Network analysis of knowledge building on rural extension in Colombia

Análisis de redes de generación de conocimiento en la extensión rural en Colombia

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ABSTRACT

Based on the analysis of scientific papers published on rural extension in Colombia since 2010, an interpretive descriptive study was conducted to identify the level of collaboration between authors and institutions in the creation, systematization and dissemination of knowledge in rural extension. Information was gathered from a search in bibliographic databases to identify papers published in rural extension. 50 papers were found. They were organized in a database, and using social network analysis, a review of relational structures and indicators derived from the scientific collaboration between the authors and institutions involved in the publication conducted. Authors from 28 different institutions have participated in the 50 papers identified, 70% of them have been published by researchers working in the same institution. The findings of this study support the conclusion that actors building knowledge on rural extension in Colombia have a limited intra and interinstitutional articulation, making it urgent to strength public policies and incentives to foster relationships between research groups and institutions.

Key words: knowledge management, researchers' networks, social network analysis, rural development.

RESUMEN

A partir del análisis de la publicación de artículos científicos sobre extensión rural en Colombia desde el 2010, se realizó un estudio de carácter descriptivo interpretativo para identificar el nivel de colaboración entre autores e instituciones en la generación, sistematización y difusión de conocimiento sobre extensión rural. La información se recopiló a partir de la búsqueda en bases de datos bibliográficas para identificar los artículos publicados sobre extensión rural. Se localizaron 50 artículos, los cuales se ordenaron en una base de datos y con el uso del análisis de redes sociales se revisaron las estructuras relacionales e indicadores derivados de la colaboración científica entre los autores e instituciones involucrados en la publicación. En los 50 artículos identificados, han participado autores de 28 instituciones diferentes; el 70% han sido publicados por investigadores que pertenecen a la misma institución. Los hallazgos de este estudio permiten concluir que los actores que generan conocimiento sobre extensión rural en Colombia presentan una escasa articulación intra e interinstitucional lo cual hace apremiante el fortalecer las políticas públicas y los incentivos para fomentar los relacionamientos entre los grupos de investigación y entre las instituciones.

Palabras clave: gestión del conocimiento, redes de investigadores, análisis de redes sociales, desarrollo rural.

Introduction

According to Christoplos (2010), "extension" can be understood as the systems that facilitate the access of farmers, their organizations, and other market players to knowledge, technologies and information. Extension encourages their integration with research members, teaching, agro-industry and other institutions; and contributes to the design of practices and technical, management and organizational skills. At an international level, extension services among other factors, are recognized as key points for the development of the agricultural activity (Kilelu *et al*., 2014; Klerkx and Leeuwis, 2009; Muñoz and Santoyo, 2010).

Rivera and Sulaiman (2009) indicate that extension was originally conceived as part of a "knowledge triangle", formed by research, education and extension. However, today it is addressed in a more comprehensive manner and is valued by various actors participating in rural development, not only in the context of improving productivity, but also for its contribution in strengthening bonds between farmers, researchers, agricultural education institutions, and other actors in society (Faure *et al*., 2012), that somehow form what could be called an "innovation system", through actors interacting in a process of generation, dissemination and use of knowledge in order to increase agricultural production looking for economic and social changes (Hellin, 2012).

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In this regard, Universities and National Research Centers as well as public and private institutions have a strategic role within the process of building codified knowledge that is regularly measured through the publication of scientific research products and patents (Rivera-Huerta *et al*., 2011). Furthermore, in the case of the agricultural sector, these actors have the mission of strengthening extension, improving their innovation capabilities, through interactions and coordination to create new information articulated with the demand (Klerkx and Leeuwis, 2008; Spielman and Birner, 2008), building networks for strengthening relations and ties, which increase the production and dissemination of knowledge (Aguilar-Gallegos *et al*., 2015, 2016; Brunori *et al*., 2013; Vega de Jiménez and Rojo, 2010).

This approach replaces the linear view of knowledge creation and innovation, by an interactive process between different actors in agricultural innovation systems (Muñoz and Santoyo, 2010). In fact, in the case of Colombia, this approach was adopted by the Ministry of Agriculture and Rural Development (MADR) setting up the National Subsystem of Agricultural Technical Assistance (SSATA), tied to the National System of Agricultural Science and Technology (SNCTA), in order to coordinate actors to improve the development and dissemination of knowledge (MADR, 2012).

