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Leveraging communities' network strengths to support climate change adaptation information-sharing: a study with coffee farmers in Risaralda, Colombia

Jessica Eise[1] · Natalie J. Lambert[2] · Eric C. Wiemer[3]

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Abstract
The success of climate change adaptation measures is influenced by social factors that are context specific. An important social factor influencing outcomes is communication or the way information spreads through groups of people who need adaptation support. A community's unique information-sharing potential can be understood through social network analysis. A social network perspective views humans as actors in a system of interconnected relationships. This approach is useful for mapping information flows or how adaptation strategies can spread within a community. Through a study with coffee farmers in Risaralda, Colombia, we demonstrate how a community's network strengths can be identified in order to develop tailored climate change adaptation communication strategies. To do this, we measure ego networks, which are social relations stemming from one "unit of interest," or coffee farmers, around climate change. From there, we identify the information attributes or the preferred ways farmers receive and send information on climate change. Lastly, we analyze this data against the broader stakeholder system to provide a macro level context. Together, this provides a clear vision of how climate change adaptation strategies may be spread through a community's information network. For coffee farmers in Risaralda, Colombia, key institutions and their agents do not currently acknowledge long-term climate change. The farmers interact the most on this subject with their self-organizing associations. Therefore, targeting information campaigns to local associations offers the most potential for effective climate change adaptation information-sharing, and these same associations also offer the in-person communication these farmers indicate they prefer.

Keywords Climate change adaptation · Climate change communication · Social network analysis · Ego networks · Information attributes · Colombian coffee farmers

✉ Jessica Eise
jessica.eise@utsa.edu

Extended author information available on the last page of the article

1 Introduction

For well over a decade, we have seen an increasing recognition of the social factors that influence adaptation outcomes (Adger et al. 2009; Barnett 2010; Biesbroek et al. 2013; Owen 2020). This has spurred a simultaneous recognition of the need for integrated approaches to plan for and communicate about climate change adaptation (Eise and Rawat 2021; Linkov et al. 2011; Mimura et al. 2015; Scarlett 2011). Today, we see studies that examine the context-specific nature of climate change that draw upon local groups' knowledge systems, such as herder perceptions of climate change (Mijiddorj et al. 2020), smallholder farmers' perspectives on climate change (Hoang 2020), and the specific vulnerabilities of watershed communities' livelihoods (Adhikari et al. 2020). This valuable local knowledge of climate change impacts will inform tailored adaptation solutions. In keeping with this trend, we can also draw on local knowledge systems to inform how climate change adaptation solutions may be most effectively communicated to and within the community itself.

There is a longstanding body of literature in communication demonstrating that communication campaigns designed on the basis of outsiders' intuitive beliefs about "what works" run the risk of having no effect or, even worse, backfiring (Atkin 1981; Flora et al. 1989; Michal-Johnson and Bowen 1992; Salmon 1989). In the case of climate change adaptation, the anticipated costs of climate change adaptation are rising (United Nations Environment Programme, 2016), and we already face limited resources to implement strategies. With high stakes and limited resources to pay for adaptation efforts, the risk of campaigns backfiring must be mitigated as much as possible.

Through a study with coffee farmers who report uncertainty due to climate change impacts in Risaralda, Colombia (Lambert and Eise 2020), we demonstrate how a community's network strengths can be identified to tailor communication strategies. A network perspective illuminates the system of interconnected relationships that influence behavior (Brass et al. 2004; Borgatti et al. 2013), which can be used to map information flows between individuals within particular social systems (Lee et al. 2018; Sadri et al. 2018; Park et al. 2012). Use of social network analysis is growing within environmental research, such as being used to visualize and describe social structures in management of water resources in order to understand governance systems (Aubin et al. 2018) or to expose the competing actors in the climate change arena (Ortega Díaz and Gutiérrez 2018).

Our approach to building on social network analysis in environmental research is based on triangulation, in which we use multiple methods or data sources to provide a comprehensive understanding of a phenomenon or challenge. First, we provide a description and visualization of the broader coffee-growing stakeholder system in Colombia to provide a macro level context against which to contextualize the more granular findings. Second, we collect data and perform a social network analysis specifically by measuring ego networks, which are social relations stemming from one "unit of interest," or coffee farmers, around climate change. From there, we identify the information attributes or the preferred ways farmers receive and send information on climate change. Together, this provides a clear, integrated vision of how climate change adaptation strategies may be spread using a community's information network strengths. We believe this method can be replicated and refined in other communities to assist in communicating important information about climate change adaptation. By understanding a particular community's information flows in their broader context, we may target communication efforts to its strengths to help spread adaptation strategies. This can offer a "magnification" effect, in which a local community does the work of sharing information within its own group.

Additionally, it increases the impact of adaptation strategies by helping them reach as many members of the target population as possible.

2 Utilizing ego networks to understand climate change adaptation information-sharing

From a network perspective, actors exist in a system of interconnected relationships that allow for opportunities and constraints on behavior (Brass et al. 2004). Particularly relevant to research on coffee farmers and climate change are *ego networks*, a system of social relations stemming from one social unit of interest, such as a person or organization (Freeman 1982). Ego networks provide the advantage of revealing unique properties about a social system of interest from the perspective of one group of actors (Freeman 1982), in this case the actual coffee farmers themselves. It would take vast resources to exhaustively map the entire network of communication linkages of coffee farming, production, and distribution members due to pragmatic constraints such as geographic access, financial limitations, and knowledge access impediments. The succinct structure of ego networks and the focus on a single scope of social connections give researchers an opportunity to home in on a social unit of actors directly impacted by an issue (Everett and Borgatti 2005). Here, we prioritize the ego networks of coffee farmers and demonstrate how understanding this, when contextualized within the broader system, can provide keen insights on climate change adaptation constraints and opportunities for hard-to-reach stakeholder groups.

Ego networks possess unique structural qualities that can also be used to predict various social and behavioral outcomes, such as information-sharing and exchange (Cannella and McFadyen 2016; Arnaboldi et al. 2016). Predicting social outcomes such as information-sharing in an ego network is often conditional on the presence or absence of ties between an ego and its alters (i.e., the people with whom the ego has connections), the redundancy of such ties, and the strength of ties, among other structural qualities (Cannella and McFadyen 2016; Tabourier et al. 2016). The capacity to predict outcomes within a targeted group of actors is essential in tailoring or developing effective adaptation strategies.

Ego networks can extend beyond more traditionally structured organizations (Jarvenpaa and Majchrzak 2008), which makes an ego network approach useful when examining the flow of information and knowledge in a specific social context. Ego networks focus on the social actors themselves and how they exist within a broader, more formal organizational structure. In the following section, we describe the stakeholders involved in the formal organizational production and distribution of coffee in Colombia. This provides the broad network-level context in which the coffee farmers operate. Absent here, however, is a representation of the actual connections the producers themselves depend upon when receiving and imparting knowledge about issues that impact their farming, such as climate change. This is the data that we collect by asking the farmers who they seek out or rely on for information-sharing on such issues, which addresses an aspect of the Colombian coffee production system missed when only relying on formal ties between actors in the broader, organizational network system. This missing link prohibits effective communication or co-development of adaptation strategies to climate change tailored to the reality of the coffee farmers' actual informational networks.

