whether networks are built for efficiency, or whether they are predicated on social relationships and interpersonal ties that might not consider efficiency.

Here, we analyze the spatial and organizational dynamics of the Thrive Network, which is in the New River Valley Region in southwestern Virginia, USA (2019 estimated population of 200,000). The Thrive Network was created in 2016 by local community groups to connect organizations that can distribute food (both perishable and nonperishable items) to clients experiencing food insecurity. Its goals are to increase opportunities for community outreach, education, and technical assistance; implement a food hub; secure and transport food donations; and share knowledge on food habits (Edwards 2020; Community Foundation of the New River Valley 2022). Participation in the network is voluntary and no single entity oversees relationships or optimizes a supply chain (although the founding organization helps facilitate ties). However, ties are based on a fuzzy mixture of ad hoc social and interpersonal relationships and strategies to connect to nearby organizations to facilitate easy, convenient transfer of food.

The New River Valley Region area contains towns Christiansburg, Floyd, Pearisburg, and Blacksburg, Virginia, which is home to many students enrolled at Virginia Tech, a large university.

ARTICLE HISTORY
Initial submission, December 2022; revised submissions, June and September 2023; final acceptance, January 2024

CORRESPONDING AUTHOR Clio Andris clio@gatech.edu

Nearby Roanoke serves as an anchor city. The community is located in mountainous Appalachia, with nearly one in five families experiencing food insecurity. Due to the mountainous landscape, members say that geography hampers collaboration, citing that geographic distance is a major "external barrier to collaboration" (Edwards 2020).

Our research goal is to quantitatively capture the principles driving the Thrive Network, which includes forty food-sharing organizations and fifty-one connections between organizations. Our secondary goal is to suggest new connections between nearby organizations. Accordingly, we pose hypotheses about this network, based on prior knowledge about food-sharing systems and social networks:

H1. Power, situation, and accessibility

> **H1.1.** Better connected organizations (with higher degree and network centrality) will be in areas that are near other points of interest (POIs), to facilitate trip chaining, whereas organizations with fewer ties will be in more remote areas.
>
> **H1.2.** Organizations near the geographic center of the network will play a more central role in the network.

H2. Physical distance. To minimize the cost of transferring goods between organizations and given the likelihood of relationships between organizations in the same small town, we posit that organizations are likely to share food with their nearest organizations.

H3. Local disconnection. We also hypothesize that some nearby neighbors are separated by many hops in the network, despite their proximity, and suggest new ties between these nodes.

To test these hypotheses and make new recommendations, we embed this spatial social network (SSN) within a geographic information systems (GIS) environment and calculate new metrics to capture proximal relationships and find areas with tight-knit communities. Following, we assess why near or far connections might have occurred and make suggestions for future ties using local knowledge.

This interdisciplinary research is conducted using a research framework of spatial interaction and SSN analysis. It designs new methods of SSN analysis within GIScience, as it requires the fusion of a social network with underlying geographic space and infrastructure.

The main contributions of this article are new SSN metrics that help explain whether network power correlates with location, whether nodes value local or distant connections, and which types of places have tight-knit or loosely connected ties. We also put forth a new metric of "missed connections," adapted from the theory of intervening opportunities (Stouffer 1940), to help organizations create strategic new connections to provide faster food transfer and better service to customers. The more extended outcome is a resilient safety net of food sharing in a region with pronounced rates of food insecurity. Our results can inform real-world policy on the network creation process of local organizations, leading to more sustainable communities.

The article proceeds as follows. We first describe literature on food insecurity, purpose-driven networks, and SSNs. We next outline data collection and analysis methods. Following, we present our results and discuss our findings.

Literature Review

Food Insecurity in the United States

Food insecurity is defined as the lack of access to adequate food due to limited funds or resources (Coleman-Jensen et al. 2019). In the United States, in 2022, 10.2 percent, or one in nine Americans, experienced food insecurity (U.S. Department of Agriculture [USDA] 2022). Food insecurity in the United States affects certain populations disproportionately, including:

- Households with children (12.5 percent) and single-mother-led households (24.3 percent).
- Black (19.8 percent) and Hispanic households (15.6 percent).
- Southern United States (11.4 percent).
- Rural households (11.0 percent; USDA 2022).

For most U.S. households, food insecurity is a recurring issue. For example, in 2018, three-quarters of food insecure households experienced hunger in at least three months (Coleman-Jensen et al. 2019). Food insecurity is high and rising for college students (Freudenberg, Goldrick-Rab, and Poppendieck 2019) and can lead to decreased nutrient intake, which correlates to many health threats (Rose and Oliveira 1997). Food-insecure women are 30 percent more likely to be obese, which can lead to health issues

such as heart disease and diabetes (Townsend et al. 2001). Food insecurity can be especially devastating for children (Murphy et al. 1998; Olson 1999). Moreover, Black and Hispanic households have higher rates of food insecurity than White households (Schanzenbach and Pitts 2020).

Food insecurity especially affects rural households, as 87 percent of counties with the highest levels of food insecurity are rural (USDA 2022). Furthermore, Black Americans in rural areas are 2.5 times more likely to experience food insecurity than their White counterparts. Rural areas, unlike their urban counterparts, face additional barriers to ending food insecurity that include the cost of nutritious food (Piaskoski, Reilly, and Gilliland 2020) and accessing food without a vehicle (Piontak and Schulman 2014).

Purpose-Oriented Service-Delivery Networks and Geography

A coalition of government, nonprofit, and for-profit actors work to address food insecurity. These organizations can work independently, but in some cases (as we examine here), organizations cooperatively create formal networks to share information, solve problems, build community capacity, or provide services (Milward and Provan 2006). In public administration, food sharing networks are an example of purpose-oriented networks, which can be defined as "networks comprised of three or more autonomous actors who participate in a joint effort based on a common purpose" (Carboni et al. 2019, 210).

