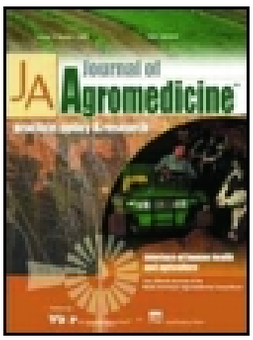

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PRACTICE/CASE HISTORY

Social Networking in an Agricultural Research Center: Using Data to Enhance Outcomes

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ABSTRACT

The purpose of this article is to present a case study of one midwestern Agricultural Center (Ag Center) that used social network analysis (SNA) to (1) evaluate its collaborations with extramural stakeholders and (2) strategically plan for extending outreach for goal achievement. An evaluation team developed a data collection instrument based on SNA principles. It was administered to the Ag Center's intramural stakeholders (N = 9), who were asked to identify the key extramural stakeholders with whom they had collaborated within the previous 12 months. Additional questions about each extramural stakeholder helped to categorize them according to SNA network measures for degree of centrality, betweenness centrality, and closeness centrality. Findings showed the Ag Center had N = 305 extramural stakeholders. Most of these were other researchers and did not represent the diverse group of stakeholders that the Ag Center had targeted for engagement. Only a few of the intramural stakeholders had national or international connections. Findings were used to improve and diversify connections in order to leverage the Ag Center's expertise and ability to translate research into new best practices and policies. The SNA case study has implications for other evaluators and project directors looking for methodologies that can monitor networks in large science consortia and help leaders plan for translating research into practice and policies by networking with those who can influence such change.

KEYWORDS

Evaluation; science consortia; social network analysis

Introduction

Improving population health is a multidisciplinary effort. It requires teams of investigators, educators, and community outreach partners to understand and address the complex, multifaceted health concerns of populations. Over the past decade, extramural federal funding agencies such as the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC) have increasingly looked to research networks, or science consortia, as a way to more holistically bridge the gap between scientific discovery and clinical practices/policies that can improve population health.[1,2] This shift from traditional research (i.e., single investigator–driven research) to multigroup, cross-institutional consortia teams composed of academic and community partners has greatly facilitated the translation of evidence-based solutions that solve population health issues at the point of care.[1,3,4]

By their very nature, science consortia are complex entities. They require well-planned collaboration networks to function effectively.[1,5] Evidence suggests that when consortia members (e.g., principal and co-investigators, directors) have collaborative communications, they generate more grants and publications, which has been used as a measure of successful networkings.[1,6] They are also more likely to enhance the consortia's research capacity based on training and mentoring,[7] and there is dissemination of knowledge across broader sectors of the economy—from technology industries, to health providers, to professional associations, to government agencies. The goal is that research is picked up by external stakeholders who can help advance its application through best practices and policies.

Agricultural Centers (Ag Centers; the Centers) funded through the National Institute of Occupational Safety and Health (NIOSH)[8] are

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one such example of the federal government's focus on supporting complex, multidisciplinary science consortia across the country.[2] The stated purpose of the NIOSH-funded Ag Centers is to improve the health and safety of the population employed in forestry, fishing, and agriculture through the use of applied translational research, community outreach, and prevention education. Most Ag Centers operate according to an adapted version of the logic model first proposed by NIOSH wherein Ag Center *Activities* in research, education, and outreach produce *Outputs* (e.g., publications, presentations) that must be moved to *Stakeholders* who develop and revise best practices and policies *(Intermediate Outcomes)* that enhance the knowledge of *End Users* (e.g., Ag workers, scientists) and ultimately results in measurable, long-term *End Outcomes* for improved population health, safety, and quality of life. Attaining these goals requires extensive collaboration and networking within and across teams, as well as with a wide variety of external key *Stakeholders* and groups from different industries (e.g., universities, extension agencies, academic medical centers, government). Evaluators are therefore challenged to provide Ag Center leaders with formative data to help them monitor and track the degree of collaboration and networking that is occurring so they can (1) gauge the degree of success they are likely to have in ultimately impacting the agricultural population's health and safety (*End Outcomes*) and (2) make necessary adjustments in programming to ensure that *Intermediate Outcomes* can be achieved. Ideally, the networking that occurs would extend beyond the immediate region served by each Ag Center and radiate outward to a vast array of external stakeholder networks and researchers having national and international spheres of influence.