3 The formal stakeholder system governing coffee farming in Colombia

Here, we provide a description and figure of the broader coffee-growing stakeholder system in Colombia to provide a macro level context against which to contextualize the social network and information attribute data presented later in this article. This section is informed by an in-depth review of data sources, observations, and field notes. To begin, in Colombia, climate change impacts threaten agricultural production, which in turn risks the livelihoods of millions of people and subsequently political and economic stability (Ramirez-Villegas et al. 2012). Coffee is the most important agricultural export by value in Colombia and is the most essential crop for approximately 500,000 farmers (Federación Nacional de Cafeteros 2017), providing jobs for over 2 million people. Colombian coffee crops are threatened by climate change due to weather fluctuations and the subsequent increase in pests and plagues wrought by unusual weather events (Constantino et al. 2011; Hodson de Jaramillo et al. 2017; Lozano-Povis et al. 2021). Scholars have long noted the urgency to adopt actions to anticipate the impacts of climate change in Colombia based on existing knowledge and innovative technology (Costa Posada 2007) and yet report low levels of planning and implementation of adaptation measures (Muñoz et al. 2017).

The most important institutional player in Colombia's coffee growing macro context is the Colombian Coffee Growers' Federation (Federation), which reports that it represents 540,000 Colombian families dedicated to growing coffee (Federación Nacional de Cafeteros 2019a). The Colombian Coffee Growers' Federation is a powerful, independent, non-governmental organization founded in 1927. It historically played an important role in the development of Colombia and its coffee industry, particularly during difficult times of civil conflict when they served as a stabilizing role within coffee-producing regions (Thorp 2000). The Federation leadership comes from elite families (Bates 1997), and there are economic, class, and educational differences between the Federation leadership and their smallholder members (Bentley and Baker 2000).

Today, the Federation operates under a complex relationship with the Colombian government, as it is a non-governmental organization with commercial ties and mandatory member contributions that receives considerable funding and legal autonomy from the government. The Colombian Ministry of Agriculture and Rural Development transfers governmental funds into an account called the *Fondo Nacional del Café* (Minagricultura 2018) that is administered by the Federation per a 10-year signed agreement with the Colombian Federal Government to use at their discretion for agricultural extension and other activities (Gobierno y Federación de Cafeteros renuevan contrato del fondo parafiscal 2016). This is supplemented by a "contribution" paid by coffee farmers that has been reported as six cents to the dollar of each pound of exported coffee (Gobierno y Federación de Cafeteros renuevan contrato del fondo parafiscal 2016), a number that conflicts with what has been described as a 15% tax cited by interview participants in this study as well as in other popular media decrying a lack of transparency around the Federation's taxation system on coffee farmers (Lora 2015a).

The Federation is granted authority by the Colombian Federal Government to regulate national coffee exports to the global market (Se modifican las normas, 2016; Lora 2015b; Federación Nacional de Cafeteros de Colombia 2007). The Federation sets the internal price for coffee purchasing, and their formula is the daily value of washed Arabica coffee on the New York Stock exchange plus the premium for Colombian coffee, from which the above-cited 6% tax to the Federation is subtracted, after which this number is translated into pesos according to the daily exchange rate, and an additional fee to the Federation is extracted at an

undefined amount for "logistics and financial costs" (Federación Nacional de Cafeteros 2015). For Colombian coffee producers, this results in a continuously fluctuating internal purchasing price lower than that set by the New York Stock exchange for Colombian coffee.

The Federation has 15 departmental offices across Colombia that coordinate extension services (agricultural outreach services) within that department, under which exist 366 municipal offices (Federación Nacional de Cafeteros 2019b). These offices are colloquially known as *comités*. The Federation has 33 coffee purchasing "cooperatives," commonly known as *cooperativos*, that manage 530 purchasing points for coffee farmers to sell their yields (Federación Nacional de Cafeteros 2019c). The National Coffee Research Center (Cenicafé) is the scientific research branch of the Federation. The Federation thus far has focused on short-term climatic variability and rejects long-term climate change, asserting that short-term climatic variability will be managed by farmers adopting agronomic measures developed by Cenicafé and promoted by Federation extension agents through a strategy called "More Agronomy, More Productivity" (Alfonso 2018), the appropriateness of which has been questioned in the face of long-term climate change (Baker et al. 2019).

Another important player in the broader communication network in which individual coffee farmers are members are coffee associations. While no exact statistics exist as to the number of associations and associated farmers, there is a rich and growing culture of small, regional self-organizing groups of coffee farmers who form to collectively strengthen their commercial positions through knowledge exchange, local brand development, or other activities. Participation in associations is not compulsory, and some coffee farmers remain independent of associations, while others participate in multiple associations. Associations vary in strength, organizational capacity, and efficiency. Some associations seek permission to export and then strive to pool enough members' harvests in order to fill a shipping container for exportation to the international market in attempts to secure a higher sale price by avoiding the "middle men" of the existing coffee supply chain.

Figure 1 presents a graphical representation of the coffee stakeholder network described above. Dark gray represents governmental members, light gray represents Federation members, and white represents the farmer members of the network. Flows of money and coffee are indicated with directed arrows. This is likely not a complete inventory of the coffee stakeholder communication network because any linkages that exist outside of accessible resources will be missing. However, we believe that this is a close approximation and have received input from colleagues and coffee stakeholders in Colombia that this is the best representation of the network that can be gained with the informational barriers that exist in this context.

4 Method

In this study, we chose to measure the information-sharing ego networks of the farmers in addition to their information attributes through first-person interviews, collaborating with local faculty with experience engaging with coffee producers in this region. Self-reported information-sharing networks are more likely to possess a level of trust that is unique to that particular network (Bodin and Crona 2009). Additionally, the collection of attribute information about the channels through which farmers communicate with others, as well as attributes of the farmers themselves, is also essential for understanding not just with whom farmers communicate about climate change adaptation, but also how and why. The inclusion of such information is useful because in-person social networks, particularly in rural farming areas,