Purpose-oriented networks like food-sharing networks face challenges including limited resources (van Gorp 2014), a lack of internal and external legitimacy (Human and Provan 2000), a lack of organizational engagement (Poocharoen and Ting 2015), and the inability to collectively agree on goal setting and implementation (Vangen, Hayes, and Cornforth 2015). Purpose-oriented networks that cooperate to provide services to clients have an additional burden: geography. In many networks, geographic distance limits its members' ability to have informal encounters (Knoke 2004) and direct communication and interaction (Rallet and Torre 1999; Gilly and Torre 2000; Knoben and Oerlemans 2006). These geographic challenges create a lack of trust between collaborators (Noll, Beecham, and Richardson 2010) because of delayed communication (Nguyen and Rose 2009) and increased costs to facilitate collaboration (Katz 1994). In the case of food-sharing networks, these challenges are exacerbated by the need to meet in person to transfer perishable food quickly.

Relatively little is known about the role of geography in purpose-oriented, service delivery networks (Edwards 2020). Service-delivery networks are often geographically constrained both because of the types of services they provide and the clients they serve. In addition, political boundaries might also create complexities for these networks, as funding for service delivery may be tied to political jurisdiction (Edwards 2020).

Geographic Social Networks

Geographically embedded social networks, or SSNs, are networks in which nodes have a distinct geographic location and edges connect the nodes over geographic space (Andris and O'Sullivan 2021). SSNs can describe health and well-being, such as the proliferation of cholera and shigellosis within families and across space (Emch et al. 2012) and teen substance abuse in Philadelphia (Mennis and Mason 2011). SSN structures also help tie patterns of gang behavior and criminal associations to geographic space: Andris et al. (2021) analyzed the family structure of U.S. mafia associations as recorded by federal investigations in the 1960s, and Papachristos, Hureau, and Braga (2013) and Radil, Flint, and Tita (2010) showed how street networks and highways affect gang-related crime in Chicago and Los Angeles. At a larger scale, SSNs describe conflict and terrorism on the African continent (Walther, Radil, and Russell 2021) or cooperation between transportation policy organizations in Western Europe (Sohn, Christopoulos, and Koskinen 2020). Other studies examine cooperation and sharing in rural areas such as how households trade and share firewood and fuel in South Africa (Schramski and Huang 2016), how job referrals connect villages in Uganda (Sarkar et al. 2019), and seed-sharing and agricultural labor among small Peruvian villages (Abizaid et al. 2018).

Data and Methods

Case Study

The Thrive Network is located in the Blacksburg–Christiansburg–Radford Metropolitan Statistical Area (Blacksburg, Virginia). The area's population is about 200,000 people, and 9 percent of households are below the Census-distinguished

poverty rate (New River Valley Regional Commission 2019). The rate of food insecurity in this area is 12.5 percent, ranging from 8.5 percent in Floyd County to 19.6 percent in the City of Radford (CFNRV 2022). In 2011, The Livability Consortium, a "coalition of local governments, nonprofits, educational institutions and community organizations interested in having a regional conversation about the future" was awarded a Federal Partnership for Sustainable Communities grant to conduct a three-year study called "Livability in the New River Valley" (New River Valley Livability Initiative 2014, 4). The study identified eighteen overarching goals for the region, one of which was to address regional food insecurity. In response, the Community Foundation of the New River Valley (CFNRV n.d.) created the Fund for the NRV, which has collected nearly $700,000 in funding since 2014.

With this funding, the CFNRV formalized a network of approximately 100 local public, private, and nonprofit organizations that provided support, services, and food directly to clients in need (Thrive 2018, "Supporting Nutrition and Health," para. 1). This network was intended to eliminate redundancy in services, help organizations share best practices, and identify where resources could be directed to create the greatest good (Figure 1). Thrive's first meetings were community conversations across the New River Valley that sought buy-in from the community for the creation of a Food Access Network Survey, the result of which we analyze in this research.

Data Collection

Data were collected from December 2017 to April 2018 via an organizational survey and interviews with select respondents (see Appendixes A and B in the Supplemental Material). Organizations were selected to participate in this network by the CFNRV and Thrive leadership. The survey was distributed via e-mail, follow-up phone calls, and in-person survey sessions. Of 112 organizations contacted, ninety-four answered the survey. Data on five types of relationships between the ninety-four organizations were collected, including information sharing, shared resources, program coordination, client referrals, and food sharing. Each organization was asked to list the organizations they were "involved with for the provision or support of services, programs or activities related to food access over the past 12 months" (Appendix A). The networks were produced by linking each organization's name with the names of the organizations that they listed in the survey to produce a network edge list.

Here, we use a subset of the network that specifically is involved with food sharing. The network is unweighted and undirected and includes forty nodes and fifty-one edges. The nodes range from a degree of 1 to 16 ($M = 2.5$), and the network density is 0.0653. The average path length is 3.0, and the network's clustering coefficient is 0.31. Two nodes are disconnected from the main component (but are connected to each other).

Geographic Data

We geolocated organizations (nodes) by address using the Google Maps application programming interface, to produce a spatial network at the coordinate (latitude, longitude) level. Maps were created by drawing edges between the organizations' points, if the two organizations were linked. To represent amenities and measure travel time, we used

Figure 1. New River Valley Thrive participants stocking the food pantry at an organization (left) and a member delivering a food donation to an organization (right). Photos by Jessica Wirgeau.