At the international level, there is a consensus through university researchers and their research groups about scientific collaboration between universities and other actors playing a key role in the progress of knowledge (De Stefano *et al*., 2013), since networking allows sharing ideas, methodologies and approaches, which may help provide solutions to common problems. However, in Colombia the empirical evidence indicates a low articulation between actors; therefore, it is important to conduct studies in order to determine levels of cooperation and coordination between them. According to the findings of the Mission for Rural Transformation (Misión para la Transformación del Campo, in Spanish) (2015), the promotion of networking and development of capabilities, should generate knowledge management strategies to achieve greater impact in rural areas, improving performance of sectors and alternatives to strengthen rural producers.

In this context and in the case of Colombia, this paper aims to analyze the level of collaboration between actors in the creation and dissemination of knowledge on rural extension, using social network analysis in order to guide public policy to strengthen rural extension under an innovation system approach.

Methodology

An interpretative and descriptive study was conducted based on the analysis of co-authorship of scientific papers on rural extension, which is a partial indicator of scientific collaboration (Katz and Martin, 1997) between researchers, especially in the publication of papers (Lopaciuk-Gonczaryk, 2016). A social network analysis was used, following other studies of this type (De Stefano *et al*., 2013; Russell *et al*., 2009; Valderrama-Zurián *et al*., 2007; Zazo *et al*., 2015). Documents considered by Faure *et al.* (2012) as "gray literature", such as information booklets, sector reports, books, theses or other documents without peer review were not included in the analysis.

Data collection and editing

Information was gathered through bibliographic databases search (Dialnet, Ebsco, Redalyc, Redib, Scholar, SciELO, Scopus, Sciencedirect) to identify all papers published on rural extension in Colombia, based on the definition of rural direct technical assistance provided under Colombian law (Congreso de Colombia, 2000), which includes social, environmental, economic and technical issues; between 2010 and 2015, because during that period, the MADR revived interest in improving the quality and coverage of the ATDR service. Information of Author (Aut), institution of affiliation (Ins), year of publication, and name of the journal were linked to each paper (Art), making the necessary adjustments for homonymy and synonymy results (Calero *et al*., 2006).

Network analysis and collaboration indicators

A social network analysis (SNA) was used as a tool for observing, studying and understanding the relational structures derived from scientific collaboration between authors and institutions involved in the publication of papers on rural extension; the relationship analyzed in this study is the participation of the different authors in the different papers. SNA allows to identify the positions of actors within the network, which partly determines the limitations and opportunities that those actors and the network have in general (Borgatti *et al*., 2013).

To analyze the participation of authors in each paper, 2-mode networks were used; to analyze collaboration between authors, 1-mode networks were used (Borgatti *et al*., 2013; Wasserman and Faust, 1994). Adapting the indications of Valderrama-Zurián *et al.* (2007), the number of relationships between authors participating in a paper is calculated as m!/(m-n)!n!, where m is the number of authors in the article and n the number of elements of groups. This

analysis approach was also used to analyze the collaboration between the authors' institutions of affiliation.

Based on Freeman (1979) and Borgatti *et al.* (2013), the indicators used for the network analysis were as follows: 1. Degree: number of links or relationships that a node has. Thus, the higher the degree, the higher the level of collaboration of an author. 2. Betweenness: frequency measurement of a given node when it is on the shortest path connecting other pairs of nodes. It was only measured for 1-mode networks to make reference to the relative importance that an author has in connecting other authors. 3. Density: measure of cohesion that makes reference to the number of existing links on the network in relation to possible links, expressed as a percentage. It was only considered for 1-mode networks.

Additionally, homophily - the tendency to bond with individuals who have characteristics similar to ours (Lazarsfeld and Merton, 1954) - was calculated. It was only calculated for the 2-mode network using the E-I index (external and internal links) from Krackhardt and Stern (1988), classifying institutions into three types: public, private and others (NGOs, trade unions and independent). Calculation of indicators and network observation were performed using Ucinet (Borgatti *et al.*, 2002) and NetDraw (Borgatti, 2002) software.

Results

Scientific collaboration during the period 2010-2015

115 authors participated in the 50 papers analyzed. Some of them contributed with more than one participation, for a total of 103 different authors (Tab. 1). 74% of the papers have two or more authors. Within the period analyzed, collaboration increased, as in 2010 less than half of papers were written in co-authorship and by 2015 that figure reached nearly 86%.

