IMPROVING COMMUNICATION IN DROUGHT PREPAREDNESS CAMPAIGNS IN IRRIGATION SYSTEMS: A Network Analysis

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ABSTRACT

One common finding in recent diffusion research is that ideas, beliefs, and behaviors tend to diffuse more quickly in disassortatively than in assortatively mixed social networks. This outcome may have important implications for the design of communication strategies to increase the participation of farmers in drought preparedness programs. For instance, if the underlying social network is disassortatively mixed by degree, i.e., if highly connected farmers tend to preferentially associate to less connected ones, community involvement programs should focus on convincing opinion leaders on the need to adopt the recommended measures. If, otherwise, the network is assortatively mixed by degree, communication should be more focused on horizontal campaigns targeted to the average farmer. We tested a typical irrigation system in the semi-arid region of Brazil for degree and geographic assortativity. The main finding was that the underlying informational network is disassortative by degree and assortative by geographic location of the farmers. This result suggests that community involvement campaigns in similar systems should be designed based on some variation of the basic "two-step flow" model of communication, in which most of communication and marketing researches are based on. Specifically, it appears that policies seeking to improve the response of irrigation systems to severe droughts should focus on influencing local leaders able to act as mutually reliable information bridges between irrigators and government agencies.

Keywords: *drought preparedness, irrigation, network analysis, assortative and disassortative networks, two-step flow model of communication*

INTRODUCTION

Although droughts are the type of natural disaster most gradual and hard to predict, recent initiatives in areas like agrometeorology, arid/dryland farming systems and hydrology have contributed substantially to the knowledge base on drought prediction and management all around the world. However, the translation of this knowledge into the adoption of effective practices to face severe drought by stakeholders in drought-prone areas, has not been to the desired extent. For instance, during the 1990s a huge campaign was launched by Australian government bodies to demonstrate to farmers the links between ENSO (El Niño-Southern Oscillation phenomenon) and rainfall variation. Despite this link was widely known and accepted within the Australian agricultural community by 2000, nevertheless, only 32% of farmers used to take those predictions into account (1). The ability of government agencies to influence farmer`s preparedness for withstanding severe droughts appears to be still lower in developing countries such as Brazil. In the region known as the drought polygon, for instance, less than 10% of the population classified the year of 1997, the first of a severe ENSO drought, as a drought one. That happened despite the fact government agencies have officially labelled that year this way (2). These two examples suggest that the lack of preparedness for severe droughts may stem not from a lack of good quality information on climate issues amongst farmers, but from the way that information is communicated to people potentially affected. While communication of climate information between agencies and users has improved in recent years, there appears to be still room for improvement (3). This paper seeks to contribute to this goal by studying how, under the lens of network theory, information about climate issues flow among the key players in a typical irrigation system located in the Brazilian drought polygon: The Gorotuba Irrigation District.

A major finding of recent diffusion research, to begin with, is that the spread of whatever is flowing through a social network - diseases, information or behaviors – is more quickly in disassortatively than in assortatively mixed networks (4,5). There are, however, two competing hypothesis about how new ideas and behaviors flow through social networks. The first one assumes that they spread like infectious diseases in which a single contact with an infected individual is sufficient to transmit an idea or behavior. This hypothesis is consistent with the hypothesis that disassortative networks, which are bridged by long, weak informational ties among spatially and socially distant agents, will spread new information more quickly and farther than a network characterized by highly clustered ties. The second hypothesis states that the diffusion of ideas and behaviors is essentially different from the spread of diseases, because people usually require contact with multiple sources of "infection" before being convinced to adopt new ideas or behaviors. Recent research indicate that the second hypothesis is close to the empirical evidence in behavioral diffusion processes, in which individual adoption is improved by reinforcing signals that come from clustered social ties (6).

This paper suggests that irrigation systems, as other man made systems, are of the second kind, including features of both disassortative and assortative networks (7). That is so because, due to physical and geographic constraints, people have incentives to build long heterophilous links with geographically and socially distant individuals, alongside homophilous bonds with similar individuals within their own communities. That means people search for information about their economic environment (e.g., tips about new irrigation techniques and weather forecasts) among higher status and more informed individuals usually located outside their immediate neighborhood. These practices, however, have to be suited to the local conditions and be acceptable to the social norm (8), which requires that individuals get information and social approval from their close neighbors with whom they normally maintain stronger homophilous ties. This is of course what Burt (9) famously labeled as the brokerage and closure process. Increasing variation in a group by stablishing informal relation with dense clusters separated by structural holes pays-off. But up to a certain point a decrease variation in group is called for, in the sense that bridging structural holes can create value, but delivering that value requires the trust provided only by closed networks of mutually supportive people.