OpenStreetMap POI data and road data from Virginia Road Centerlines (The Virginia Geographic Information Network 2022). The bounding box used for POI retrieval was determined as the bounding box of the nodes, with a 500-m buffer around the box. We removed POIs that are not common destinations, such as graveyards, benches, and trash cans.

Analysis Methods

Power, Situation, and Accessibility. To measure the association between power and accessibility, we calculated degree, betweenness centrality, closeness centrality, eigenvector centrality, and eccentricity for each node (see Hanneman and Riddle 2011). We calculated global geographic centrality as the mean and median geographic center of the nodes. We then measured the road network distance between each organization to the mean and median centrality points. We define geographic local centrality as the total number of POIs within a one-mile road network distance to each organization (Yang and Diez-Roux 2012). We correlated the network "power" metrics and geographic centrality metrics using the Pearson correlation coefficient to ascertain whether important players are "in the thick of things."

Local Disconnection. To find whether organizations connect to their nearest organizations we computed two new descriptive metrics. In the following, k is equal to the node's degree and d is equal to the distance between nodes on the road network.

- *K-fulfillment*. In network logistics, a *fulfillment* metric indicates the extent to which a node's capacity for supply has been met (Li et al. 2019). In our model, this metric is defined as the number of a node's k-nearest neighbors that it is connected to. Nodes that are exclusively connected to their nearest neighbors will have a *k-fulfillment* value of 1.
- *Local network flattening ratio*. This metric (adapted from Sarkar et al. 2019) is defined as the ratio of a node's minimized distance (d_{opt}) needed to connect to any k nearest neighbors to the total actual distance (d_{act}) of its connections. Nodes with low values prioritize distant connections.

Missed Connections. To suggest potential new relationships to make this network more complete, we computed a metric called *missed connections*. This metric detects pairs of nodes that are geographically close but are separated by many network hops. We measured the route factor, defined as the number of hops $h_{i,j}$ divided by the $d_{i,j}$ (Hay 1973), for each node pair (i, j). We find pairs with the highest route factor and suggest these as potential new connections in the network.

We performed analysis and designed visualization using R Studio, Datawrapper, ArcMap 10.6, and ArcGIS Pro.

Results

Power, Situation, and Accessibility

On average, organizations are 23.17 km from the mean center and 24.27 km from the median center of the network. The closest organizations to the center of the network are Spiritual Roots Community Food Bank (8.38 km to mean center, 5.1 km to median center) followed by Gethsemane Baptist Church (8.58 km, 5.31 km). The most distant organization is the large nationwide organization Feeding America, at almost 50 km from the mean center. Organizations have, on average, 22.22 POIs within one mile of road distance. This value ranges from 1 to 135, the latter of which is Blacksburg Farmers Market located at the convergence of Blacksburg's lively main street and Virginia Tech.

Important organizations, as measured by degree and centrality metrics, are not statistically near the center of the network or near dense sets of POIs (Figure 2), suggesting that node power and capacity to connect is not correlated with being more accessible to all organizations. One notable example is Feeding America in nearby Roanoke, Virginia, which has a degree of 16, but is on the periphery of the study area. Feeding America attracts distant organizations by selling goods at a discounted price. Not all organizations travel to Feeding America, however, due to limited resources and lack of training on their online ordering program. As one organization stated, "It's a thirty-five-minute drive … and we could purchase from them at a discount, but we don't always know what's going to be there. Do we bring one car or two? What else are we going to need [that Feeding America doesn't] have available?" (personal communication 2019).

Local Disconnection

Local connections between entities are uncommon in this network, per results of the k-fulfillment test. Only six nodes (12 percent) are connected to

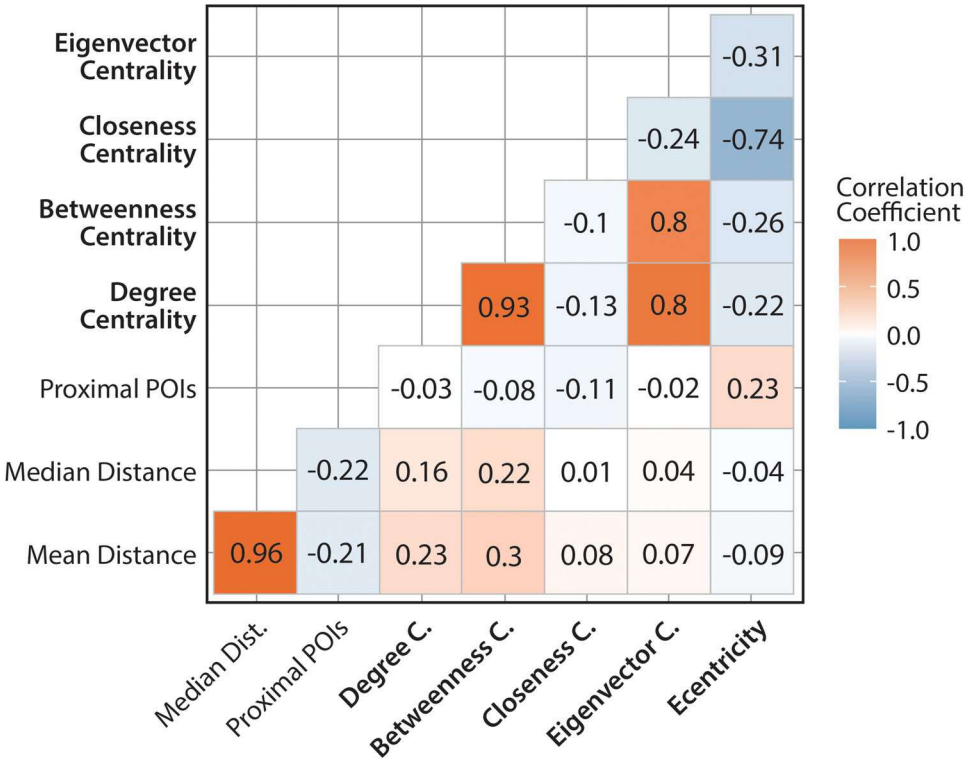

Figure 2. Correlation plot illustrating the Pearson correlation coefficients between pairs of variables representing network centrality and power (in bold), and variables representing geographic location (i.e., mean distance of connection, median distance of connection, and number of proximal points of interest [POIs]).