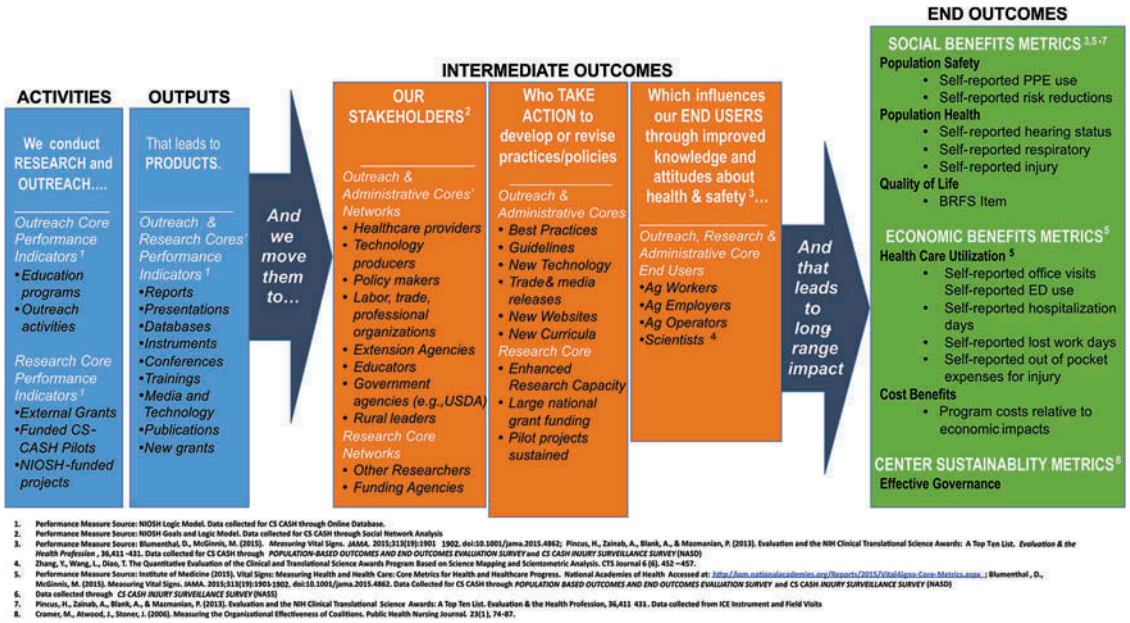
To date, there has been little research that analyzes how Ag Center members collaborate or network with intended external stakeholders. Such evaluative information could better inform strategic planning to build and strengthen an Ag Center's networks of collaboration. Networks are essential to advancing knowledge to *End Users* in the form of new technologies, best practices, or policies and which can achieve the ultimate goal of improved agricultural health and safety.

Social network analysis (SNA) is a strategy for investigating social structures and relations through the use of network and graph theories.[9,10] SNA has been used by other science consortia, including the NIH-funded clinical and translational research award (CTSA) centers to (1) measure and track the degree of collaboration and teamwork, (2) provide insights on team development, and (3) understand the impact of community outreach interventions.[1,5] SNA has been called the most systematic way of analyzing relationships and knowledge that flows between individuals, organizations, and groups. It has wide-reaching applications and purposes. For example, SNA has been used to establish safety alliances that reduce injury[11]; to understand knowledge generation and transfer patterns in biotechnology[12] and biomedicine[13]; to understand interorganizational collaborations and predict future collaborations in public health[14,15]; and to establish safety alliance networks that reduce injury.[14] Similar to this study, Petrescu-Prahova et al. used SNA to assess the cohesiveness of a collaboration network in public health for healthy aging research network.[16]

The purpose of this article is to present a case study of one midwestern Ag Center and how SNA was used to evaluate the quality and quantity of collaborative networking that occurred between the Ag Center leaders and their targeted external stakeholders. Findings were used to expand and enhance the Ag Center's intentional networking activities and will serve as a baseline to track changes in future collaborations.