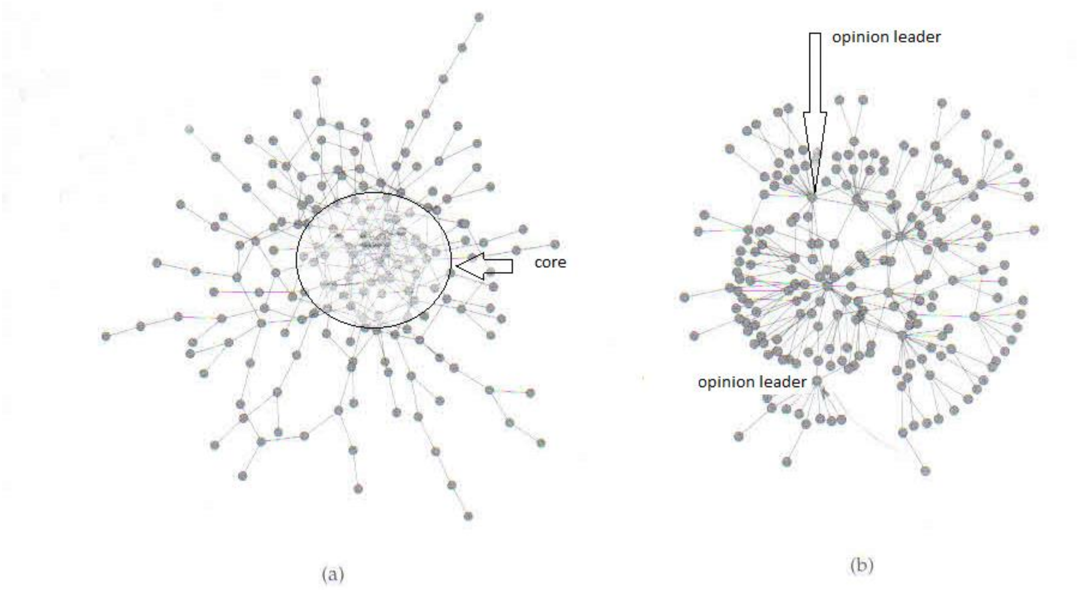
DEFINITIONS: Assortativity and Disassortativity

Recent studies in network analysis have found that local rules of partnership formation that operate at the local individual level, such selective mixing patterns among different groups, may govern the structure of a social network (10). Mixing refers to assortative and disassortative biases in the joint distribution of patterns attributes such as centrality degree – i.e. the number of relations agents have within the network - race, age, social status and the like. Assortative biases can create clustered networks, which tend to increase the speed of spread different types of influence within groups, and slow the spread between them. Disassortative biases typically have the opposite effect, ensuring rapid spread of whatever is flowing through the network to all groups.

Figure 1a), based on (11), displays the pattern of a dense core of high-degree vertices (agents) surrounded by a periphery of lower-degree ones typical of assortative systems. Figure 1b) displays the star-like structure characteristic of disassortative networks, in which high degree vertices – such as the opinion leaders in social networks - tend to be connected to low degree ones, which are relatively disconnected from each other.

Homophily, that is the fact that people are more likely to maintain relationships with whom are similar to themselves, is the main source of assortativity in social network formation. While there is little systematic study of assortativity, there is some evidence that positive assortativity is a property of many socially generated networks, while disassortativity is more prevalent in technological and biological networks. Economic networks, such social networks in irrigation systems, have some aspects of both social and technological relationships (7).

Figure 1. Assortative and disassortative networks



As new ideas usually enter a network through higher status members, a higher degree of homophily would mean that innovation usually hardly reach nonelites. Innovations tend to spread horizontally, rather than vertically, which slows down the rate of diffusion. Because links reach out into the entire system, on the other hand, heterophilous disassortative networks aid rapid diffusion (12). In this class of network followers tend to seek the more connected opinion leaders of higher socioeconomic status and/or more formal education, perceived as more technically competent. This makes the most influential opinion leaders key targets in diffusion campaigns as they are in general influent in political, health, agricultural and educational issues (5).

Hence, as the pattern of connections in a network can have a profound impact on the diffusion of information on irrigation systems, it is important to develop a better understanding of assortativity and other underlying networks' characteristics in order to design better drought preparedness campaigns.