their nearest neighbor, and twelve (30.0 percent) are connected to either their first or second closest neighbor. Twenty-eight organizations have a *k*-fulfillment value of 0 (Figure 3). Organizations with high *k*-fulfillment values (and more than 1 degree) include the Meadowbrook Public Library Backpack Program and the Giles County Christian Service Mission (Giles Mission), the latter of which is highly connected to local organizations in local Pearisburg. On examination, we found that Giles Mission is highly locally connected because its leader actively linked nearby organizations with different service provision agencies within the town of Pearisburg and focused resources to help local residents needing social services (Giles County 2022).

The global flattening ratio for the network is 0.313. The local network flattening ratio ranges from 0.0039 (Beans and Rice of Pulaski) to 1 (four organizations), with a mean value of 0.276. The Giles Mission has a low local flattening ratio (0.045), implying it forgoes nearby nodes for distant nodes (Figure 3). The Giles Mission, as mentioned, however, connects to nearby nodes, but its flattening ratio is low because it connects with the very distant Feeding America, in Roanoke. Feeding America has a low *k*-fulfillment (0.300) but a high flattening ratio (0.679). At the town level, there is little local coordination in Pulaski or Radford; Christiansburg's nearby organizations also do not connect to themselves. We note that *k*-fulfillment results are sensitive to few (connected) near neighbors (yielding many 0s) while local flattening ratio values are more evenly distributed between 0 and 1.

Missed Connections

This descriptive metric detects pairs of nodes that are geographically close but are separated by many network hops. Broadly, Figure 4A (called a route factor diagram after Hay's (1973) metric) can be used to discover node pairs that are nearby but highly disconnected in the network, as these pairs may be good candidates for a new connection. The Blacksburg Farmers Market (BFM) is present in many pairs of missed connections, as its nearby

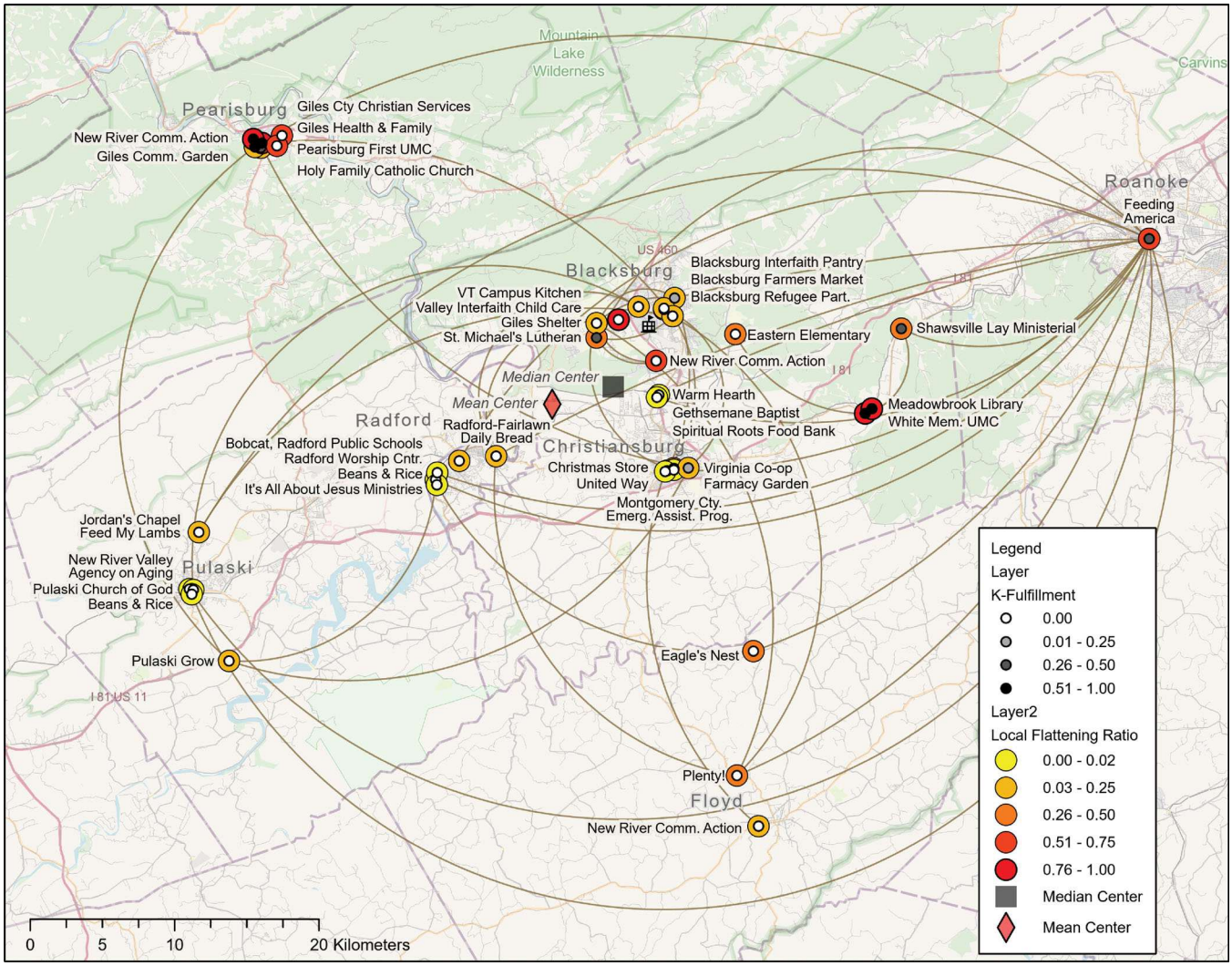

Figure 3. Organizations (nodes) are connected with an edge if they share food (e.g., nonperishable foods and fresh produce) with each other (per Edwards 2020). Nodes are colored by both *k*-fulfillment and local flattening ratio values.