A growing trend was found in the increase of both publications and authors, additionally, there are increasingly more authors involved (Fig. 1). However, the number of new authors involved in publications on rural extension in Colombia is decreasing. The largest increase was seen in 2011, when 15 new authors joined the 19 existing ones. In the last year (2015) there were only 14% new authors. This situation may be considered normal, as the data is cumulative; however, there are few authors contributing with more than one collaboration, as three authors have published three articles; six have published two, and the remaining 94 have only participated in one paper. This could indicate the insufficiency of critical mass discussing this topic.

Scientific collaboration network between authors

It was found that authors have in general little participation in several publications. There are few authors having two or three links to papers; i.e., author 007 (Aut-007), who participates in three papers (003, 027 y 031) (Fig. 2). Likewise, it can be observed that there are more papers with two or more authors than papers published by a single author. 74% of papers have been published in co-authorship, although the participation of the same author in several papers is lower.

From the 2-mode network, consisting of authors and papers, it was possible to obtain a 1-mode network (Borgatti *et al.*, 2013) and therewith a representation of direct collaboration between authors (Fig. 3). It was found that 11 authors have individually published a paper; without any collaboration. They have published 13 papers, since an author (Aut-001) published two papers individually, and another author (Aut-017) published one individually and other in collaboration. The maximum number of co-authorship in a paper was 5, in two different cases. Three papers have been published by four authors. The most frequent collaborations occur between two and three authors. In both cases 16 papers have been published by that number of authors.

TABLE 1. Scientific collaboration in the production of papers 2010-2015.

Year	No. of papers	No. of papers written in co-authorship (%)	Total No. of authors	Authors per paper	Maximum No. of authors in a paper	New and different authors	Increase in new authors (%)
2010	13	6 (46.2)	21	1.6	3	19	—
2011	7	6 (85.7)	16	2.3	3	15	78.9
2012	8	5 (62.5)	19	2.4	5	17	50.0
2013	8	7 (87.5)	21	2.6	4	19	37.3
2014	7	7 (100.0)	20	2.9	5	20	28.6
2015	7	6 (85.7)	18	2.6	4	13	14.4
Total	50	37 (74.0)	115	2.3	5	103	

Collaboration has been based, almost entirely, on the publication of one article. This occurs because interaction between pairs of authors is limited to a single time (weak ties). Only two pairs of authors (Aut-007 and Aut-008; Aut-010 and Aut-011) have collaborated twice (strong ties) in the publication of two different papers. In both cases, other authors have participated in the publication of those papers.

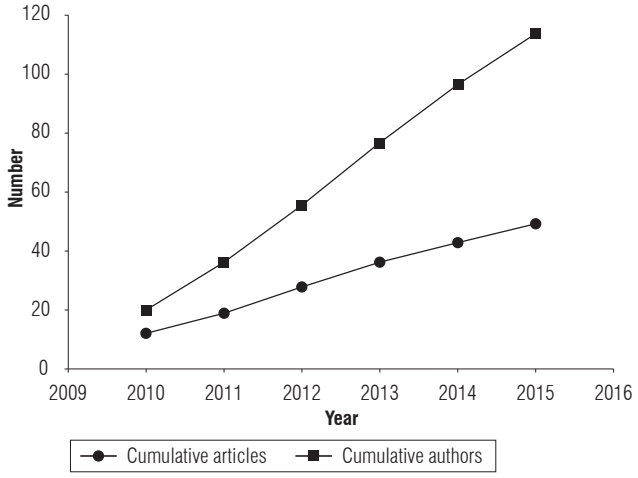

FIGURE 1. Paper publishing and author participation trends.

There are few authors who manage to connect different collaborations. This is the result of publishing different papers with different authors. Take Aut-040 for example, who manages to connect authors 041, 042 and 047. This author published one paper with the first two, and another one with the latter. Only five authors of this type (black nodes) were found across the entire collaboration network.

Network indicators show that 103 authors have managed to establish 200 links between them. Therefore, network density is low, as well as the degree average of each author (Tab. 2). The last indicator shows that, on average, each author has collaborated with nearly two authors. This is supported by the fact that collaboration between two and three authors is quite common. However, the collaboration network is fragmented as there are 40 components. The best connected component links only six authors. This is also the reason why the network diameter is low. In fact, the last indicator is achieved through any of the five nodes

