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Social Network Analysis: A useful tool for studying Innovation diffusion processes

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Abstract

In our note, we tried to realise a comprehensive document dedicated to Social Network Analysis, in which we focused on its origin, application and adoption in analysing the diffusion of innovation, with particular attention paid to the agriculture sector, because we believe that farmers can easily exchange knowledge with each other and boost the diffusion of innovation in terms of agricultural techniques.

Most of the scientific researches reported in our note in which SNA was applied are carried out in developing countries, we reckon that in these countries information is not usually recorded in a database, and farmers can easily get innovation through their system of acquaintances.

We noted that SNA is a flexible and useful tool because it can be applied jointly with several approaches and theories. Through SNA, we can get relevant information about the network to understand how innovation gets shared and to assess the role and importance of different actors involved in the network.

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Introduction

Innovation has different definitions. For businesses and enterprises, it usually means something costly, risky, and time-consuming (Costello & Prohaska, 2013). Croitoru provided the influential interpretation of innovation as the commercialisation of the invention (Croitoru, 2012). He noted that innovation could be founded on new scientific findings, although more frequently it was from re-combinations of existing technologies. As mentioned, innovation is a knowledge research and creation process, demanding the reduction of uncertainty. Innovation can be categorised into two concepts: radical and incremental innovations. Radical innovations are new technologies, which catch the needs that are not yet recognised and involve technology, science, research, and development (Dosi & Grazzi, 2010). Instead, incremental innovations enhance what already exists and mostly come from production workers, engineers, and preservation workers. Innovation can also be explained as a new idea, product, suggestion, or novelty (Hollander, 1965). According to Romer, the essential sources of innovation and economic growth are the new knowledge accumulation (Romer, 1990). Furthermore, Katila stated that the combination of different knowledge allows companies to solve problems and innovate (Katila, 2002). Baregheh *et al.* reported a definition of innovation as a multi-step process by which companies transform an idea into a new or enhanced product, process, or service, aiming to advance, compete and successfully distinguish themselves in their local market (Baregheh *et al.*, 2009). Gisbert-López *et al.* reported a positive relationship between creative climate and innovation (Gisbert-López *et al.*, 2014). Innovation processes are stimulated and supported by a good creative climate, in which various actors act with each other in a way that can prompt or limit the creative climate.

The association between creativity and new ideas is very close. Organisations and economies must innovate and induce innovation to maintain and reinforce their competitive position. Thus, innovation is a fundamental policy and strategic matter (Baregheh *et al.*, 2009). Rogers developed the diffusion of innovation theory to explain how an idea or product achieves momentum and spreads across a specific community (Rogers, 1983). As a result of this process, people adopt a new idea, product, or behaviour. Adoption means that people do something new that they had in the past, such as using or buying a new product, acquiring a new practice or tools, etc. The essential point in the adoption is that people must recognise the idea, product, or behaviour as innovative, and only through this recognition diffusion can happen. However, some individuals are more inclined to adopt innovation than other groups of people. Rogers stated that people who adopt innovation early have distinct features from people

who adopt the same innovation later (Rogers, 1983). Therefore, promoting a specific innovation to a community is helpful to understand the characters of the target population that will speed or block the adoption of that innovation. Rogers, established five adopter categories as following (Rogers, 2003):

i. *Innovators*: 2.5% of individuals want to be the first to get and experiment with the innovation. Rogers recognises that those individuals are aware of taking a risk and are the first to promote a new idea.
ii. *Early adopters*: 13.5% of individuals act as opinion leaders. This category of individuals is already aware of the need to change and is pleasant adopting a new idea.
iii. *Early Majority*: 34% of individuals are infrequently leaders and adopt new ideas before the average person. These people need to see evidence that the innovation works before they are inclined to adopt it.
iv. *Late Majority*: 34% of individuals doubt change and adopt innovation only after the majority has tested it.
v. *Laggards*: 16% of individuals are conservatives, traditionalists, and very doubting about change (most complicated people to get innovation).