Background

The Central States Center for Agricultural Safety and Health (CS-CASH) serves seven states in the Midwest. It has four cores—administration/evaluation, research, preventive/intervention, and education—that focus on improving agricultural workers' hearing, respiratory health, injury prevention, and general farm safety. The administrative leadership includes the Center director, deputy director, and the project coordinator. There are two boards—internal advisory and external advisory—that provide oversight and guidance for programming and to identify emerging agricultural issues. The CS-CASH logic model (Figure 1; adapted from the generic



1. Performance Measure Source: NIOSH Logic Model. Data collected for CS CASH through Online Database.
2. Performance Measure Source: NIOSH Goals and Logic Model. Data collected for CS CASH through Social Network Analysis
3. Performance Measure Source: Blumenthal, D., McGinnis, M. (2015). *Measuring Vital Signs.* JAMA. 2015;313(19):1901 1902. doi:10.1001/jama.2015.4862; Pincus, H., Zainab, A., Blank, A., & Mazmanian, P. (2013). Evaluation and the NIH Clinical Translational Science Awards: A Top Ten List. *Evaluation & the Health Profession* , 36,411 -431. Data collected for CS CASH through *POPULATION-BASED OUTCOMES AND END OUTCOMES EVALUATION SURVEY* and *CS CASH INJURY SURVEILLANCE SURVEY* (NASD)
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5. Performance Measure Source: Institute of Medicine (2015). Vital Signs: Measuring Health and Health Care: Core Metrics for Health and Healthcare Progress. National Academies of Health Accessed at: http://iom.nationalacademies.org/Reports/2015/VitalSigns-Core-Metrics.aspx ; Blumenthal , D., McGinnis, M. (2015). Measuring Vital Signs. JAMA. 2015;313(19):1901-1902. doi:10.1001/jama.2015.4862. Data Collected for CS CASH through *POPULATION BASED OUTCOMES AND END OUTCOMES EVALUATION SURVEY* and CS CASH *INJURY SURVEILLANCE SURVEY* (NASD)
6. Data collected through *CS CASH INJURY SURVEILLANCE SURVEY* (NASS)
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Figure 1. Ag Center logic model.

NIOSH logic model) reflects the unique goals and objectives of the Center, and it incorporates specific metrics and methodologies derived from the literature[2,17–19] as well as from the Institute of Medicine *Vital Signs Report* (2015).[20] Our intended *Stakeholders, Intermediate Outcomes*, and *End Users* are identified in the model as well as our long-term *End Results* that focus on our own metrics and methodologies to measure (1) social benefits, (2) economic benefits, and (3) center sustainability.

The evaluation team implemented SNA to measure the degree and types of collaborations that our Center leaders had with external stakeholders in the state, region, nation, and internationally (Figure 1). These collaborations were examined for connectedness and centrality. Findings were used for strategic planning and as a baseline to longitudinally track the Ag Center's collaborative growth. The study was approved by the university's institutional review board.

Methods

The SNA methodology for this study involved two phases (Figure 2). This article addresses only the two stages of phase 1. In stage 1, Center leaders (N = 9) were identified for purposes of our study as funded staff or faculty members in the roles of Center director, project coordinator, education director, evaluation director, deputy director, pilot project/emerging issues director, outreach director, prevention/intervention director, and project principal investigator. The external stakeholders were defined as individuals outside the Center and with whom the Center leaders had collaborated during the previous 12 months. For the purposes of this study, collaboration was defined as working cooperatively on a specific activity or project (as opposed to contact or communication interactions without a specific joint project interface). Center leaders were asked to identify by name those external stakeholders who were in the targeted categories: policy makers; health providers; technology producers; other researchers; labor/trade/professional organizations; educators; and representatives for rural communities (Figure 1). If an external stakeholder had various roles, Center leaders were asked to make a determination about the most applicable role category for their collaboration.