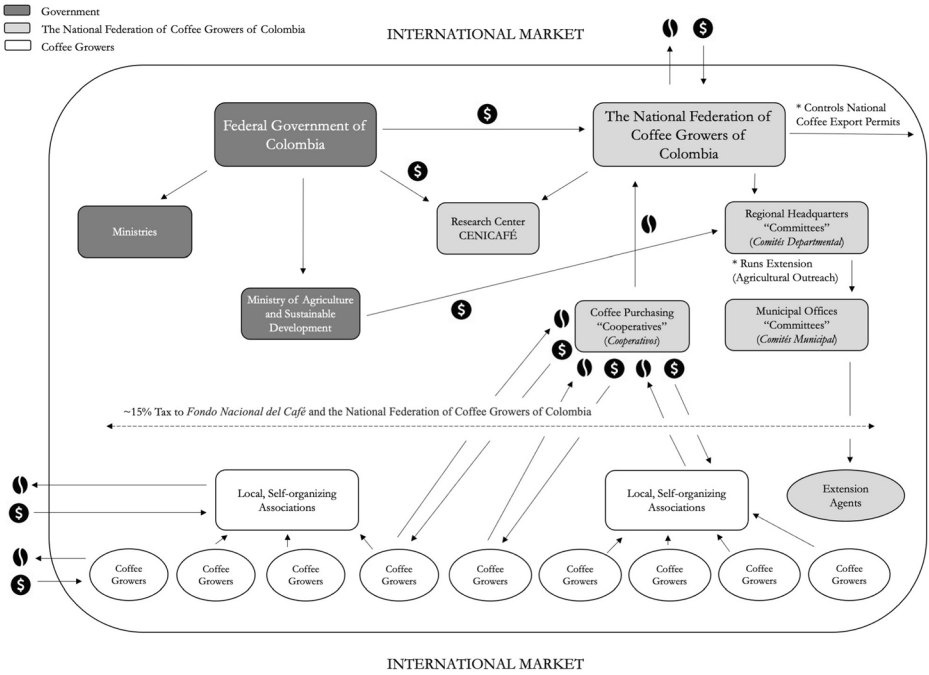

Fig. 1 Visual representation of components of coffee system in Colombia

likely operate differently than other contexts and possess unique qualities that would need to be understood in order to engage with this population in behavior change around climate change adaptation (e.g., Bodin and Crona 2009).

Data was gathered through 42 in-person, structured interviews with coffee farmers in Risaralda, Colombia. After 42 interviews, we reached theoretical saturation (Marshall et al. 2013), which complies with standards for interviews in qualitative research that suggest more than 30 interviews and less than 50 (van Rijnsoever 2017). Colombia is comprised of 26 departments, and Risaralda is a department in the coffee-growing zone in the western central region of Colombia. It is a part of the UNESCO World Heritage Site, the Coffee Cultural Landscape of Colombia, locally known as the *Eje Cafetero*. Risaralda has 14 municipalities, and coffee is grown in each of these municipalities. To gather a regionally representative sample, between two and four coffee farmers were interviewed in each of the 14 municipalities of Risaralda.

Interviews were conducted by four CITI-certified interviewers in Spanish. Three of the interviewers were collaborators from a university in Colombia and are all native Spanish speakers familiar with the region. The fourth interviewer is an author of this paper and a non-native fluent Spanish speaker. The interviewers were trained on the interview protocol as a group prior to beginning the interview process. The interviewers traveled to a central point in each municipality where they met with the coffee farmer interviewees. Interviews were conducted concurrently but in separate locations. Interviewees were not paid as it was not considered culturally appropriate by local Colombian collaborators, and interviewees signed an IRB consent form translated into Spanish and were given a copy to keep. Prior to their signing, the consent form was also verbally explained to each interviewee, with an emphasis

placed on the voluntary nature of the interview, their right to end the interview at any point without repercussion, and the steps taken to ensure their anonymity.

For this study, we analyzed the responses to 38 questions regarding demographic data (11 questions), climate change communication ego network data (3 questions), and information network attribute data (24 questions; see Appendix for our interview protocol). The interviews were recorded and subsequently transcribed by a paid team of three undergraduate students from a local university who were familiar with the regional Spanish dialect. The transcriptions were then translated by two bilingual members of the team. An author of this paper, non-native fluent in Spanish, checked the final coding against the original Spanish transcriptions for accuracy. The network data, information attribute data, and demographic data were initially coded by an undergraduate research assistant who was trained in the codebook using the English translation. Completeness of the data was defined as an answered question in which an interviewee's answer was directly responding to a properly posed question (e.g., if an interviewee misspoke or misread the question and it could be misunderstood or misinterpreted by the interviewee, it was removed). Analysis of "completeness" of an answer was rigorous and conservative. If there was any doubt, the answer was not included. Total questions analyzed are included in the "Results" section. When coding responses to climate change network data questions, if respondents listed two identities for a person with whom they discuss climate change, the primary identity name became the coded identity based on the assumption that the first verbally mentioned indicates it as the most important to the interviewee. Coding responses to general information attribute data required the creation of a qualitative codebook developed by one of the authors of this paper based on verbal cues present in the interviews indicating what was considered infrequent or frequent based on local cultural norms. For ego network data, the interviewees were asked specifically who they speak with about climate change. In the context of information attribute data, interviewees were not being asked about climate change information exclusively but general usage. Interviewees were questioned on their use of seven different media: talking on the phone, texting on cell phones (this includes messaging functions such as WhatsApp), watching TV, listening to the radio, email, Internet, and talking face-to-face. Only complete data are included. Unanswered responses were removed from the data set.

In our analysis, we use the term "extension agent." Extension is a global term for agricultural outreach programs. In the global context, extension tends to be a publicly funded and publicly run program to educate and assist agricultural producers in growing crops. The case of Colombia is somewhat unique. As described in Fig. 1, extension in the coffee sector is run by the non-governmental agency called the *Federación Nacional de Cafeteros de Colombia* or the Federation. Within the department we studied, Risaralda, the National Federation of Coffee Growers of Colombia's regional presence, is colloquially known simply as *comité* or committee. In interviews, farmers used the terms *committee technician* and *extension agents* in almost equal proportion. Given that the Federation's departmental committee is tasked by the Colombian government to run the extension program, we have folded these two designations—committee technician and extension agent—into one denomination: *extension agent*. In this context, *extension agent* refers to an employee of the National Federation of Coffee Growers of Colombia who interfaces with the farmers in some manner of formal educational or professional support capacity.

The interviewed coffee farmers were 16% female and ranged in age from 23 to 81 (M = 51.86, SD = 14.01). Total years as a farmer ranged from 2 to 63 years (M = 27.31, SD =