nodes are disconnected by many hops; the BFM appears three times in annotated points in Figure 4A. In one example, the BFM is separated from the Eastern Elementary Backpack Program by six hops in the network (the maximum number of intermediary hops) yet they are about 5 km apart (Figure 4B). BFM prioritizes providing a network for farmers to sell their goods over engaging with charitable aspects of ending food insecurity. Encouraging the BFM network to share food could improve the famers market, and help local farmers build ties with other organizations in the network. Another notable missed connection in this network is between Farmacy and the Montgomery County Emergency Assistance Program (in orange in Figure 4A).

Discussion and Conclusions

In this research, we describe how a food-sharing network is connected. We find that despite prior knowledge that geography is a cost to collaboration, organizations are sometimes required to collaborate across interorganizational, political, and cultural boundaries. We also find that being in the "middle" of the geographic network does not equate to more connections or higher network centrality. We find that multiple organizations could benefit from connecting with other organizations in their towns. We also identify pairs of places that, if connected, would improve the overall connectivity of the network. Our results contribute to the scholarship of geography by proving methods and

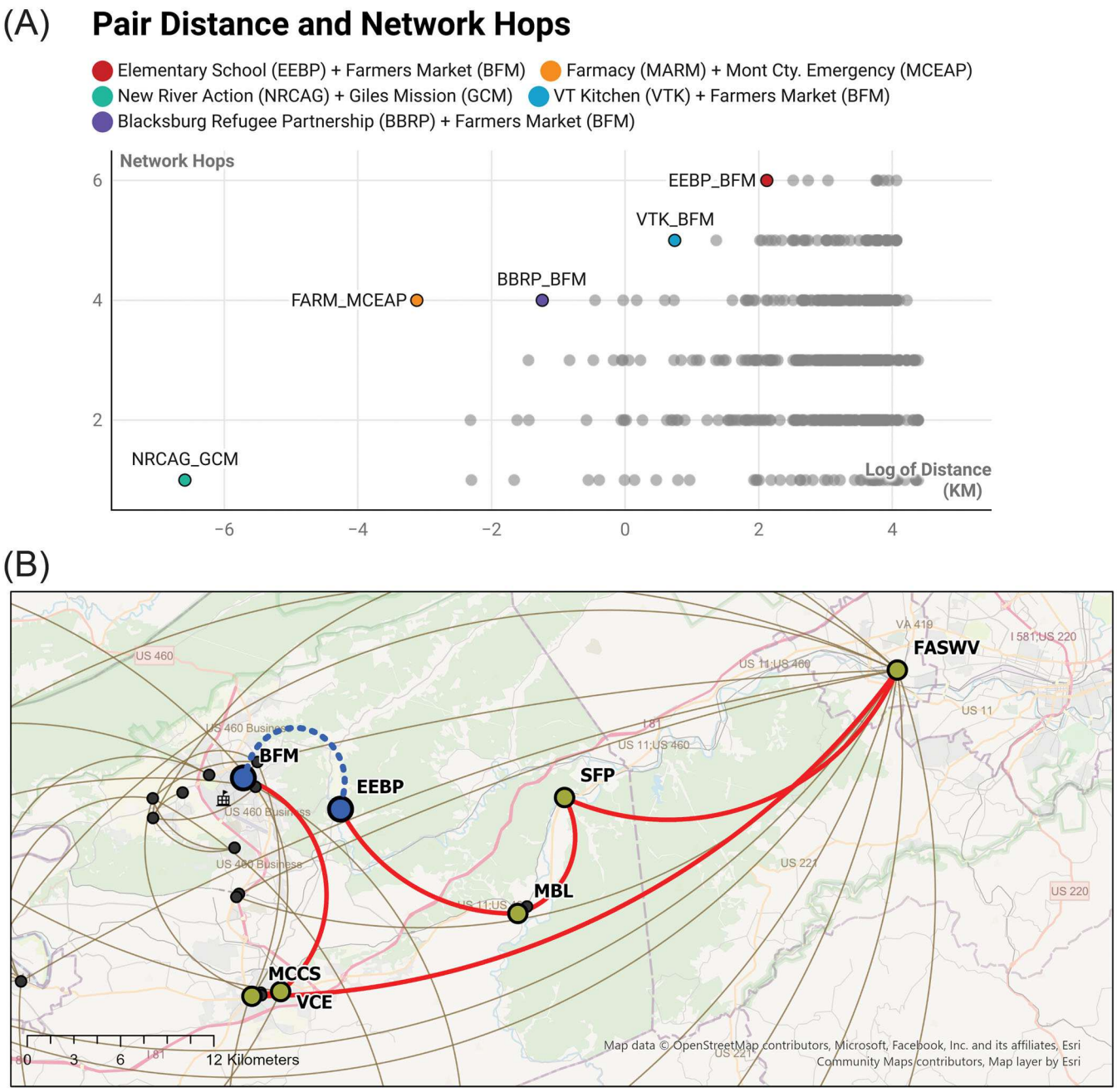

Figure 4. (A) The route factor diagram illustrates pair distance in kilometers and the number of network hops between them. (B) The map illustrates the number of network hops (red) and conceptual connection (blue dashed) between a program at an elementary school (Eastern Elementary Backpack Program [EEBP]) and the Blacksburg Farmers Market (BFM).

narratives that can be used to respond to philosophical geographic questions such as how an entity's location affects its ability to make connections, whether moving an entity might alter its ability to achieve desired outcomes, and whether an entity's popularity (e.g., degree) might be a factor of its location.