Next, we developed a data collection instrument in accordance with SNA principles and network terminology and measures.[9] *Nodes* refer to individuals in the network and *edges* refer to the collaborations. Measures included (1) *degree*, or the number of edges that are connected to a node for determining "popularity," which is defined as being in the middle of a group and having influence on it[20]; and

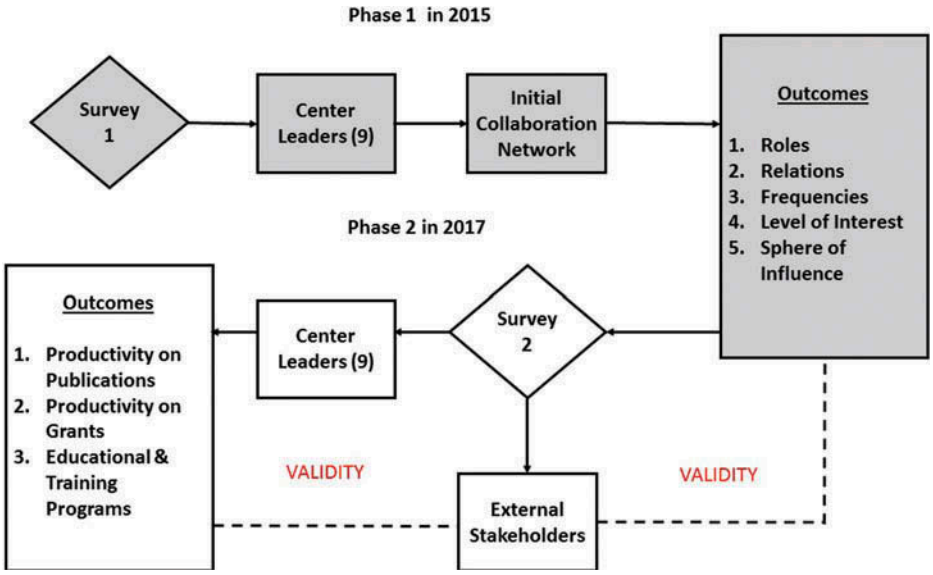

Figure 2. Ag Center social network analysis (SNA) model.

(2) *betweenness centrality*, which is an indicator of a node's centrality in a network and equal to the number of shortest paths from all nodes to all others that pass through that node (i.e., considered as being a bridge measure).The final instrument (Table 1) contained five items having discrete response sets to capture the attributes, or SNA network measures, for each external stakeholder. The attributes included (1) collaboration purpose (i.e., Ag Center–funded project or general topic-specific); (2) role category (i.e., policy maker; health provider; technology producer; other researchers; representatives of labor, trade, and other professional organizations; community representatives; Figure 1); (3) frequency of contact (i.e., weekly, monthly, quarterly, annually); (4) primary sphere of influence (i.e., state-only, regional, national, and international); (5) level of external stakeholder's importance for influencing Center's intended outcomes (i.e., very important, important, somewhat important, and not very important). In stage 2, we administered the instrument to Center leaders via e-mail. There was a 100% response rate (9/9).

Data analysis

Results were analyzed using R statistical software.[21] In addition, SNA and visualization were performed with NodeXL Software[22] to calculate the network statistics for each of the Center leaders and to determine information about the roles in connecting to others (i.e., popularity and position in the network). Using social network statistics, the number of connections, i.e., degrees, for each stakeholder were analyzed and the betweeness centrality, i.e., the proportion shortest paths between each pairs of contacts that include a specific contact, was computed.[16] These analyses provided information about the position of each stakeholder in the network. Then the quality of collaborations was analyzed by investigating the types of contacts, frequency of contacts, and the sphere of influence distribution these collaboration contacts have in the network. After the results were studied, the evaluators met with the Ag Center leaders to review findings and to discuss their interpretation of findings as well as recommendations for strategic planning based on the Ag Center's logic model.

Results

Figure 3 presents the complete network structure of the reported relationships with external stakeholders. There were a total of $N = 305$ external stakeholders identified by the 9 Center leaders. Of these, there were a total of $N = 433$ external stakeholder relationships after duplicates were removed.

Table 1. Social network analysis survey instrument.