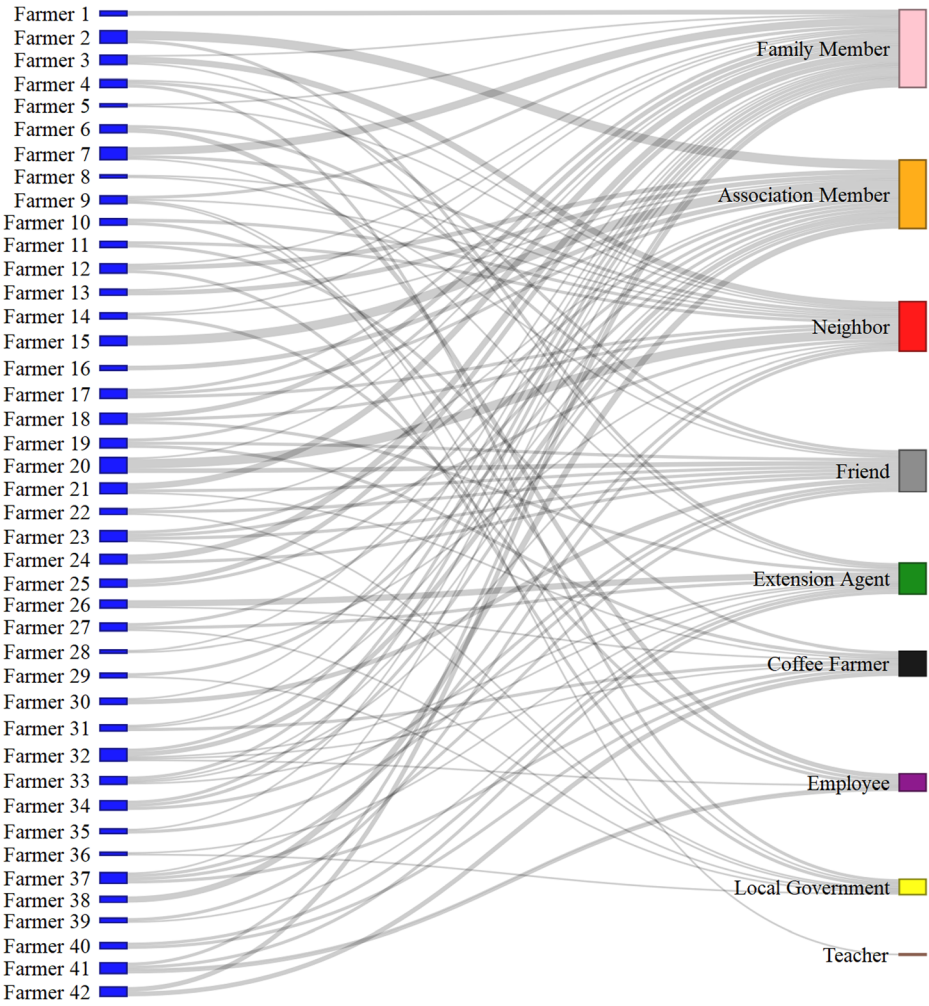

Fig. 2 Network visualization of farmers and people that farmers talk to about climate change

15.03), and farm sizes ranged from 1.5 to 100 ha (M = 9.41, SD = 15.59), with one farmer reporting that they owned multiple farms.

5 Results

Two networks were constructed from the interview data using a Sankey network visualization tool in *RStudio* and a network software program called *NodeXL* (Smith et al. 2010). The climate change information-sharing ego network, as seen in Fig. 2, shows the farmers themselves as blue nodes, and the people to whom the farmers reported talking about climate change are shown as colored nodes. This network is directed in nature, meaning the ties between nodes are directional, where a connection from one node to another node indicates that the first node is communicating to that second node. Because of the way data

was collected, all ties are directional *from* interviewed coffee farmer nodes *to* nodes represented by people to whom coffee farmers reported talking. The size of the connections between nodes is represented by the frequency of that connection occurring in the data, where higher frequencies are represented by thicker lines. The size of the nodes varies by degree centrality, a network metric that measures the number of ties that flow to or from a node, where high instances of degree centrality signify larger node sizes (Wasserman and Faust 1994).

In Fig. 2, we folded sub-identities into primary identity groups in order to create a clear visual display of the primary groups with whom farmers discuss climate change. The largest node, with the highest instance of degree centrality, is *family member (degree centrality* = 25). Family member includes designations such as parent, sibling, child, and cousin. The second largest node is *association member* (*degree centrality* = 17). In the region where this study was conducted, coffee farmers commonly associate with other coffee farmers. Associations indicate a self-organized group of coffee farmers who associate for increased benefits such as information-sharing, local brand development, and negotiating higher sales prices. The third largest node is *neighbor (degree centrality* = 16). This implies agricultural or non-agricultural neighbors. The fourth largest node is *friend (degree centrality* = 13). In the case that the designation Friend was used, the identity of Friend was chosen to take priority if listed first over additional identities such as coffee farmer or agriculturalist.

Fifth in size within the network is *extension agent* (*degree centrality* = 12). Following *extension agent* in size are *employee* (sixth; *degree centrality* = 5) and *local government* (seventh; *degree centrality* = 5), followed by very rare cases of climate change communication contact with a school teacher. In order to investigate the groups of people farmers are choosing to share information with *in general* (an "average" ego network for a coffee farmer in this region based on our data), we created an ego network with all farmers represented as one central node seen in Fig. 3. The relative percentages of self-reported social connections among farmers displayed in Figure 3 are reported in Table 1.

Within this ego network, we use a more refined and detailed account of a generalized ego network. Sub-fields are listed independently. In any case a neighbor or family member was described with higher resolution, this was included. For instance, if a neighbor was identified as a coffee farmer, they are listed as such. If a family member was identified as a spouse or sibling, they are listed as such, as well. This provides a higher level of detail when viewing a single generalized ego network. The ties between the farmer node and the people receiving information from farmers are weighted to represent the frequency with which those people were reported to be receivers of information-sharing. The darker and thicker the tie is, the more frequently that category of person was reported by farmers.

Frequencies of information attribute data for the coffee farmer sample can be seen in Table 2. This data probes ways in which interviewees receive information. Talking with neighbors is the most prevalently used method of receiving information, followed by watching TV and talking on the phone. The second column, frequency, indicates whether a particular medium is used often or simply used occasionally. Determining this label required comparing the responses with one another to discern what the coffee farmers themselves described as frequent or infrequent. Based on the responses, we created the following labels of *frequent* as follows: talking and texting on the phone more than three times a day, watching TV, listening to the radio once, using email, using the Internet once or more per day, and talking to a neighbor once or more per week. This gives a rough insight into not just usage but common