The geography community can use the techniques described in this research to study local interpersonal connections and describe which areas (towns, neighborhoods, etc.) are fertile for these connections and why. Geographers might also find that these approaches can help enhance place-based initiatives between local organizations (e.g., religious

organizations, youth programs, schools, universities, libraries) with like-minded goals and identify programs that have not connected due to resource constraints, institutional barriers, or lack of social capital.

There are several limitations in our findings. First, case study research is limited in its statistical generalizability and the results found here might not be applicable to other geographic areas in scale or scope. We did not have access to temporal data, although conducting temporal analysis might describe connection growth or dissolution over time and whether older, established organizations have more ties. We also did not examine group effects, such community detection, as modules are not a strong method of organization in this system. Also, our analysis might be biased by the study area's bounding box and our results might be subject to edge effects in both the network and geographic space. For instance, Feeding America is attached to other nodes that are located east of the study area. Although in our study it appears beneficial to move this high-degree organization toward the geographic center of the Thrive Network area, doing so would strain Feeding America's access to its connections that are outside the study area.

Furthermore, our study did not address logistical aspects of the network. We did not measure food transfer volume, distinguish between perishable or nonperishable goods, model food distribution to *residents*, and detect where these residents reside. Accordingly, the concepts of sinks, sources, node removal, and capacitated facility problems, which are native to geographers (Hodgart 1978; Church, Scaparra, and Middleton 2004; Grubesic and Murray 2006; Scaparra and Church 2012), are not at the forefront of our study. Instead, we test for geocontextual determinants of high-degree nodes, develop new metrics that highlight areas and organizations with highly local ties, and suggest where new connections could be made.

Our methods are suited for social networks of independent organizations that have individualized protocols, missions, and capacities, and lack one-size-fits-all objectives, benchmarks, or measures of success. If the network instead described outlets under "one umbrella" (e.g., a network of Starbucks shops), we could employ long-standing geographic top-down analytics to streamline and coordinate across these outlets.

Next, our metrics are descriptive and lack statistical confirmation or inferential power. Future work includes developing null models of what we expect a network to look like, given input parameters such as gravity functions, preferential attachment rules, or a scale-free degree distribution and deriving the extent to which the actual Thrive Network resembles the predicted null model. Future work also includes modeling directed edges and weighted edges to capture the key players in the network not just in terms of number of connections, but in terms of volume of goods transferred and volume of goods distributed to residents in the area.

In addition to addressing the aforementioned limitations, we also plan to share our results with organizations in the network. There are real-world implications for this research, as the CFNRV organizes in-person meetings to introduce previously unfamiliar organizations and encourage them to share stories, discuss challenges, and solve problems. The visualization of the networks on maps and the quantitative analysis performed here can help Thrive make more informed decisions on how to create new collaborations and target areas that are underresourced. The results provide insights for network managers who are seeking to invest in whole-network-level solutions. In the future, we hope to use the Thrive Network's information sharing and referral connections and compare their structure to the food-sharing network.

In summary, this research articulated the relationship between geography and collaboration in the Thrive Network, a food-sharing, purpose-oriented, service-delivery network in a rural, mountainous area. Detecting local cohesion, the role of centrality, and geographical missed connections might help the organizations overcome barriers to collaboration by giving them meaningful, yet efficient, ways to improve food sharing and reduce food insecurity in the region.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

Dipto Sarkar acknowledges support from the Social Science and Humanities Research Council of Canada (File number 430-2021-00686). Clio Andris acknowledges support from the National Science Foundation (NSF-BCS-2045271).

Supplemental Material

Two supplementary files are associated with this article. Both are research protocol instruments that were used to collect the data we analyze in this article. The first file (Appendix A) entitled "Food Security Survey" is a copy of the survey that was given to research subjects. The second file (Appendix B) entitled "Interview Questions" is an outline of the semistructured interview questions that were given to research subjects. Each are described further in Edwards (2020). These data can be accessed on the publisher's site at: https://doi.org/10.1080/24694452.2024.2338096

ORCID

Jaimie Kelly http://orcid.org/0009-0001-8410-6069
Dipto Sarkar http://orcid.org/0000-0003-2254-049X
Clio Andris http://orcid.org/0000-0002-8559-5079

References

Abizaid, C., O. T. Coomes, Y. Takasaki, and J. P. Arroyo-Mora. 2018. Rural social networks along Amazonian rivers: Seeds, labor and soccer among communities on the Napo River, Peru. *Geographical Review* 108 (1):92–119. doi: 10.1111/gere.12244.

Andris, C., D. DellaPosta, B. N. Freelin, X. Zhu, B. Hinger, and H. Chen. 2021. To racketeer among neighbors: Spatial features of criminal collaboration in the American mafia. *International Journal of Geographical Information Science* 35 (12):2463–88. doi: 10.1080/13658816.2021.1884869.

Andris, C., and D. O'Sullivan. 2021. Spatial network analysis. In *Handbook of regional science*, ed. M. M. Fischer and P. Nijkamp, 1727–50. Berlin, Germany: Springer-Verlag.