MATERIALS AND METHODS

Characterization of the irrigation system studied

The Gorotuba Irrigation District is a medium size gravity-fed system located in the region known as the drought polygon in the Northeast of the Minas Gerais state/Brazil. Water is distributed along 134.3 km of canals that irrigate 4,893 hectares. Furrow is the main irrigation method, used in about 50% of the irrigated area for 447 irrigators, who produce fruits, grains and other crops, in 61%, 25% and 15%, respectively, of the irrigated area. The irrigators occupy 11 settlements distributed over five regions, which operate with different levels of productivity.

Data collection

Information to draw friendship and informational networks in figure 2 was obtained through a roster study. The 447 stakeholders were approached with a list of all the other members of the system and asked two questions: a) who on the roster you meet often in social occasions (question 1) and b) whom do you turn to get environmental and economic information, such as weather forecasts, market conditions for produced goods, new production practices, and new irrigation technologies (question 2).Two binary social matrices then were built with cells valued 1 if there is a relationship between stakeholders in terms of questions 1 and 2 and zero otherwise. The graphs in figure 2 were drawn using the computer program UCINET (13). Only the irrigators that keep at least one friendship or informational link in the respective network were considered.

Methods

The assortativity degree of the networks was calculated by using the formula proposed by Newman (11), as follows:

$$r = (S\_1\ S\_e - S\_2\text{^}2)/(S\_1\ S\_3 - S\_2\text{^}2\ )$$

In which,

$$S_e = \sum A_{ij}\text{, } k_i\, k_j\text{ ,} \quad S_1 = \sum k_i, \quad S_2 = \sum k_i^2, \quad S_3 = \sum k_i^3$$

Where A_{ij} is a cell of the adjacency matrix of the network of interest and k_i and k_j are in-degree and out-degree vertices, respectively.

The networks' spatial assortativity was assessed by running the logistic regression procedure in UCINET, which uses the QAP technique which is designed to correlate whole matrices. To calculate the significance of a coefficient the method compares the observed correlations between a thousand pairs of matrices that are just like the data matrices but are known to be independent of each other.

RESULTS

Figure 2 displays the friendship and the informational networks of the Gorotuba Irrigation District, in which the size of vertices is given by their degrees. An accurate measure of the degree assortativity of a network is the Pearson correlation coefficient between the vertices, where 1 indicates a perfectly assortatively mixed network. Computation of that coefficient indicates that both are disassortatively mixed: -0.240 and -0.212, respectively, although the informational network looks somewhat more assortative than the friendship network (note the communities of similar individuals at the top of the informational network).

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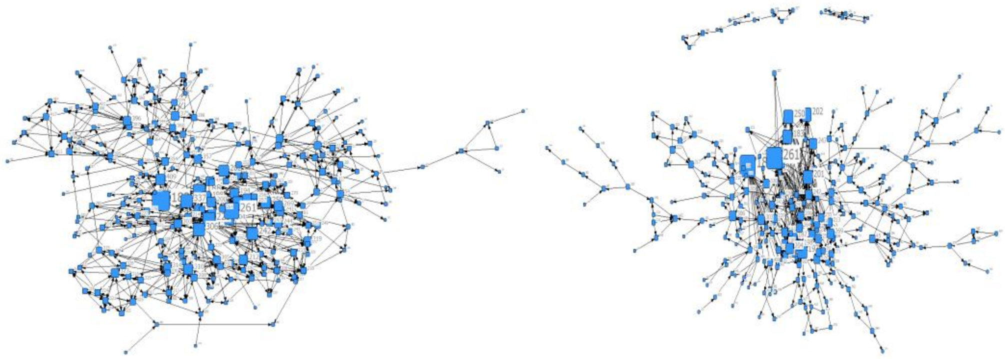
Figure 2. Gorotuba Irrigation District`s social networks

Friendship Network | Informational Network



In order to shed some light on this result we use the QAP logistic regression method to assess the importance of independent variables, such as the region and the settlement in which irrigators are located, for building friendship (model 1) or informational (model 2) bonds (elicited by means of questions 1 and 2 above, respectively). These independent variables are depicted in binary matrices, valued 1 if irrigators are located in the same region, settlement and canal, and zero otherwise. There are 5 regions in the district, which present different conditions of soil and access to water, 16 irrigation canals, and 12 settlements, founded in different times.