Complete the table below for all of your external stakeholder contacts during the 2014 calendar year. 100 rows provided—insert more rows as needed. NOTE: Drop down boxes appear in Columns F–J by clicking in the cell.

Center Leader	External Stakeholder First Name	External Stakeholder Last Name	External Stakeholder's Email Address	What Organization is the External Stakeholder Affiliated With?	External Stakeholder relates to Ag Health & Safety *Topic* or a Specific CS-CASH *Project*	What Role Category is the External Stakeholder?	Frequency of Contact with External Stakeholder	Level of External Stakeholder's Importance for Influencing Center's Intended Outcomes	External Stakeholder's Primary Sphere of Influence
					Project Related	Policy makers	Weekly	1 = Very Important	Nebraska Only
					Topic Related	Health providers	Monthly	2 = Important	CS CASH 7
						Technology producers	Quarterly	3 = Somewhat Important	State Region
						Other researchers	Annually	4 = Not Very Important	National
						Rep of Labor, trade, professional organizations			International
						Rep of Extension agencies			
						Educators			
						Rep for Rural communities			

Network statistics

In this section, we present a summary of the descriptive statistics of the collaboration network for the Center. These statistics are commonly used in SNA to analyze and interpret network structures. Each Center leader is represented as a node in the network with their respective external stakeholders, and the edges represent the connection between the two nodes in the network.

First, we analyzed the degree centrality measure (i.e., the number of edges of a node). The average degree centrality of the whole network was calculated as 2.771, with the median degree being 1. The maximum degree centrality in the network was 128 for the Center director, indicating he was the most connected of all leaders. This was followed by the project coordinator, education director, and evaluation director. It is important to note that there was great variation in the number of degrees (i.e., contacts) for the Center leaders, with the range extending from 4 (project investigator) to 128 (Center director) (M = 48.8, SD = 39.45) (Table 2).

Another network statistic was betweenness centrality, which is an indicator of each node's centrality in the network as a bridge (Table 2). It is calculated as the number of shortest paths from all nodes to all others that pass through that node and reflects the importance of the bridging role through whom information is passed. The same four individuals—Center director (27,386), project coordinator (18,975), education director (12,863), and evaluation director (7,577) all showed highest betweenness centrality measures as well, indicating that they were most optimally positioned in the network as bridges. Even though the pilot project/emerging issues director had the lowest betweenness centrality (590), his/her role was better positioned in the network than the project investigator (1,667) or the prevention/intervention director (1,550) in terms of bridging (Figure 3).

Network measures

Most of the reported connections with external stakeholders were not for Ag Center–funded projects, but for topic-specific projects outside of the Ag Center. Of the 437 external relations, only 125 involved collaborations specific to Ag Center–