Diffusion is completed when an individual adopts an innovation based on steps that include awareness of the need for innovation, decision to adopt (or reject) an innovation, initial use of the innovation to experiment with it, and continued use of the innovation. Five essential attributes influence the adoption of innovation, and each of these elements is at play to a different extent in the five adopter categories.

1. *Relative advantage*: the extent to which an innovation is seen as better than the idea, product, or practice it replaces.
2. *Compatibility*: that is the consistency of the innovation with the needs and experiences of the potential adopter.
3. *Complexity*: that is the difficulty the innovator can face to understand or apply the innovation.
4. *Triability*: the degree to which innovation can be experimented with or applied before a commitment to adopt is made.
5. *Observability*: the degree to which an innovation yields tangible outcomes.

The theory of innovation adoption has been used successfully to explain many sectors' evolution, including agriculture. For instance, according to Pretty *et al.* organic farming is a complex of agricultural innovations and they affirmed that organic farming becomes more acceptable, when it was seen to be more fruitful than conventional agriculture (Pretty *et al.*, 2010). This result explains what is reported in relative advantage and observability attributes. Similarly, according to Padel, diffusion of innovation theory can help to understand the process of diffusion of organic farming into a community, as well as to understand how this process possibly can

be supported and enhanced, i.e., across the agricultural extension or the knowledge and information system in agriculture (Padel, 2001). As affirmed by Finco *et al*., innovation is not a casual process. In their research, they focused on investigating some factors of innovation making start from small size agri-food firms linked with cluster agri-food in the Marche Region (Italy). Results showed that small enterprises separately cannot get innovation due to some constraints and firms' features, as well as clusters, represent an opportunity to get both innovation and to become more competitive in the local market (Finco *et al*., 2018).

Valente reported that the diffusion of innovation via social networks could be clarified by comprehending the fundamental basis of the social networks (Valente, 1996). A social network is recognised as a dense interconnectedness among individuals that furnishes patterns of relationships and reinforces a group of people in a social system. The first method to understand how a network acts as a means of diffusion was to analyse the number of times that any person was named as an associate of the network to gauge his/her leadership and attitude. Thus, inside each network, the opinion leaders or influencers are defined as those individuals who are capable to get to a wide number of individuals and they may have a significant role in the adoption and diffusion of innovation within the network. Following that and as recorded by Rogers, this will be linked to innovativeness as measure by how many times the person adopts an innovation (Rogers, 1983).

This paper is related to a "Note" based on a short literature review and aimed to shed light on the SNA as a tool to analyse how innovation is diffused within a social network, as well as to assess the role and importance of different actors involved in the network. We would like to clarify that the note's goal was not to compare different methods used by several authors in analysing the diffusion of innovation, as well as is not structured as an article.

This "Note" is structured as follows: Section 1 includes an introduction; Section 2 gives a brief overview of the SNA; Section 3 describes some empirical studies in which SNA was applied to understand how innovation is shared; Section 4 reports on the use of SNA in analysing the innovation diffusion in the agricultural sector and Section 5 concludes the note. Instead, in the appendix is reported the methodology applied for the literature review.

1. Brief overview of Social Network Analysis (SNA)

In this paragraph, our objective is to provide readers with a simple description concerning the SNA and not to compare the existing methods applied by several authors to analyse the diffusion of innovation. In the

following paragraph, we reported an explanation of SNA, an overview of its origin and application in several disciplines and sectors, as well as we highlighted its importance in analysing how knowledge is shared within a community. We tried to highlight that SNA could be a useful method to be applied in analysing how innovation is diffused in a social network.

According to Bourne *et al.*, SNA is the process of examining a social network, and a set of research methods, including network matrices, network diagrams, and mathematical measures aiming to depict the social network structure (Bourne *et al.*, 2017). As noted by Scott & Carrington the beginnings of SNA include maths (graph theory), sociology, and psychology (Scott & Carrington, 2011). Network theorists have discovered examples of the concept of SNA in the work of such geniuses of sociological theory as Weber, Durkheim, Marx, Goffman, and even Parsons and the work of leading intellectuals from Heraclitus to Einstein.