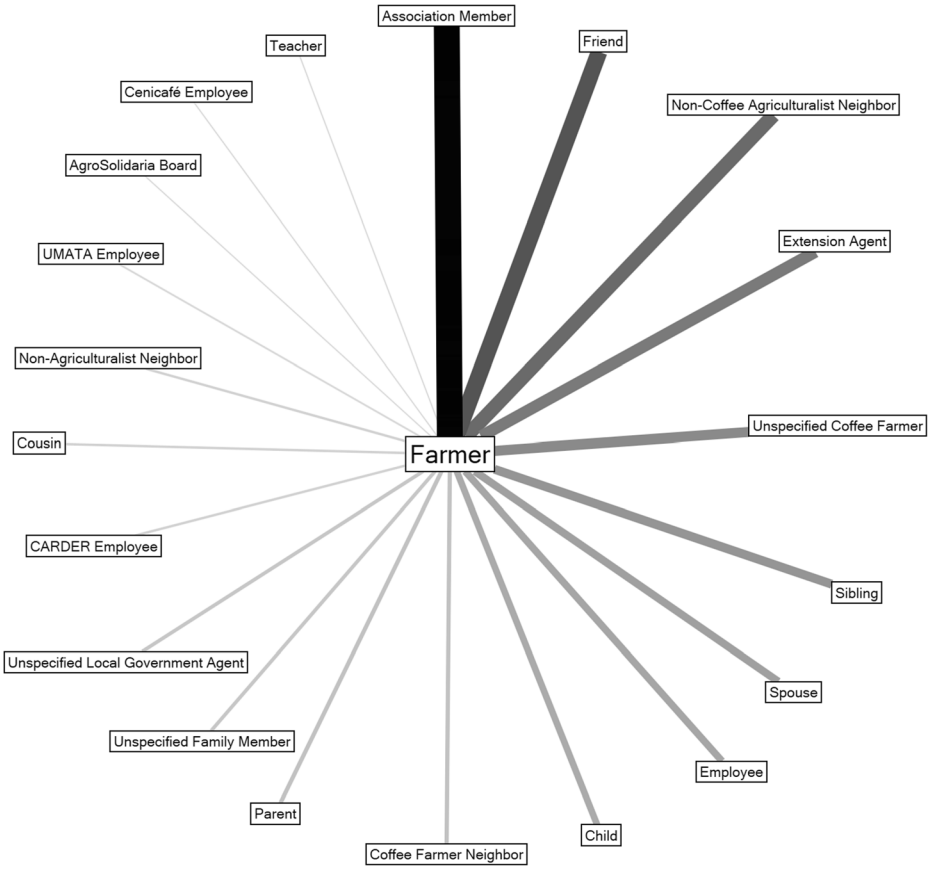

Fig. 3 Ego network of farmers and people that farmers talk to about climate change

usage. For instance, approximately half of the interviewees report using email. However, of that half, only 37% use it once a day. The majority of email users use it less than once a day,

Table 1 Relative percentages of selfreported social connections among coffee farmers

Social connections with farmers	Relative percentage of reported connections
Association member	20.5%
Friend	13%
Extension agent	9.5%
Non-coffee agricultural neighbor	9%
Unspecified coffee farmer	8%
Sibling	7%
Spouse	5%
Employee	5%
Child	4%
Coffee farmer neighbor	3%
Local government	2.5%
Parent	2%
Unspecified family member	2%
Cousin	1%
Non-agriculturalist neighbor	1%
Teacher	0.5%

Table 2 Reported usage of communication technologies for seeking and sharing information

	Total	Use frequently	Use in frequently	Rated as used most frequently
Talking on the phone	78%	44%	56%	31%
Only land line	0%	–	–	–
Only cell phone	96%	–	–	–
Both landline and cell phone	4%	–	–	–
Texting on cell phone	70%	60%	40%	20%
Watching TV	84%	61%	39%	9%
News	36%	–	–	–
Telecafe	7%	–	–	–
TV Agro	5%	–	–	–
Science/history	11%	–	–	–
Sports	7%	–	–	–
Other	34%	–	–	–
Listening to the radio	69%	44%	56%	4%
News	43%	–	–	–
RCN	14%	–	–	–
Blu	10%	–	–	–
Other	33%	–	–	–
Email	53%	37%	63%	9%
Internet	74%	28%	72%	9%
Google	63%	–	–	–
Facebook	11%	–	–	–
YouTube	11%	–	–	–
Other	16%	–	–	–
Search topic				
News	10%	–	–	–
Farming	27%	–	–	–
Work	14%	–	–	–
Other	50%	–	–	–
Talk with neighbor	88%	73%	27%	17%
Farming	31%	–	–	–
Community	17%	–	–	–
Politics	7%	–	–	–
Economy	5%	–	–	–
Climate	10%	–	–	–
Other	31%	–	–	–

which indicates that even among those who do use this medium, only very few use it with frequency. The final column indicates what farmers self-reported as the media they perceive that they use most frequently, and they lead with talking on the phone (31%), texting (20%), and talking with neighbors (17%). Radio, Internet, email, and watching TV are ranked the lowest in terms of which are used most frequently.

It is important to note that this data is gathered from coffee farmers in Risaralda, Colombia, and cannot necessarily be extrapolated to other coffee farming regions in Colombia.

Five of the media have additional attribute data. Regarding talking on the phone, 96% use only a cell phone and do not use a landline. When watching TV, most report that they use it for the news, as is the case with radio. Perhaps most interestingly is the reported data on Internet usage. With 74% reporting they use the Internet (albeit the majority less than once a day), only 22% report using social media (e.g., Facebook, YouTube). Well over half report that they use the Internet for Google. When talking with neighbors, farming and community tend to be the most common topics.

6 Discussion

6.1 Broad stakeholder context

Figure 1 illustrates the broad stakeholder context within which the coffee farmers operate that both constrains and enables information flow. Apart from the coffee farmers, the primary players in this context are the Colombian government and National Federation of Coffee Growers of Colombia. The Federation, a non-government organization, is empowered by the Colombian government to manage the nation's coffee industry through management of governmental resources, running agricultural outreach services (extension) and controlling export permits. The Federation is therefore the major institutional entity controlling information flows as well as other crucial economic and political components. They do not currently acknowledge long-term climate change, and as such do not educate farmers on nor focus attention on developing long-term climate change adaptation strategies. The presence of self-organizing farmer associations is also an important component of this context, indicating farmers' desire to create their own self-managed system to better meet their tailored needs either personally or regionally. This context can also be analyzed through what is absent. There is a lack of competing organizational components within this context that farmers might utilize. Additionally, there is no strong international organizational presence in the form of a predominant non-profit or other business interests.

6.2 Social networks

The social network visualizations and data reveal several insightful elements. Figure 2 illustrates the importance of informal contacts. Family members, friends, and neighbors make up the vast majority of the people with whom coffee farmers discuss climate change. Informal connections are where most conversations and knowledge exchange around climate change are happening. In regard to formal contacts, association members are notably the largest point of conversation and knowledge exchange. Extension agents, local government, and other non-governmental entities are the smallest. Figure 3 serves to reinforce the importance of the association in climate change information networks for coffee farmers. It also demonstrates the wide range of familial contacts: siblings, spouses, children, parents and cousins.

Several conclusions can be drawn from these insights. First, in discussions around climate change, we can surmise that coffee farmers are relatively isolated from formal governmental or organizational support structures (apart from self-organized associations). As for the cause of this, we may hypothesize reasons such as the Federation not acknowledging climate change and therefore ignoring it during outreach as other issues may be perceived to take precedence, a limited number of extension agents which places a natural cap on the number of conversations that can be regularly held with coffee farmers, and the remote location of certain coffee farmers. What is clear is that in this region, the coffee farmers generally rely on their associations, which are comprised of other coffee farmers, as well as families, friends, and neighbors to principally discuss and exchange knowledge around climate change. A minority of the coffee farmers have contact with resources beyond informal support structures to discuss climate change. When examined through the lens of implications for climate change adaptation, it could be beneficial to increase governmental and institutional involvement with coffee farmers to educate, interface, and prepare them for the current and ongoing impacts of climate change. However, if governmental or institutional resources are constrained, it is clear that

resources can be maximized by leveraging associations as outreach hubs for climate change adaptation.