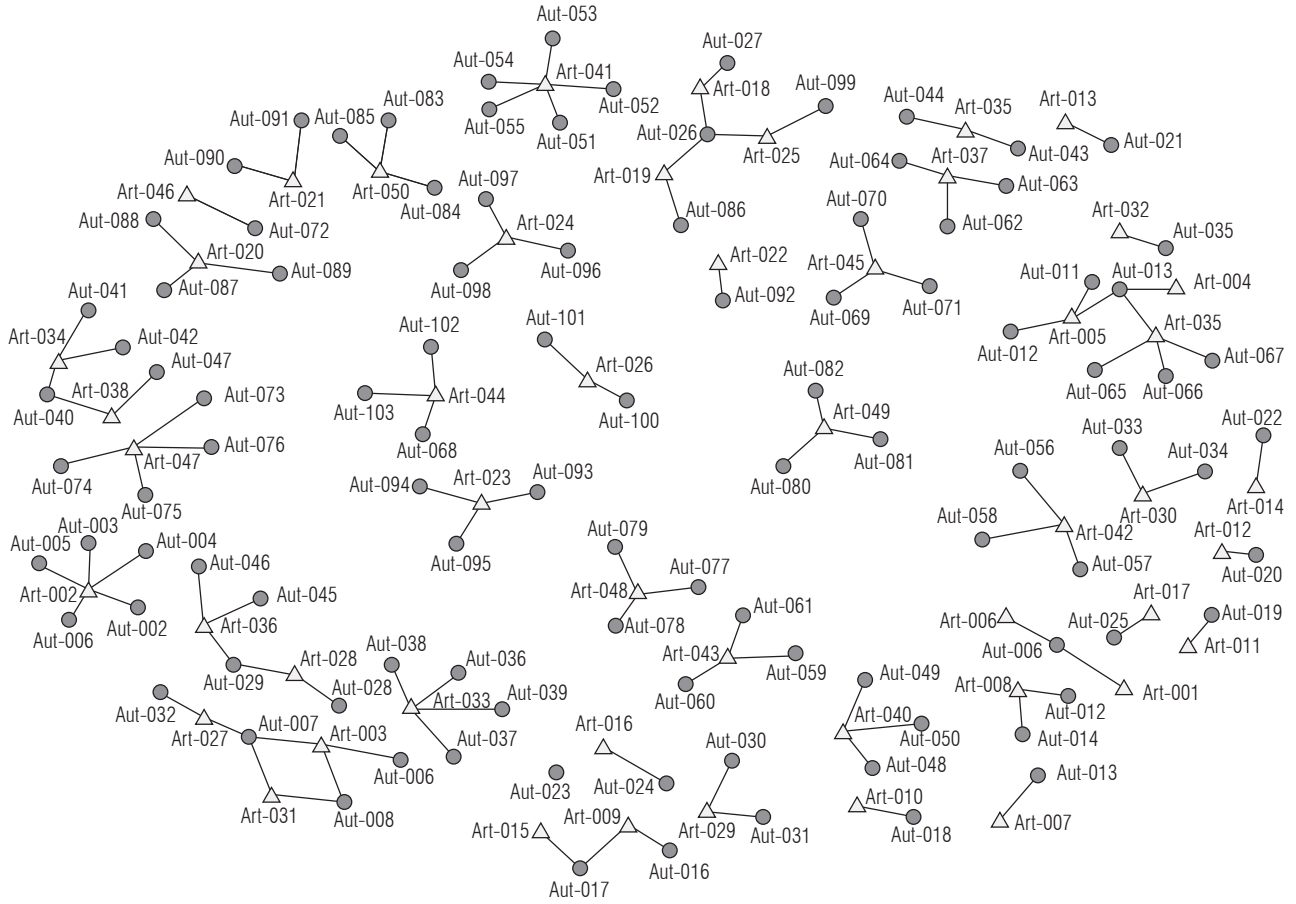

FIGURE 2. 2-mode network of collaborators. Authors (circles); papers (triangles).