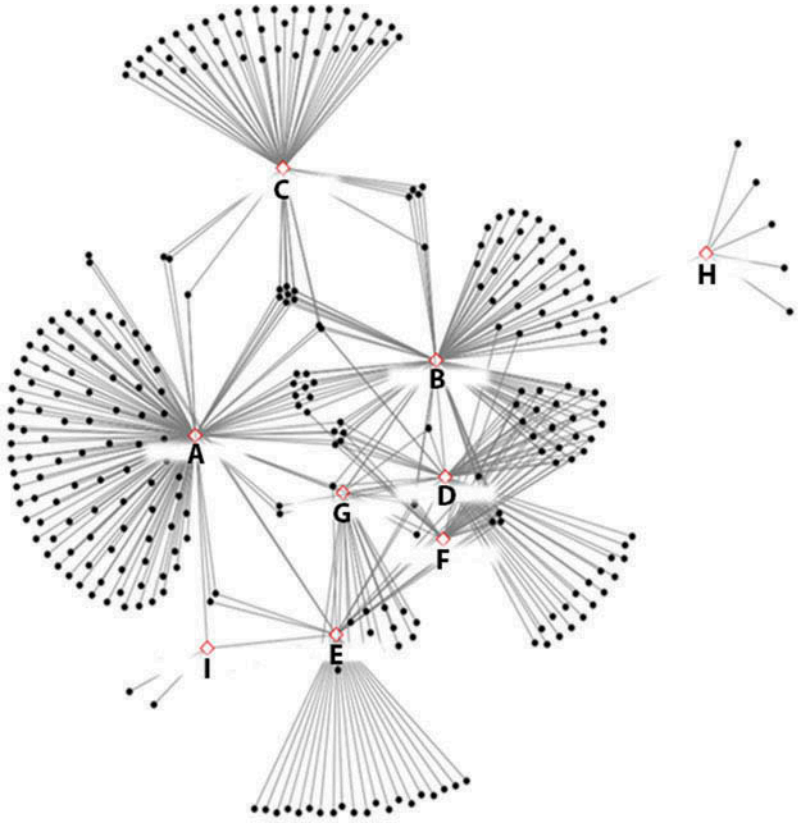

Figure 3. Ag Center network complete structure. Only the Center leaders are presented with their labels in the figure, which include (A) Center director, B) project coordinator, (C) education director, (D) evaluator, (E) deputy director, (F) pilot program/emerging issues director, (G) outreach director, (H) prevention/intervention director, and (I) project investigator. Each link represents the connection between the nodes on the network regardless of the frequency of the contact.

Table 2. The degree distribution of Center leaders with number of degrees (degree centrality measure) and betweenness centrality measure.

Center leaders	Number of degrees	% Degree	Betweenness centrality
A. Center director	128	29.16	27386.04
B. Project coordinator	97	22.1	18975.20
C. Education director	60	13.67	12862.70
D. Evaluator	59	13.44	7577.01
E. Deputy director	35	7.97	7129.46
F. Pilot project/emerging issues director	28	6.38	590.53
G. Outreach director	22	5.01	5556.03
H. Prevention/intervention director	6	1.37	1550.00
I. Project investigator	4	0.91	1666.97
Average	48.78	11.11	9254.88
Standard deviation (*SD*)	39.45	8.99	8493.57

funded projects, whereas 312 were listed for topic-specific areas (Figure 4).

The distribution of the role categories for these listed connections is presented in Table 3. The category of other researchers formed the majority (56%) of the connections followed by labor/trade/professional organizations (23%). Least cited categories included health providers (9%), educators (6%), representatives of rural communities (2%), technology producers (2%), policy makers (1%), and representatives of extension agencies (1%).

External stakeholders' primary sphere of influence was at a national level (37.5%). This was followed by regional (23.6%) and state-only (22.2%) connections. International influence measured the least response (16.7%). Most of the Ag Center's leaders collaborated with external stakeholders on a quarterly basis. Very few identified having weekly collaborations with external stakeholders. Most collaborations, which were with other researchers and labor/trade/professional organizations, occurred on a quarterly basis and at a national level (see Table 3).

Center leaders mostly rated their external collaborative networks as very important to important for influencing the Center's intended outcomes (Figure 5). The evaluator rated most networks at