6.3 Information attribute data

Information attribute data paint a general picture of media habits of this demographic. The most striking element of note is that access to digital resources is low. Email was used by only half of the interviewees, and of that half, only a third reported using it daily. This implies that only approximately one-fifth of the farmers use email daily. Internet was reported as being accessed by approximately three quarters of the interviewees, primarily to Google information; however, three quarters of this group use the Internet less than once a day. In other words, only slightly over a quarter of the farmers use the Internet daily. Face-to-face conversations, watching TV, and talking on the phone are reported as the most common; an indication that this demographic is more comfortable with personal or what we may describe as more traditional media. This is likely attributed to financial, logistical, and educational constraints; Internet access and computers are expensive, and using them is not intuitive but must be taught through exposure or formal education. Additionally, connectivity is poor in many rural areas.

We may draw several valuable conclusions from this data. First, Internet and email as methods of information delivery and engagement are not the most efficient. Social media usage is not prevalent as it is in some regions of the world. Television spots, word-of-mouth, and phone calls/texting are the most popular and common media. In terms of climate change adaptation, the implications are that outreach efforts and engagement will require more effort. Websites and social media posts are effective in some environments and are expedient as they require a low degree of investment. However, in this environment, online initiatives without an additional outreach component will isolate a large proportion of the population, likely the poorest and those with the least amount of resources, for whom this information and engagement would be most valuable. For this region and demographic, outreach efforts around climate change adaptation will require more upfront planning and investment and will need to incorporate some form of preferred media: in-person meetings, TV programs, printed pamphlets, phone calls, etc. Digital literacy campaigns or digital tools tailored to lower levels of digital literacy and digital accessibility may also be effective in the long-run, especially those that include some form of hybrid online/offline outreach.

6.4 Combined analysis

By combining social network data and information attribute data and situating them within the broader context, we are able to garner a rich and situated description of the communication environment of the coffee farmers of this region. Taken together, these reveal both constraints and opportunities for effective climate change adaptation efforts for this demographic. Additionally, they reveal how constraints can be *turned into* opportunities. For instance, the prominence of informal networks—friends, family, and neighbors—in climate change information exchanges and conversations could be perceived as a constraint insofar as it reveals a lack of connection with more formal governmental organizations and other institutions. However, due to the reality of financial limitations, competing priorities, or other institutional realities, it may be unrealistic to assume that formal governmental or institutional outreach organizations can or will step in and become a central player in everyone's network. In this case, coffee farmers can be empowered to serve as informal educators or knowledge-

disseminators within their own informal networks, which could serve the dual purpose of also taking advantage of their agency and local expertise. What is more, self-organizing groups of farmers—associations—can be folded into this process. They are existing, strong networks that contain great potential for engagement and dissemination. Both of these avenues also contend with the reality of preferred media; they do not rely on Internet access nor email and maximize preferred contact such as face-to-face engagement and phone calls/texting. In the case of outreach where a group cannot be present on-the-ground, television spots could be another form of effective communication.

Based on the combined analysis, we conclude with the following three implications and supporting recommendations:

1. The Federation's prominence in the Colombian national coffee context makes it the dominating, institutional force for information flows. The Federation's decision to focus on short-term climatic variability over long-term climate change implications means it is unlikely to be a partner (at this time) on climate change adaptation efforts. This is reinforced by the farmers' reports of using informal or self-organized associations as primary sources of information for climate change. Considering this current scenario, effective next steps could be working with the Federation to shift priorities or seeking out and reinforcing alternative information flows.
2. The emergence of self-organizing associations is a central opportunity and strength point. Coffee farmers exhibit a high level of interaction with associations around climate change information, and they are also regional, thus complementing the coffee farmers' preference for in-person or more tailored, personal communication initiatives and dependence on family and neighbors for information flows. Supporting these associations or leveraging them for assistance in information campaigns around climate change adaptation may prove useful and also highly interactive, insofar as it can invite the farmers to participate in adaptation processes.
3. The information attributes of this population reveal a general disconnection from web information sources, such as the Internet and email. Online tools may be effectively geared toward association leaders or other coffee stakeholders, who may be encouraged to disseminate it online-to-offline with other farmers. However, if farmers are the target audience, it is unlikely it will be effective. This isolation from external digital information sources places the farmers in a disadvantaged position in terms of access to a range of information flows. They are largely reliant upon only one institutional source of flow, which is the Federation, and this makes them dependent upon the agenda of only one organization, which may or may not complement their individual needs at any given time. This constrained information environment does not imply that the farmers are in any way limited in their potential, but only that their information flows are systemically constricted.

7 Limitations

This research contains limitations. First, the method used for data collection with coffee farmers required participants to self-report people with whom they talk about climate change. Previous research has noted the potential downsides to using self-report data in this manner because of the possibility of recall bias (Rice et al. 2014; Brewer 2000). However, there are justifications for using such a method, particularly for the kinds of questions we sought to answer in this study. For example, we were only concerned with the affective, strong ties and

social ties that have existed for longer durations. Social ties of this nature are said to mainly be listed in name-calling studies (Marin 2004). Even still, future researchers interested in the problem our study addressed may consider implementing methods similar to those proposed by Rice et al. (2014), another form of mixed method approach used to triangulate the data, in order to more holistically capture the social and information networks of Colombian coffee farmers.

Another consequence of the decision to use name generation techniques in our interviews is the amount of missing data that results from unanswered or inadequately answered questions (Brewer 2000). Missing data, though, is a product of interviewing as a data collection technique. It is not the fault nor the problem of our interview subjects that led to more missing data, and the answers they chose to provide adhere to the assumptions and practice of interview methodologies (Bernard et al. 1984). We are confident that, despite limitations that may have arisen from any missing data, the analyses we conducted and the conclusions we drew from said analyses were as true to the answers we were given by our interviewees as possible. In essence, we prioritized the authenticity of our interviewees' answers over any added statistical or network completeness that could have been achieved with a greater frequency of complete or adequate answers.

Selection bias and the limited number of interviewees are two potential limitations. Regarding selection bias, we can conjecture that farmers who were actually interested in and made the effort to attend an interview may, to some degree, differ slightly from the rest of the population. For instance, they may be slightly more engaged with their associations and extension agents. Or, they may be slightly more socio-economically well-off (able to take time off of work to attend an interview), which could lead to a slightly higher report of Internet and email usage. Lastly, this research focused specifically on Colombian coffee farmers in Risaralda, and the answers that informed our conclusions reflect a snapshot in time. We view this localized and narrow scope as a strength, rather than a weakness, because it afforded us the ability to make more relevant and specific claims about our subjects of interest. It will be important to follow the patterns discussed in this article at future points in time to assess if and how they change as climate change progresses, and we encourage replication, or modification, of this type of localized environmental research in the context of climate change information networks.

Interview protocol for data collection

Demographic questions:

The question on ethnicity was removed from the interview protocol after several interviews as it was unclear to interviewees what type of answer we were seeking and appeared to prompt confusion and general discomfort.

1. What is your name? (Verbally asking an interviewee to identify their gender was not considered culturally appropriate for the context. Gender was later coded using the first name as the indicator, as Spanish names are typically already gendered.)
2. How old are you?
3. Where do you live? (town and area)
4. Where were you born?
5. What were your parents' occupation and other primary relatives in your life (uncles, aunts, grandparents, etc.)?