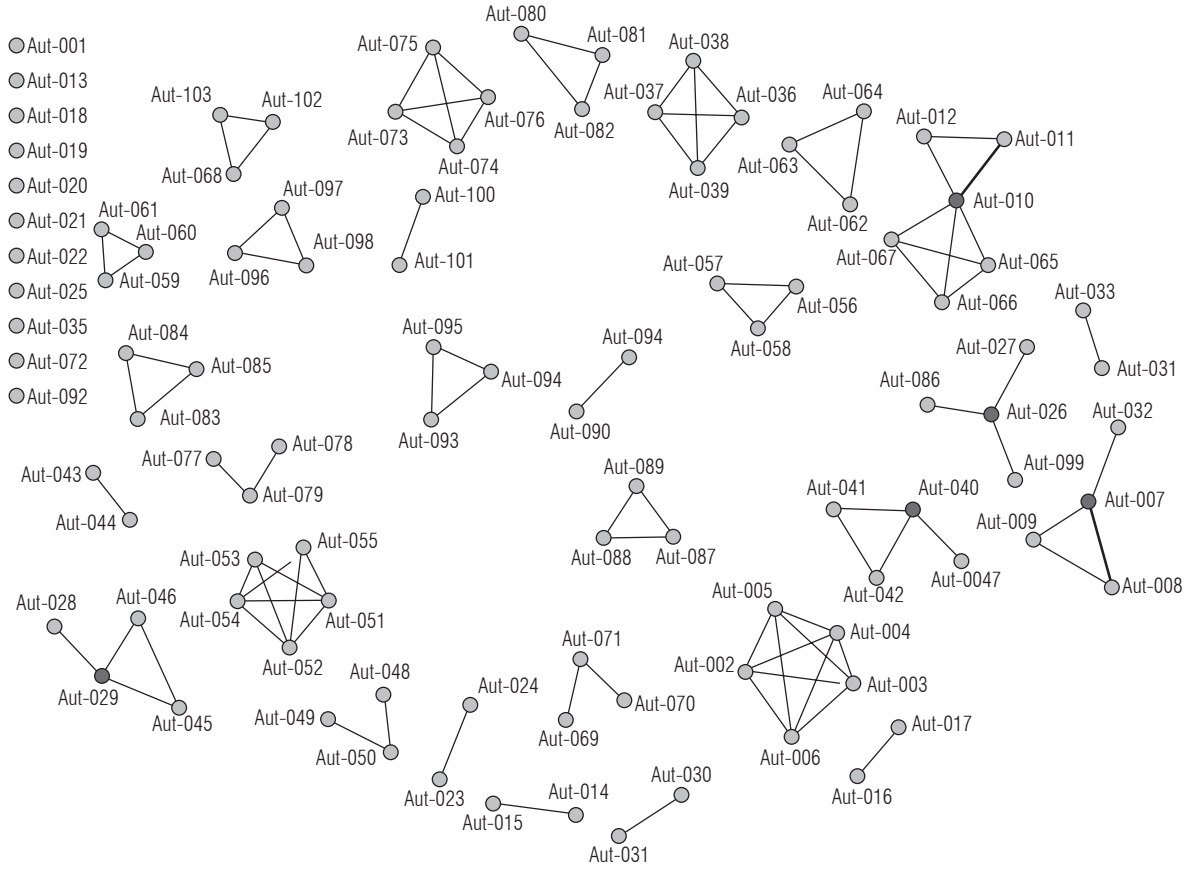

FIGURE 3. 1-mode network of collaboration between authors.

that serve as intermediary between different collaborations (Fig. 3, black nodes). That is, although 74% of the 50 papers have been written in collaboration, there is not a real dense collaboration network between all the authors. Likewise, there are no authors having a significant centrality; network centrality is only 3%.

TABLE 2. Basic indicators of the collaboration network between authors.

Indicator	Value
N	103
Links	200
Average degree	1.942
Density (%)	3.807
Components	40
Diameter	2
Average distance	1.130
Network centrality (%)	3.060

Scientific collaboration network between institutions

The participation of authors from 28 different institutions was found. 70% of papers analyzed were published by researchers belonging to the same institutions, that is, there was no inter-institutional collaboration. The remaining 30% were published in institutional collaboration. It is worth mentioning that inter-institutional collaboration was analyzed, that is, collaboration between different institutions, but intra-institutional collaboration: between different departments, faculties, specialties of the same institution, etc., was not considered, as it is common for authors to include only the main institution to which they are affiliated.

Participation analysis of authors from 28 institutions (circles) with 50 papers (triangles) shows the institutions of affiliation of the authors with most publications (Fig. 4). Authors from Ins-001 have participated 17 publications, out of which 8 have been in collaboration with other institutions. The participation of each of the authors' institutions of affiliation and their collaboration with other institutions, that is, papers with two or more links, can be observed. This is significant since, just as there are institutions with prolific authors, there are also others with fewer publishing authors, and most of these publications are made in collaboration. Take the case of Ins-025 who has four papers, three out of which were published in collaboration. There

is also Ins-007 with three papers, all of them in collaboration. Finally, there are institutions whose authors do not publish in collaboration (bottom right of the graph) or whose authors have published several papers, but none in collaboration; for example, Ins-002.