Model 1
Dependent variable: Friendship Links
Overall fit of the logistic regression model

	LL	R-Sqr	Sig	Obs	Perms
Statistics	-3677.497	0.054	0.001	73170	1000

1 rows, 5 columns, 1 levels

LR Coefficients & Permutation Results (T-stats used in permutations)

	Coef	OddsRat	T	Sig	Avg	SD
Intercept	-6.266			0.002	-66.758	
Settlement	1.123	3.073	8.602	0.001	-0.003	0.186
Canal	1.350	3.859	10.996	0.001	0.004	0.197
Region	1.393	4.026	9.813	0.001	-0.003	0.136

Model 2
Dependent variable: Informational Links
Overall fit of the logistic regression model

	LL	R-Sqr	Sig	Obs	Perms
Statistics	-2442.822	0.025	0.001	155630	1000

1 rows, 5 columns, 1 levels

LR Coefficients & Permutation Results (T-stats used in permutations)

	Coef	OddsRat	T	Sig	Avg	SD
Intercept	-11.751			0.000	-11.747	
Settlement	8.816	6741.747	8.754	0.001	0.005	0.402
Canal	-0.413	0.662	-3.105	0.008	-0.005	0.286
Region	-0.365	0.694	-2.003	0.053	-0.003	0.154

The r square values of 5.4% and 2.5% in models 1 and 2, respectively, indicate that the tested independent variables are not major factors in determining who an irrigator decides to seek advice from or to be friend of. The fact that variables are all statistically significant in both models, nevertheless, indicates that they are at least a piece of the puzzle. Moreover, the odds ratios in model 1 indicate that the three variables are almost equally important in determining whom people choose to be friend. Looking at this result together with the computed assortativity coefficient, we infer that farmers seek to connect preferentially to the most influential individuals throughout the district. Model 2, on the other hand, suggests that the only factor that influences the formation of informational links is living in the same settlement. Moreover, the very high odds ratio related to this independent variable means that it is virtually null the chance of two people belonging to the same settlement not to build an informational link between them. Living in the same region or sharing the same irrigation canal, on the other hand, seems to decrease the chance of people to share information (an odds ratio in the interval [0, 1] indicates a negative correlation between the variables analyzed).

DISCUSSION

The aim of this paper was to try to better understand how the structure of social networks of irrigation systems influences the community involvement programs for the mitigation of severe droughts. Recent literature suggests that relevant information flow more quickly in disassortative networks by degree, where disassortativity refers to non-random association of attributes having dissimilar characteristics. In this case, government agencies should focus on convincing individuals recognized as most influential by other farmers to adopt the recommended measures. The topology of the networks of social interaction would then play a key role in determining the most efficient communication strategies among agencies and farmers. To identify those strategies, it is therefore necessary to characterize the social network underlying the irrigation system at hand. To show how to do that, we characterized the social network of a typical irrigation system in the region most devastated by droughts in Brazil, which nevertheless has responded effectively to periods of drought since its founding 40 years ago.

The calculated assortativity coefficient indicates that both, the network of social relations and the informational network of the Gorotuba Irrigation District are indeed disassortative by degree, as predicted by theory for relatively efficient systems. The informational network, however, seems to be assortative in terms of the geographic location of the farmers, as indicated by the results from the logistic regression analysis. This suggests that farmers turn preferentially to neighbors in their own settlements to obtain relevant information about economic environment. The reason for that is likely most individuals do not appear to evaluate new information on the basis of scientific studies, but depends on a subjective evaluation of that information, which is conveyed to them from other individuals like themselves. This dependence on the experience of neighbors suggests that the diffusion process, unlike the spread of infectious diseases which may occur through simple contacts between unknown individuals, consists of the imitation by less connected farmers of their networks partners who have successfully used the new information available. Yet, as the informational network is disassortative by degree, farmers with higher levels of connection in their settlements – i.e., local opinion leaders – appear to be critical to the dissemination of information. An important policy implication of this result is that farmer participation in preparedness measures to severe droughts, in similar social networks, might be enhanced by policies based on some variation of the classic two-step flow model (14), in which a minority of local leaders act as intermediaries between the government agencies and the majority of farmers (5,15).

Further research is needed to find out to what extent these results can be applied to other types of irrigation systems. One apparently general implication of the analysis is that the perception of drought risk is in large part a social construct, which cannot be measured outside of the social networks in which individuals are embedded. The marginal contribution of science to assessing and managing drought risks, if we are right, may be modest in countries such as Australia and Brazil, that already have significant scientific knowledge and expertise in meteorological, climatological, agricultural, and hydrological monitoring and forecasting (16, 17). The key issue may be to find better ways to involve communities in programs of preparedness. Improving communication is certainly a piece of the puzzle, but that has not been as straightforward as it could appear. Business and marketing literature on the potential influence of opinion leaders in accelerating or blocking the adoption of new products or ideas (18, 19) may well be a guiding theme for research seeking to find ways to improve the diffusion of information in drought-prone areas.

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