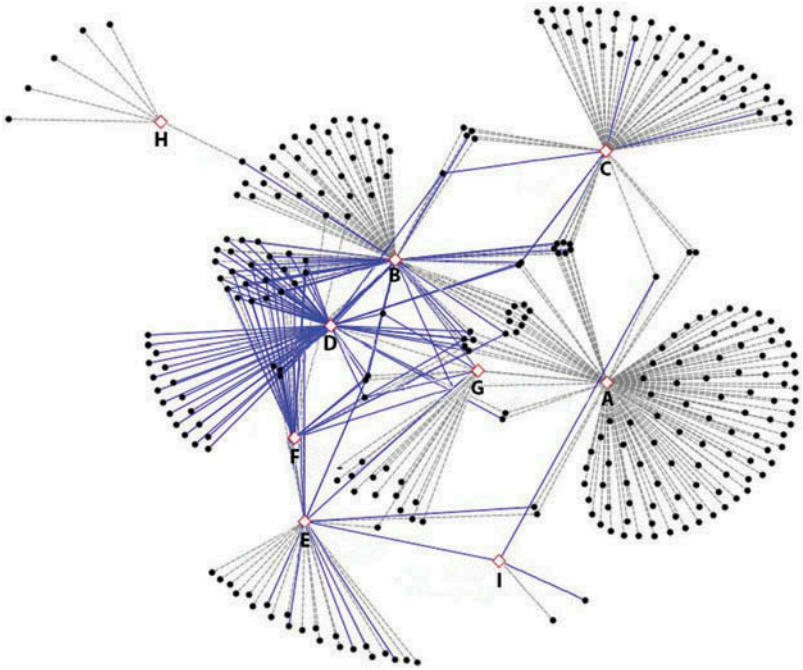

Figure 4. Ag Center network based on the collaboration type. Dashed gray lines show the "topic related" collaborations and solid blue lines show the "project related" collaborations. (A) Center director, (B) project coordinator, (C) education director, (D) evaluator, (E) deputy director, (F) pilot program/emerging issues director, (G) outreach director, (H) prevention/intervention director, and (I) project investigator.

Table 3. Cross-tabulation of type of contacts center leaders have with their distribution of frequency of contacts and sphere of influence.

		Frequency of contact						Sphere of influence			
Type of contact	Total	Annually	Monthly	Quarterly	Occa-sionally	Weekly	NA	Ag Center	International	National	Nebraska
Policy makers	4	1	1	2	0	0	—	0	1	3	0
Health providers	39	16	12	9	1	1	—	9	4	5	21
Technology producers	10	1	5	2	0	2	—	0	6	2	2
Other researchers	245	33	72	112	7	20	1	72	29	94	49
Rep of labor, trade, professional organizations	98	37	12	49	0	0	—	9	21	53	15
Rep of Extension agencies	6	1	2	3	0	0	—	0	1	2	3
Educators	25	6	2	17	0	0	—	6	11	4	4
Rep for rural communities	10	6	1	3	0	0	—	7	0	1	2
Total	437 (100%)	101 (23%)	107 (24%)	197 (45%)	8 (2%)	23 (5%)	1 (0%)	103 (24%)	73 (17%)	164 (38%)	96 (22%)

higher levels of importance. The director, education director, and project coordinator all rated their networks as having the most diverse levels of importance. Interestingly, the prevention/intervention director, deputy director, and project investigator all ranked their networks as relatively less important for influencing Center outcomes.

Discussion

Overall, Center leaders were connected to a large number of external stakeholders and they had extensive collaborative relationships. Four Center leaders—the director, project coordinator, education director, and evaluation director—were highly central to the network and positioned as bridges through which information was passed. But there was great variation between Center leaders in terms of numbers of external contacts and their level of importance for influencing Center outcomes. Overall, Center leaders mostly collaborated with other researchers external to the Center as well as labor/trade/professional organizations and most were at a national level; however, the research