Some points of interest were found when turning the 2-mode network (Fig. 4) into 1-mode between institutions (Fig. 5). Nine institutions of affiliation appear isolated, since the papers published by their authors were not written in collaboration. There is a very central institution of affiliation (Ins-001), who managed to establish links with other 10 institutions from the 8 papers published in collaboration. This fact is related to the importance of the institution in Colombia. Nevertheless, most of the collaborations have occurred between two institutions of affiliation. There is only one paper with collaborations from three institutions, and another one from four. Only in one case, between Ins-001 and Ins-025, two papers were published in collaboration (thicker line). This implies that inter-institutional research needs strengthening.

Just as there are authors who manage to link other actors, i.e. intermediaries between collaborations, several institutions were also found to play this role with their participation in two or more papers. The diamond-shaped circles represent the institutions that play this role within the network. Out of the 28 institutions, only 6 actors of this type were found.

The calculation of indicators of the previous network revealed that the 28 institutions have established 42 collaborative links; therefore, each one of them has an average of 1.5 links (Tab. 3). Network density also serves as an indicator to measure the level of articulation and the number of existing links, which is 11.1%. This type of indicators would serve as a baseline to analyze in the future the evolution of articulation within the network. In comparison to the network of authors, this one reflects a greater articulation, as there are fewer components. A fact to note is that the best connected component manages to link directly or indirectly 60.7% of all institutions, but this is achieved with a higher network diameter, that is five steps, and also for that reason, the average distance is 2.6. Network centrality is 33.9%, which is very visible because of the importance that the institution of affiliation Ins-001 has within the network.

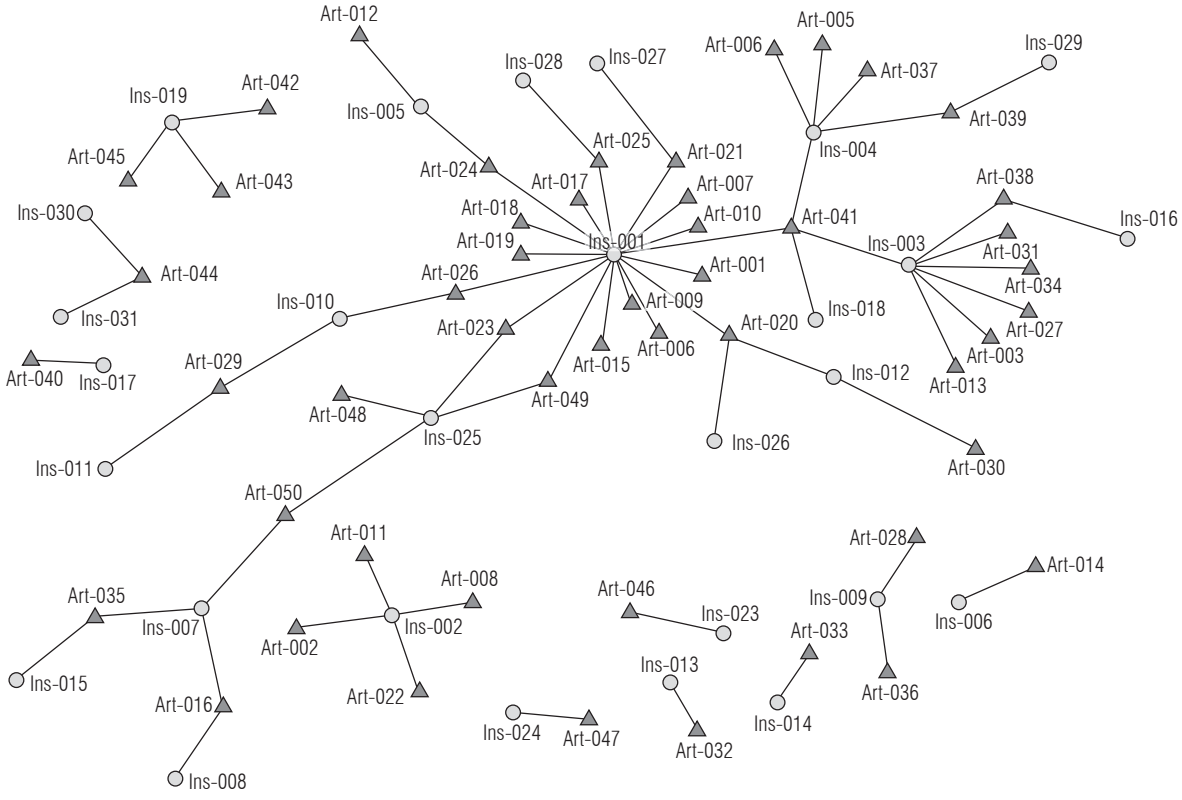

FIGURE 4. 2-mode network of collaboration. Institutions (circles); papers (triangles).