Carboni, J. L., A. Saz-Carranza, J. Raab, and K. R. Isett. 2019. Taking dimensions of purpose-oriented networks seriously. *Perspectives on Public Management and Governance* 2 (3):187–201. doi: 10.1093/ppmgov/gvz011.

Church, R. L., M. P. Scaparra, and R. S. Middleton. 2004. Identifying critical infrastructure: The median and covering facility interdiction problems. *Annals of the Association of American Geographers* 94 (3):491–502. doi: 10.1111/j.1467-8306.2004.00410.x.

Coleman-Jensen, A., M. P. Rabbitt, C. A. Gregory, and A. Singh. 2019. *Household food security in the United States in 2018*. Economic Research Report No. 270, U.S. Department of Agriculture, Economic Research Service, Washington, DC.

Community Foundation of the New River Valley (CFNRV). 2022. Thrive/food access network. Accessed November 3, 2022. https://cfnrv.org/category/fund-for-the-nrv/thrive/

Community Foundation of the New River Valley (CFNRV). n.d. *The NRV Livability Initiative*. Accessed December 15, 2023. https://cfnrv.org/livability/

Edwards, J. 2020. Over the river and through the woods: Examining the relationship between network structure, collaboration and geography. PhD diss., Virginia Tech.

Emch, M., E. D. Root, S. Giebultowicz, M. Ali, C. Perez-Heydrich, and M. Yunus. 2012. Integration of spatial and social network analysis in disease transmission studies. *Annals of the Association of American Geographers* 105 (5):1004–15. doi: 10.1080/00045608.2012.671129.

Freudenberg, N., S. Goldrick-Rab, and J. Poppendieck. 2019. College students and SNAP: The new face of food insecurity in the United States. *American Journal of Public Health* 109 (12):1652–58. doi: 10.2105/AJPH.2019.305332.

Giles County. 2022. Social services. Accessed December 19, 2019. https://virginiasmtnplayground.com/social-services/.

Gilly, J. P., and A. Torre. 2000. Proximity relations: Elements for an analytical framework. In *Industrial networks and proximity*, ed. M. B. Green and R. B. Mac Naughton, 1–16. Aldershot: Ashgate.

Grubesic, T. H., and A. T. Murray. 2006. Vital nodes, interconnected infrastructures, and the geographies of network survivability. *Annals of the Association of American Geographers* 96 (1):64–83. doi: 10.1111/j.1467-8306.2006.00499.x.

Hanneman, R. A., and M. Riddle. 2011. A brief introduction to analyzing social network data. In *The Sage handbook of social network analysis*, ed. J. Scott and P. J. Carrington, 331–39. London: Sage.

Hay, A. 1973. *Transport for the space economy: A geographical study*. Seattle: University of Washington Press.

Hodgart, R. L. 1978. Optimizing access to public services: A review of problems, models and methods of locating central facilities. *Progress in Human Geography* 2 (1):17–48. doi: 10.1177/030913257800200103.

Human, S. E., and K. G. Provan. 2000. Legitimacy building in the evolution of small-firm multilateral networks: A comparative study of success and demise. *Administrative Science Quarterly* 45 (2):327–65. doi: 10.2307/2667074.

Katz, J. S. 1994. Geographical proximity and scientific collaboration. *Scientometrics* 31 (1):31–43. doi: 10.1007/BF02018100.

Knoben, J., and L. A. Oerlemans. 2006. Proximity and inter-organizational collaboration: A literature review. *International Journal of Management Reviews* 8 (2):71–89. doi: 10.1111/j.1468-2370.2006.00121.x.

Knoke, D. 2004. Networks and organizations. In *The Blackwell companion to sociology*, ed. J. R. Blau, 327–41. Malden, MA: Blackwell Publishing. doi: 10.1002/9780470693452.ch23.

Li, X., J. Li, Y. P. Aneja, Z. Guo, and P. Tian. 2019. Integrated order allocation and order routing problem for e-order fulfillment. *IISE Transactions* 51 (10):1128–50. doi: 10.1080/24725854.2018.1552820.

Mennis, J., and M. J. Mason. 2011. People, places, and adolescent substance use: Integrating activity space and social network data for analyzing health behavior. *Annals of the Association of American Geographers* 101 (2):272–91. doi: 10.1080/00045608.2010.534712.

Milward, H. B., and K. G. Provan. 2006. *A manager's guide to choosing and using collaborative networks* (Vol. 8). Washington, DC: IBM Center for the Business of Government.

Murphy, J. M., C. A. Wehler, M. E. Pagano, M. Little, R. E. Kleinman, and M. S. Jellinek. 1998. Relationship between hunger and psychosocial functioning in low-income American children. *Journal of the American Academy of Child and Adolescent Psychiatry* 37 (2):163–70. doi: 10.1097/00004583-199802000-00008.

New River Valley Livability Initiative. 2014. Livability in the New River Valley: From vision into action. Accessed December 15, 2023. https://cfnrv.org/wp-content/uploads/NRV-Livability-Report.pdf.

New River Valley Regional Commission (NRVRC). 2019. Explore the data. Accessed December 19, 2019. http://nrvdata.org/.

Nguyen, T. V., and J. Rose. 2009. Building trust—evidence from Vietnamese entrepreneurs. *Journal of Business Venturing* 24 (2):165–82. doi: 10.1016/j.jbusvent.2008.03.004.

Noll, J., S. Beecham, and I. Richardson. 2010. Global software development and collaboration: Barriers and solutions. *ACM Inroads* 1 (3):66–78. doi: 10.1145/1835428.1835445.

Olson, C. M. 1999. Nutrition and health outcomes associated with food insecurity and hunger. *The Journal of Nutrition* 129 (2 Suppl.):521S–524S. doi: 10.1093/jn/129.2.521S.