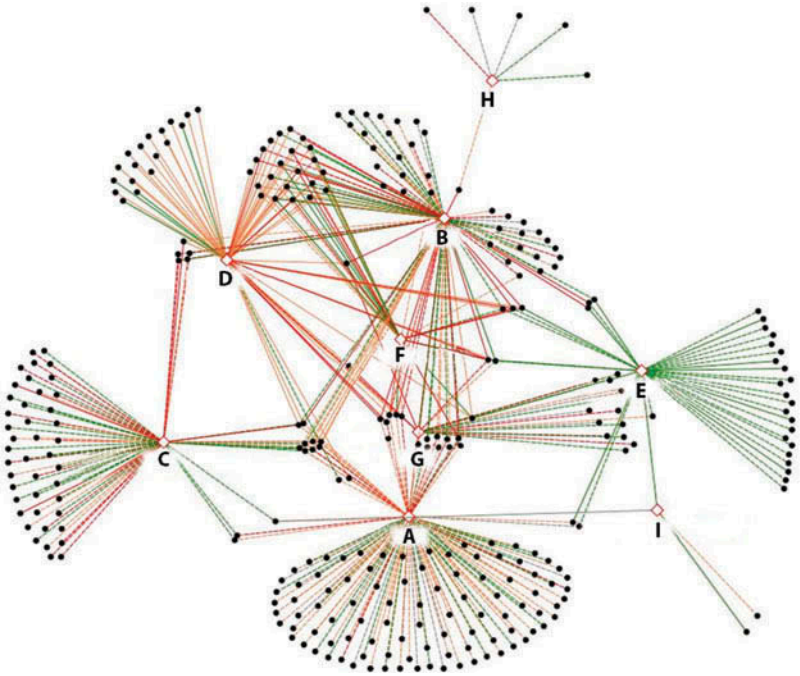

Figure 5. Ag Center network based on level of external stakeholder's importance for influencing the Center's intended outcomes (red, very important; orange, important; green, somewhat important; gray, not very important). (A) Center director, (B) project coordinator, (C) education director, (D) evaluator, (E) deputy director, (F) pilot program/emerging issues director, (G) outreach director, (H) prevention/intervention director, and (I) project investigator.

collaborations were mostly focused on projects not directly related to the Ag Center itself. The least cited collaborations were with policy makers, technology producers, community representatives, and extension agencies.

A meeting was held with the Center leaders to review the study results and discuss implications for strategic planning. First, it will be important that the Center continue to expand its external collaborations and networking among all Center leaders, not just a few. There was great variability among Center leaders in terms of numbers of contacts and their level of importance to Center outcomes. Indeed, only a few Center leaders—mostly senior status—had extensive and far-reaching collaborations. Thus, it would be optimal for those Center leaders with more extensive and influential networks to help those with fewer and less influential networks develop their own far-reaching collaborative relationships, especially those that can advance the Center. All Center leaders are important to the work of the Center, and sharing of networks can enhance their work as well as the Center's. These less well-connected Center leaders can also benefit from being aware of the key bridge roles in the CS-CASH network for effective information propagation and dissemination. The work has already begun with many more junior Center leaders now participating in national and international conferences where influential contacts can be made, and with some serving in elected leadership roles of professional associations and trade groups.

Center leaders were mostly connected with other researchers, which was viewed as a favorable indicator for sustaining and building the Center's scientific capacity. Evidence indicates that science consortia investigators who have strong and diverse research collaborations generate increased products (i.e., publications and collaborative grants) and enhance research sustainability.[1,5] The second-most cited category of external collaborators was with labor/trade/professional organizations at national levels of influence. This was also viewed as positive in terms of helping to move the work of the Center—research, education, and community outreach activities—to national stakeholders who can assist with translational applications that have the potential to impact development of best practices, health standards, and policies. An important strategic implication will be to expand collaborative networks to a more diverse group of stakeholders and who have

the ability to help Center leaders generate influence for their work in policy, technology, health care, and education as well as involving more community representatives (i.e., elevator operators, farmers) in communication networks. These stakeholders have direct influence on large groups of intended end users.

Most of the Ag Center's leaders collaborated on funded projects that were not directly related to the Ag Center's specific projects list. This was not necessarily surprising, since several Center leaders are senior researchers with other extramural funding. Their work with the Ag Center may only represent a fraction of their overall workload or research commitments. Still, the Center can continue to leverage their research expertise by developing and funding new pilot projects that are focused on topics related to senior scientists' areas of interests. In so doing, junior investigators can benefit from consultation, mentoring, and networking with senior scientists, which enhances the Center's overall research capacity. In fact, some pilot projects that are more community-based and educational in nature have been led by junior investigators with senior research scientists serving as their advisors or consultants.

A limitation of the study was that Center leaders were asked to use recall from the previous year, thus introducing an element of measurement error into the analysis.[23] There may also have been confusion on what qualified as "Topic Related' versus "Project Related," and there may be circumstances where these two options may overlap, causing blurring of the data. In addition, there may have been variability in the completeness of the list based on individual effort and motivation, resulting in a less extensive stakeholder list and resultant category response. Still, the study has important implications for evaluating Ag Centers and for documenting the degree of networking that occurs.

The evaluation team will continue to annually monitor networking using SNA in order to track changes (i.e., growth or decline, diversity) with external stakeholder collaborations, as well as the extent of geographic influence. The next step will be to survey the Ag Center's external stakeholders to determine their perspectives regarding the centrality and connectedness of this Ag Center.

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