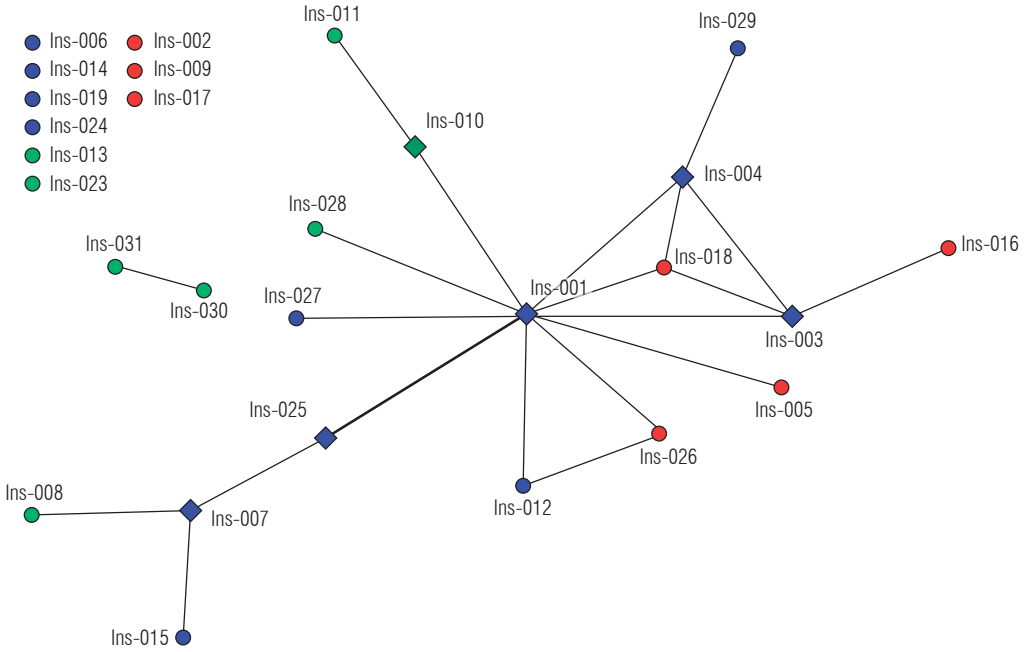

FIGURE 5. 1-mode network of collaboration between institutions. Color legends: blue nodes: public institutions; red nodes: private institutions; green nodes: other type (NGOs, independent and trade unions). Legend of shapes: diamond nodes: intermediating actors; circular nodes: non-intermediating actors.

TABLE 3. Basic indicators of the collaboration network between institutions.

Indicator	Value
N	28
Links	42
Average degree	1.500
Density (%)	11.111
Components	11
Diameter	5
Average distance	2.569
Network centrality (%)	33.900

Although the network of institutions of affiliation is denser, it is important to mention that this is partly because the network is smaller, and on the other hand, because it is the result of collaboration between the authors that have published the papers. In fact, if strategies to increase collaboration and the number of authors in each paper were implemented, it would result in a greater collaboration between institutions.

It was found a slight level of homophily on the entire network, with an E-I index of -0.048 (Tab. 4). Public institutions have more links between them than with the other types of institutions, however, homophily is more prevalent as the E-I index is -0.286. Besides, there is a higher density of links between them. Meanwhile, there are no links between private institutions, i.e. they tend to heterophily (E-I index of 1.000). It is interesting to see that their collaborative links have been established with public institutions and not with any other type. The group of other institutions has links between them and with public institutions, but not with private ones. However, as density of links is higher to the inside instead of to the outside, then the E-I index of this group is also negative (-0.143).

DISCUSSION

The results of this study indicate that in Colombia knowledge building networks on rural extension are limited; the calculated indicators show a low participation of authors and institutions in collaboration networks; nevertheless, the causes of this phenomenon should be deepenly studied. In this sense, authors like Ahrweiler and Keane (2013) find that promoting a networking approach implies complexity, related with the existence of behavior, action and communication models; actors who may present compatibilities and incompatibilities, communicative interest or perhaps different strategic perspectives. Such is the case of homophily as an attribute present in all the structures of the studied networks, and where the phenomenon is evident between universities and other public and private institutions; this behavior could influence structural links,

TABLE 4. Density matrix and E-I index by group of institutions.