6. What is the last grade that you completed in school?
7. What farmer associations do you belong to?
   a. How long have you belonged to each association?
8. How long have you been a farmer?
9. How big is your farm?
10. What variety of coffee do you produce?

Network information questions:

Interviewers were carefully trained on this question and were requested to encourage participants to list the first names of all people they speak with about climate change and to inquire as to the role of each person, such as whether the person is a farmer, a friend, a local official, an extension agent, etc. These instructions were included in the interview protocol as well. Interviewers were also trained to elaborate on the question if the interviewee was confused and to explain that we were interested in whomever they might speak to about climate change, even if it is family or friends.

1. Do you ever talk with others about climate change?
   a. If yes, with whom do you speak about climate change?
   b. If yes, what topics do you discuss when you talk with these people about climate change?

General information attribute questions:

Interviewers were given this script to read prior to these questions: "Next, I'm going to list a couple of ways people get information in general. For example, information related to work, hobbies, health, or anything else. I'll list them, and then I'll ask you if you use that medium, if you like it, and then, ultimately, you can tell me which is your favorite."

1. Do you talk on a phone to get information?
   a. If so, how frequently do you do it?
   b. If so, whom do you talk to?
   c. If so, do you use a cell phone and/or a landline?
2. Do you text on a cell phone to get information?
   a. If so, how frequently do you do it?
   b. If so, with whom do you text to get information?
3. Do you watch TV to get information?
   a. If so, how frequently do you do it?
   b. If so, what types of channels or shows do you watch?
4. Do you listen to the radio to get information?
   a. If so, how frequently do you do it?
   b. If so, what channels or programs do you listen to?
5. Do you use email to get information?
   a. If so, how frequently do you do it?
   b. If so, whom do you email with most often?
6. Do you go on the Internet to look for information?
   a. If so, how frequently do you do it?
   b. If so, what websites do you go to most often?
   c. If so, what do you search for most often?

7. Do you talk with your neighbor to get information?
   a. If so, how frequently do you do it?
   b. If so, what do you talk with your neighbors about most frequently?
8. Which of these methods of communication do you use the most frequently to get information and why?

References

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR et al (2009) Are there social limits to adaptation to climate change? Clim Chang 93:335–354. https://doi.org/10.1007/s10584-008-9520-z

Adhikari S, Dhungana N, Upadhaya S (2020) Watershed communities' livelihood vulnerability to climate change in the Himalayas. Clim Chang 162:1307–1321. https://doi.org/10.1007/s10584-020-02870-8

Alfonso K (2018) Más agronomía, más productividad. Agronegocios. Retrieved from https://www.agronegocios.co/aprenda/mas-agronomia-mas-productividad-2623175

Arnaboldi V, Dunbar RIM, Passarella A, Conti M (2016) Analysis of co-authorship ego networks. Advances in Network Science 9564:82–96

Atkin CK (1981) Mass media information campaign effectiveness. In RE Rice and WJ Paisley (Eds.), Public communication campaigns (pp. 265–280). GAL Sage

Aubin D, La Jeunesse I, Riche C, Vande Water V (2018) The central role of basin authorities in the governance of water challenges induced by climate change: a social network analysis of the Thau Basin in France. Climate Change & Water (Tours, du 05/02/2018 au 07/02/2018). http://hdl.handle.net/2078.1/204625

Baker P, Alden J, Baranowski P (2019) The changing climate of Colombian coffee. Coffee & Cocoa International 46:40–43

Barnett J (2010) Adapting to climate change: three key challenges for research and policy–an editorial essay. Wiley Interdiscip Rev Clim Chang 1:314–317

Bates RH (1997) Open-economy politics: the political economy of the world coffee trade. Princeton University Press

Bentley JW, Baker PS (2000) The Colombian Coffee Growers' Federation: organised, successful smallholder farmers for 70 years. ODI

Bernard HR, Killworth PD, Kronfeld D, Sailor L (1984) The problem of informant accuracy: the validity of retrospective data. Annu Rev Anthropol 13:495–517

Biesbroek GR, Klostermann JE, Termeer CJ, Kabat P (2013) On the nature of barriers to climate change adaptation. Reg Environ Chang 13:1119–1129

Bodin O, Crona BI (2009) The role of social networks in natural resource governance: what relational patterns make a difference? Glob Environ Chang 19:366–374

Borgatti SP, Everett MG, Johnson JC (2013) Analyzing social networks. Sage

Brass DL, Galaskiewicz J, Greve HR, Tsai W (2004) Taking stock of networks and organizations: a multilevel perspective. Acad Manag J 47:795–817

Brewer DD (2000) Forgetting in the recall-based elicitation of personal and social networks. Soc Networks 22:29–44

Cannella AA, McFadyen MA (2016) Changing the exchange: the dynamics of knowledge worker ego networks. J Manag 42:1005–1029

Constantino LM, Gil ZN, Jaramillo A, Benavides MP, Bustillo AE (2011) Efecto del cambio y la variabilidad climática en la dinámica de infestación de la broca del café, Hypothenemus hampei en la zona central cafetera de Colombia. In Proceedings, Simposio: Sociedad Colombiana de Entomología SOCOLEN 27-29

Costa Posada C (2007) La adaptación al cambio climático en Colombia. Revista de Ingeniería 26:74–80. Retrieved January 15, 2021, from http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0121-49932007000200010&lng=en&tlng=

Eise J, Rawat M (2021) Applying structurational divergence theory to climate change adaptation in a localized context: understanding adaptive potential of coffee producers in Risaralda, Colombia. Journal of Applied Communication Research. https://doi.org/10.1080/00909882.2021.1970792

Everett M, Borgatti SP (2005) Ego network betweenness. Soc Networks 27:31–38

Federación Nacional de Cafeteros (2015) ¿Como se calcula el precio interno de del café en Colombia? Retrieved from https://www.federaciondecafeteros.org/static/pergamino-fnc/uploads/como_se_calcula.jpg