SNA is centred on the thought that social interaction is developed principally by relationships and the patterns created by these relationships (Scott & Carrington, 2011). As reported by Freeman, the community itself is nothing more than a network of relations, and there is no community deprived of interactions (Freeman, 2004). Spielman *et al.* noted that SNA is the main key to manage innovation and supply indications about the relationships and roles that exist in a network in which actors are involved, interact and exchange information and resources among them (Spielman *et al.*, 2011).

As reported in Scott & Carrington, these units could be people, organisations, or positions (Boorman and White, 1976; White *et al.*, 1976; Ferligoj *et al.*), journal articles (White *et al.*, 2004) Web pages (Watts, 1999), neighbourhoods, departments within organisations (QuanHaase and Wellman, 2006), Countries (Kick *et al.*, 2014), (Scott & Carrington, 2011). Furthermore, Wasserman and Faust reported that relationships between units could be cooperation, business, friendships, knowledge flows, weblinks, interchange of any kind of support, etc. (Wasserman and Faust, 1994).

Borgatti *et al.* determined four-wide groups of relations: social relations, similarities, flows, and interaction (Borgatti *et al.*, 2018).

i. *Social relations*: include affinity or other types of role relations (e.g., student, friend, etc.); affective ties, which are based on member's feelings for one another (e.g., disliking, liking, etc.); or cognitive awareness (e.g., knowing).
ii. *Similarities*: take place when two units share any kind of attribute, like locations, attitudes, demographic characteristics, or group memberships.
iii. *Flows*: are relations built on interactions and transfers among nodes. These can include relations in which information, resources, etc. spread over the network.

iv. *Interaction*: refers to behaviour-based ties like chatting with, supporting, or hosting someone to house.

In SNA language, in each network units are figured as nodes and are connected by ties, which are information and/or relationships that interchange between nodes. As stated by Scott & Carrington, relations characterised by ties among nodes are essential elements of SNA (Scott & Carrington, 2011).

According to Coulon a network characterised by one kind of node is named homogeneous, conversely is called heterogeneous (Coulon, 2005). Ties linked pairs of nodes could be directed (i.e., bidirectional, unidirectional, such as offering suggestions to somebody) or undirected (as in human being effectively next to) and could be dichotomous (present or absent, as if two individuals are acquaintances or not) or weighted (measured on a scale, as in the intensity of closeness). All ties have values or are weighted; even dichotomous relationships have binary values. When we focus on a single node, we name it "Ego" and we name the set of nodes that ego has ties "Alters".

SNA illustrates how individuals are interrelated and work together, how knowledge and resources flow between and among them, as well as how individuals' roles and relationships are structured (Spielman *et al.*, 2011).

In conclusion, as mentioned in Scott & Carrington, SNA is not considered as a methodology or as a theory rather, it is a viewpoint or archetype (Scott & Carrington, 2011). The starting point of SNA is that social life is founded on relations and on the patterns they form. SNA provides a way of looking at a question and may give only vague answers to the question. Nowadays, SNA is practised and used in several research fields, including education (Kapucu *et al.*, 2010), healthcare (Chambers *et al.*, 2012), agroforestry (Isaac *et al.*, 2007), rural development (Murdoch, 2000; Oreszczyn *et al.*, 2010), natural resources (Bodin *et al.*, 2006), and it has become an interdisciplinary area of research.

2. SNA and the diffusion of innovation: some empirical studies

In this section, in order to analyse the diffusion of innovation, we believe that we can take advantage of using SNA also to identify the main stakeholders or brokers that are responsible for specific innovation diffusion.

According to Coulon, from 1999 ahead, it was registered a rise in the number of scientific studies using SNA, in particular aimed at analysing the structure of the relations among groups/individuals and on the effect of network structure on innovation (Coulon, 2005). According to Valente, the weaker ties guarantee that the small groups will foster the diffusion of innovation within a social system (Valente, 1996). Besides, Rogers, affirmed

that any innovation would have a chance to be adopted quickly by individuals if it does not need much time to be recognised and accepted (Rogers, 2003).