Group	n	Density			E-I index by group	E-I index of network
		Inst. Public	Inst. Private	Other Inst.		
Inst. Public	13	11.500	7.700	2.900	-0.286	
Inst. Private	7	7.700	0.000	0.000	1.000	-0.048
Other Inst.	8	2.900	0.000	7.100	-0.143	

generate processes of social selection, among others. This may hinder processes of building and dissemination of knowledge, as already addressed in other studies (Isaac, 2012; McPherson *et al.*, 2001).

The lack of networking reveals a limitation of institutions of higher education in strengthening innovative capacity of the agricultural productive sector and the direct rural technical assistance service due to the lack of generation and dissemination of knowledge on rural extension. On that subject, other authors state that universities are strategic players in the innovation system, thanks to their knowledge of local reality derived from their regional presence. They also have an additional strategic capacity for research, through the theses of their undergraduate and graduate students (Fonseca and Rugeles, 2004); nevertheless, at present, large part of the knowledge generated is not properly systematized and ends up falling into the "gray literature" (Faure *et al.*, 2012). For that reason, the number of scientific papers published is low in comparison with the number of students. Therefore, it is important to implement strategies for the codification of generated knowledge.

The centrality indicator shows the lack of authors that have an important centrality. However, at the level of institutions, results show a greater connection, probably due to the smaller number of these compared with the number of authors, a better connection, a higher diameter and a higher centrality indicator around the National University of Colombia. This implies an opportunity to implement strategies to promote networking, because the more central actor, as suggested Barrientos-Fuentes and Berg (2013), could generate feedback mechanisms between research institutions, to improve the development and dissemination of innovations on rural extension.

Thus, the consolidation of knowledge building networks on rural extension between authors and institutions should be part of the strategies in the implementation of innovation systems within the agricultural sector, in a way that spaces can be generated for collaboration between institutions, and also effective strategies to support networking research programs for generation and dissemination of knowledge on rural extension; because as De Stefano *et al.* (2013) highlight, scientific collaboration between universities and other actors is important in the progress of knowledge.

In this sense, knowledge building networks can be important for agricultural development. Several Initiatives begin to emerge as the *Red Nacional de Extensión Rural* [National Network of Rural extension], led by the University of Antioquia; and the *Red de Estudios Rurales* [Network of Rural Studies], led by the University of Tolima. Both can serve as platforms for systematizing and publishing successful experiences on rural extension, that can be imitated in other departments of the country, as in the case of the University of Tolima (Ibague, Colombia) with the internship program for service delivery of ATDR, financed by the regional government (Serrano *et al.*, 2015).

Accordingly, given the observed shortage of scientific production in matters of extension and technical assistance in Colombia, it would be relevant to conduct a cause analysis, including one of human capital skills in the use of tools for systematization and publication of papers, because many institutions engaged in rural extension does not publish papers. Nevertheless, there is a growing increase in research activities carried out by associations of producers and universities, in the diversification of institutional structures and the focus of agricultural research. This latter, in the case of the *Agronomía Colombiana* journal of the National University has led to an increase of 13.64% in the publications in the field of agricultural economy and rural development in the period 2003-2012 (Ligarreto, 2013).

Finally, it is considered important to conduct studies to determine the way in which that knowledge is used by analyzing the effect or impact of such publications, either by the number of citations received or the operability of their proposals. However, this research contributes to construct baseline indicators that could be used to assess in the future the improvement in the articulation of researchers and institutions addressing this subject.

Conclusions

The findings of this study lead to the conclusion that actors that build knowledge on rural extension in Colombia have a poor intra and inter-institutional articulation. For the foregoing, strengthening public policies and incentives becomes urgent to foster relationships between research groups and between institutions. In this way, it will contribute to the consolidation of the new collaboration networks that can serve as platforms for dissemination and especially for the use of knowledge on rural extension, strengthening the role of researchers, universities and research centers in shaping the territorial systems of innovation.

The strengthening of mechanisms to connect researchers in matters of extension and technical assistance should start from recognizing their theoretical and methodological capacities. In this regard, the SNA approach can become an important tool for monitoring the impact of implemented actions that seek to strengthen collaboration for building knowledge on rural extension. Although it is a challenge in gathering information and continuous analysis, this type of longitudinal analysis would be a very useful tool for both universities and public institutions responsible for guiding science, technology and innovation policies.

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