Federación Nacional de Cafeteros (2017) FNC en Cifras. Retrieved from https://federaciondecafeteros.org/static/files/FNCCIFRAS2017.pdf
Federación Nacional de Cafeteros (2019a) About us. Retrieved from https://www.federaciondecafeteros.org/particulares/en/quienes_somos
Federación Nacional de Cafeteros (2019b) Organos Gremiales de la Federación de Cafeteros. Retrieved from https://www.federaciondecafeteros.org/clientes/es/que_hacemos/representacion_gremial/organos_gremiales_de_la_federacion_de_cafeteros/
Federación Nacional de Cafeteros (2019c) Cooperativas de Caficultores. Retrieved from https://www.federaciondecafeteros.org/clientes/es/que_hacemos/cooperativas_de_caficultores/
Federación Nacional de Cafeteros de Colombia (2007) Exportación de café procesado procedimiento. Retrieved from https://www.federaciondecafeteros.org/static/files/procedimiento_exportacion_cafe_procesado.pdf
Flora JA, Maccoby N, Farquhar JW (1989) Communication campaigns to prevent cardiovascular disease: the Stanford community studies. In: Rice RE, Atkin CK (eds) Public communication campaigns, 2nd edn. Sage, pp 233–252
Freeman LC (1982) Centered graphs and the structure of ego networks. Math Soc Sci 3:291–304
Gobierno y Federación de Cafeteros renuevan contrato del fondo parafiscal (2016) El Espectador. Retrieved from https://www.elespectador.com/noticias/economia/gobierno-y-federacion-de-cafeteros-renuevan-contrato-de-articulo-642459
Hoang HG (2020) Vietnamese smallholders' perspectives on causes, indicators and determinants of climate change: implication for adaptation strategies. Clim Chang 162:1127–1142
Hodson de Jaramillo E, Castaño J, Poveda G, Roldán G, Chavarriaga Aguirre P (2017) Seguridad alimentaria y nutricional en Colombia. La Red Interamericana de Academias de Ciencias (IANAS)
Jarvenpaa SL, Majchrzak A (2008) Knowledge collaboration among professionals protecting national security: role of transactive memories in ego-centered knowledge networks. Organ Sci 19:260–276
Lambert NJ, Eise J (2020) Farming in the face of uncertainty: how Colombian coffee farmers conceptualize and communicate their experiences with climate change. Int J Commun 14:21
Lee S, Chung JE, Park N (2018) Network environments and well-being: an examination of personal network structure, social capital, and perceived social support. Health Commun 33:22–31
Linkov I, Bates M, Loney D, Sparrevik M, Bridges T (2011) Risk management practices. In: Linkov I, Bridges T (eds) NATO science for peace and security series C: environmental security. Springer
Lora E. (2015a). Los caficultores pagan demasiados impuestos. Dinero. Retrieved February 13, 2019, from https://www.dinero.com/edicion-impresa/opinion/articulo/impuestos-deben-pagar-caficultores-colombia/206460
Lora E. (2015b). El debate sobre la institucionalidad cafetera. Dinero. Retrieved February 20, 2019, from https://www.dinero.com/edicion-impresa/opinion/articulo/el-poder-federacion-nacional-cafeteros/207250
Lozano-Povis A, Alvarez-Montalván CE, Moggiano N (2021) El cambio climático en los andes y su impacto en la agricultura: una revisión sistemática. Scientia Agropecuaria 12:101–108
Marin A (2004) Are respondents more likely to list alters with certain characteristics? Implications for name generator data. Soc Networks 26:289–307
Marshall B, Cardon P, Poddar A, Fontenot R (2013) Does sample size matter in qualitative research?: a review of qualitative interviews in IS research. J Comput Inf Syst 54:11–22. https://doi.org/10.1080/08874417.2013.11645667
Michal-Johnson P, Bowen SP (1992) The place of culture in HIV education. In: Edgar T, Fitzpatrick MA, Freimuth VS (eds) AIDS: a communication perspective. Lawrence Erlbaum, pp 147–172
Mijiddorj TN, Alexander JS, Samelius G, Mishra C, Boldgiv B (2020) Traditional livelihoods under a changing climate: herder perceptions of climate change and its consequences in South Gobi, Mongolia. Clim Chang 162:1065–1079
Mimura N, Pulwarty RS, Elshinnawy I, Redsteer MH, Huang HQ, Nkem JN, ... Kato S (2015) Adaptation planning and implementation. Climate Change 2014 Impacts, adaptation and vulnerability: part a: global and sectoral aspects. Cambridge University Press
Minagricultura (2018) Caficultores. Retrieved from https://www.minagricultura.gov.co/atencion-ciudadano/preguntas-frecuentes/Paginas/Caficultores.aspx
Muñoz AL, Vega CA, Martínez JC (2017) Redes de conocimiento como estrategia detransferencia de tecnología para la adaptación al cambio climático. Ingenio Magno 8:10–20
Ortega Díaz A, Gutiérrez EC (2018) Competing actors in the climate change arena in Mexico: a network analysis. J Environ Manag 215:239–247
Owen G (2020) What makes climate change adaptation effective? A systematic review of the literature. Glob Environ Chang 62:102071
Park N, Lee S, Kim JH (2012) Individuals' personal network characteristics and patterns of Facebook use: a social network approach. Comput Hum Behav 28:1700–1707

Ramirez-Villegas J, Salazar M, Jarvis A, Navarro-Racines C (2012) A way forward on adaptation to climate change in Colombian agriculture: perspectives towards 2050. Clim Chang 115:611–628

Rice E, Holloway IW, Barman-Adhikari A, Fuentes D, Brown CH, Palinkas LA (2014) A mixed methods approach to network data collection. Field Methods 26:252–268. https://doi.org/10.1177/1525822X13518168

Sadri AM, Ukkusuri SV, Lee S, Clawson R, Aldrich D, Nelson MS et al (2018) The role of social capital, personal networks, and emergency responders in post-disaster recovery and resilience: a study of rural communities in Indiana. Nat Hazards 90:1377–1406

Salmon CT (1989) Information campaigns: balancing social values and social change. Sage

Scarlett L (2011) Climate adaptation. In: Linkov I, Bridges T (eds) NATO science for peace and security series C: environmental security. Springer

Se modifican las normas de exportación de Café de Colombia. (2016). Cafe de Colombia. Retrieved from http://www.cafedecolombia.com/cci-fnc-es/index.php/comments/se_modifican_las_normas_de_exportacion_de_cafe_de_colombia

Smith M, Ceni A, Milic-Frayling N, Shneiderman B, Mendes Rodrigues E, Leskovec J, Dunne C (2010) NodeXL: a free and open network overview, discovery and exploration add-in for Excel 2007/2010/2013/2016. Available from http://nodexl.codeplex.com/

Tabourier L, Libert A, Lambiotte R (2016) Predicting links in ego-networks using temporal information. European Physical Journal: Data Science 5:1–16

Thorp R (2000) Has the Coffee Federation become redundant?: collective action and the market in Colombian development (No. 183). UNU World Institute for Development Economics Research

United Nations Environment Programme (2016) UNEP report: Cost of adapting to climate change could hit $500B per year by 2050. [Webpage] Retrieved from http://web.unep.org/ganadapt/blog/unep-report-cost-adapting-climate-change-could-hit-500b-year-2050

van Rijnsoever FJ (2017) (I can't get no) saturation: a simulation and guidelines for sample sizes in qualitative research. PLoS ONE 12. https://doi.org/10.1371/journal.pone.0181689

Wasserman S, Faust K (1994) Social network analysis: methods and applications. Cambridge University Press

Affiliations

Jessica Eise[1] · **Natalie J. Lambert**[2] · **Eric C. Wiemer**[3]

[1] Department of Communication, The University of Texas at San Antonio, San Antonio, TX 78249, USA

[2] School of Medicine, Indiana University, Indianapolis, IN 46202, USA

[3] Brian Lamb School of Communication, Purdue University, West Lafayette, IN 47906, USA