As Coulon reported, the use of SNA in innovation study has been supported by the necessity to describe the causal social process connected to innovation or to analyse how social closeness influences learning diffusion or the process by which "network structure" forms or influences "innovative output" (Coulon, 2005). Besides, Scott & Carrington stated that a network is assumed to enhance the social processes like knowledge and collaboration that allow the community to adopt a powerful and dense social-ecological system (Scott & Carrington, 2011).

Furthermore, SNA was applied to investigate causal process concerning innovation research because a case study solely cannot consider the complexity of the causal process due to the huge number and diversity of individuals engaged within a network. Schuster & Kolleck elaborated a theoretical framework that aids to realise processes related to the dissemination of innovation and interaction networks, e.g., Twitter (Schuster & Kolleck, 2020). Instead, Davies affirmed that in research dealing with agricultural systems, SNA could be a method to evaluate the stakeholder's performance, and it focuses on the structure of the ties between stakeholders engaged in a community (Davies, 2015).

As reported by Schuster & Kolleck, the interest of using SNA is to get both information on the position and the framework bordering an individual involved in a network (Schuster & Kolleck, 2020).

In this regard and as stated in Burt study on structural holes, an individual improves his social capital when he gets an exclusive position that permits him to link numerous clusters in the network (Burt, 2004). According to Scott & Carrington, taking advantage of the structural holes and playing as a broker among clusters, this individual has enlightening functions or benefits and great flexibility to operate (Scott & Carrington, 2011).

3. The use of SNA and innovation diffusion in the agricultural sector

In this paragraph, we tried to report some empirical studies carried out using SNA. We listed several scientific papers, based on different research approaches and reporting the results achieved. Here we gathered the papers according to the complexity of the approach adopted. First, we describe studies in which SNA was used alone, and in the second step, we reported other studies in which SNA was used together with other approaches and in the third step we included papers in which SNA was applied with several systems and frameworks. Papers were ordered to make this section comprehensive to readers because we believe that by classifying all papers as

we did, researchers and students probably can get clear information about the use of SNA.

We paid attention to the agricultural sector because we reckon that innovation is easily shared through social structure, in which farmers can get information through their system of acquaintances. Besides, growers do not care to avoid information flow to other farmers as the inter-farm competition is very weak. They help each other, and in the meanwhile, they boost the diffusion of innovation in their narrow social system and reinforce their positions within their social network. Furthermore, farmers' activities are strictly territorial, and they tend to form tight communities, in which information is easily spread among the same individuals. In the end, farmers usually tend to follow their close similar adopting the same agricultural techniques. In this regard, we found several scientific papers related to SNA, and we aimed to highlight that SNA could be a useful tool to analyse the process of innovation diffusion in agriculture, not necessarily to boost the adoption of innovations, as well as we deduced that SNA could be applied alone or jointly with other methods, theories, and approaches, etc.

The methodology applied for the literature review is reported immediately after references. Furthermore, we classified all articles in a table organised in a framework based on the author, year, research title, scope, the approach used, the method used, dependent variable, independent variables and results obtained-table is available in "Annex A".

At the first step, analysing the literature review, we would like to report some empirical studies in which SNA was used alone, i.e.; Isaac investigated the attributes of information networks about cocoa agroforestry management (Isaac, 2012). He analysed if these attributes could improve a sustainable production system in terms of agro-diversity. The approach was based on SNA employing an Ego network and using the name generator technique to examine the structure of rural agricultural information networks. The study was conducted in two regions in Ghana, which are similar in terms of their natural and socio-demographical features, but different in terms of accessibility to market and organisations. Semi-structured interviews were carried out with professional stakeholders. The author found that if a farmer is near a metropolitan area, he will have a high probability of contacting main stakeholders and his informal network becomes more open and diverse. This helps the success of information exchange and innovation diffusion on agro-environmental practices.