Papachristos, A. V., D. M. Hureau, and A. A. Braga. 2013. The corner and the crew: The influence of geography and social networks on gang violence. *American Sociological Review* 78 (3):417–47. doi: 10.1177/0003122413486800.

Piaskoski, A., K. Reilly, and J. Gilliland. 2020. A conceptual model of rural household food insecurity: A qualitative systematic review and content analysis. *Family & Community Health* 43 (4):296–312. doi: 10.1097/FCH.0000000000000273.

Piontak, J. R., and M. D. Schulman. 2014. Food insecurity in rural America. *Contexts* 13 (3):75–77. doi: 10.1177/1536504214545766.

Poocharoen, O. O., and B. Ting. 2015. Collaboration, co-production, networks: Convergence of theories. *Public Management Review* 17 (4):587–614. doi: 10.1080/14719037.2013.866479.

Radil, S. M., C. Flint, and G. E. Tita. 2010. Spatializing social networks: Using social network analysis to investigate geographies of gang rivalry, territoriality, and violence in Los Angeles. *Annals of the Association of American Geographers* 100 (2):307–26. doi: 10.1080/00045600903550428.

Rallet, A., and A. Torre. 1999. Is geographical proximity necessary in the innovation networks in the era of global economy? *GeoJournal* 49 (4):373–80. doi: 10.1023/A:1007140329027.

Rose, D., and V. Oliveira. 1997. Nutrient intakes of individuals from food-insufficient households in the United States. *American Journal of Public Health* 87 (12):1956–61. doi: 10.2105/ajph.87.12.1956.

Sarkar, D., C. Andris, C. A. Chapman, and R. Sengupta. 2019. Metrics for characterizing network structure and node importance in spatial social networks. *International Journal of Geographical Information Science* 33 (5):1017–39. doi: 10.1080/13658816.2019.1567736.

Scaparra, M. P., and R. Church. 2012. Protecting supply systems to mitigate potential disaster: A model to fortify capacitated facilities. *International Regional Science Review* 35 (2):188–210. doi: 10.1177/0160017611435357.

Schanzenbach, D. W., and A. Pitts. 2020. *How much has food insecurity risen? Evidence from the Census Household Pulse Survey*. Institute for Policy Research Rapid Research Report. Accessed September 15, 2023. https://www.ipr.northwestern.edu/documents/reports/ipr-rapid-researchreports-pulse-hh-data-10-june-2020.pdf.

Schramski, S., and Z. Huang. 2016. Spatial social network analysis of resource access in rural South Africa. *The Professional Geographer* 68 (2):281–98. doi: 10.1080/00330124.2015.1065545.

Sohn, C., D. Christopoulos, and J. Koskinen. 2020. Borders moderating distance: A social network analysis of spatial effects on policy interaction. *Geographical Analysis* 52 (3):428–51. doi: 10.1111/gean.12218.

Stouffer, S. A. 1940. Intervening opportunities: A theory relating mobility and distance. *American Sociological Review* 5 (6):845–67. doi: 10.2307/2084520.

Thrive. 2018. *Thrive/food access network*. Accessed December 20, 2019. https://cfnrv.org/partnerships-initiatives/fund-for-the-nrv/thrive/.

Townsend, M. S., J. Peerson, B. Love, C. Achterberg, and S. P. Murphy. 2001. Food insecurity is positively related to overweight in women. *The Journal of Nutrition* 131 (6):1738–45. doi: 10.1093/jn/131.6.1738.

U.S. Department of Agriculture (USDA). 2022. *Food security in the U.S.: Key statistics and graphics*. Accessed October 28, 2022. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics.aspx.

Vangen, S., J. P. Hayes, and C. Cornforth. 2015. Governing cross-sector, inter-organizational collaborations. *Public Management Review* 17 (9):1237–60. doi: 10.1080/14719037.2014.903658.

Van Gorp, A. F. 2014. Integration of volunteer and technical communities into the humanitarian aid sector: Barriers to collaboration. In *Proceedings of the 11th International ISCRAM Conference – University Park, Pennsylvania, USA, May 2014*, ed. S. R. Hiltz, M. S. Pfaff, L. Plotnick, and P. C. Shih.

The Virginia Geographic Information Network. 2022. *Virginia road centerlines*. Accessed November 1, 2022. https://vgin.vdem.virginia.gov/.

Walther, O. J., S. M. Radil, and D. G. Russell. 2021. Mapping the changing structure of conflict networks in North and West Africa. *African Security* 14 (3):211–38. doi: 10.1080/19392206.2021.1996173.

Yang, Y., and A. V. Diez-Roux. 2012. Walking distance by trip purpose and population subgroups. *American Journal of Preventive Medicine* 43 (1):11–19. doi: 10.1016/j.amepre.2012.03.015.

JAIMIE KELLY is an Assistant Professor in the Department of Political Science and International Affairs at the University of North Georgia, Dahlonega, GA 30597. E-mail: jaimie.kelly@ung.edu. Her research interests include network structure in purpose-oriented networks, organizational theory and management, and the role of gender in public policy.

DIPTO SARKAR is an Assistant Professor in the Department of Geography and Environmental Studies at Carleton University, Ottawa, ON K1S 5B6, Canada. E-mail: dipto.sarkar@carleton.ca. His research interests include GIScience, social network analysis, and biodiversity conservation.

CLIO ANDRIS is an Associate Professor in the School of City and Regional Planning and the School of Interactive Computing at Georgia Institute of Technology, Atlanta, GA 30303. E-mail: clio@gatech.edu. Her research interests include GIScience, social network analysis, urban planning, and geovisualization.