Hermans *et al.* focused on investigating the ability to innovate and to explore the potential for scaling innovations in three multi-stakeholder platforms (MSPs) in Congo, Rwanda, and Burundi (Hermans *et al.*, 2017). They applied SNA in combination with Exponential Random graph modelling (ERGM) to explore the knowledge exchange, structural properties of the

collaborative, and influence networks of three MSPs. Their approach was based on three steps: a) recognise in each country the long-term established partners of the CGIAR (Research Program on Integrated Systems for the Humid-Tropics) centres; b) map the participatory stakeholders based on Humid-Tropics workshops for which the main individuals were invited; c) prepare informative materials related to the program and distribute them in different areas. In each country, data were collected from questionnaires focused on a name generator and asking participants to list the name of five organisations with whom they cooperate. The analysis of network properties showed an imbalance between knowledge exchange, collaboration, and influence networks for the diffusion of innovation and scaling processes. For example, the private sector and NGOs are respectively under and over-represented in the MSP networks, as well as connections among local and public organisations are weak, and influential public organisations are not actively connected to other groups and are often not part of the MSP. Furthermore, they discovered that organisations with a central position in the network are more appreciated for cooperation, and the diffusion of innovations is mainly among the same type of organisations across various administrative levels, but not among various types of organisations.

Ravula focused on using social networks and mapping the network of rural farmers located in two Indian villages to identify the nature of relations (informal and formal) and associations for poor farmers (Ravula, 2012). The study analyses how these networks can boost the diffusion of agricultural innovation and how the relations support rural people to enhance both themselves and their societies. The study focused on a transaction-based approach to record the social network architectures in Aurepalle and Kanzara villages through semi-structured questionnaires and focus group discussions. The author found that both villages have good levels of social capital in terms of social networks. The variation in resources (natural and financial) between the two villages has encouraged the improvement of relationships in one village and self-help communities in another.

In the end, Birkenberg & Birner focused on analysing how Costa Rican coffee cooperative "Coopedota" applied certification for carbon neutrality as innovation, which challenges faced, and how it overcame them (Birkenberg & Birner, 2018). Besides, they analysed the main factors that encourage the diffusion of this innovation. Their approach was based on the SNA and Process Net-Map tool which was applied to visualise the network and to identify the role and importance of different types of individuals. Data were collected from depth interviews with thirty experts and semi-structured interviews with one hundred Coopedota' farmers. On this basis, the authors calculated SNA indicators as centrality, betweenness, closeness, and degree. The results confirmed that the certification for carbon neutrality created

awareness on emission hot spots alongside the coffee value chain. The major successes include a combination of a) visionary and strong individuals who performed the necessary network functions and b) accomplishments in Coopedota's sustainability policy, which was supported by international and national trends. Results indicated that the network of individuals is extremely centralised, as well as the network analysis confirmed the importance of double linkages among individuals, which points to the role that combined services (advice and funding), acted in the introduction of innovation.

At the second step, in the other scientific paper's authors used SNA jointly with the diffusion of innovation theory, learning pathways, social capital, decision-making, and homophily concept, i.e., the approach of Aguilar-Gallegos *et al*. was based on the process of diffusion and adoption of innovation, homophily concept and SNA. They stated that in the agricultural sector, networks illustrate the engagement of many stakeholders that provide information and resources to farmers (Aguilar-Gallegos *et al*., 2015). Those stakeholders could be NGO's, farmer field schools, and extension agents. They are in contact with farmers, establishing and building ties. Moreover, they found that various farmers have different rates of adoption of innovation, as well as innovation is adopted based on farmers' incomes. Growers with high incomes are advanced adopters and they have more contacts with various stakeholders. Furthermore, they found that homophily in the network can impede the diffusion of certain knowledge among actors.

Garbach & Morgan applied SNA to investigate the farmer's familiarity with three different pollination techniques, their experience and the benefits obtained from each practice (Garbach & Morgan, 2017). Their approach was based on quantitative interviews to analyse the farmer knowledge systems, demographic characteristics, communication networks to understand the prominent individuals and knowledge origin through which farmers communicate information about pollination management. Diffusion of innovation theory was used to describe how information about pollination practices diffuse within farmer networks. After network visualisations, logistic regression was applied to analyse the influence of technical learning and social learning considering numerous variables of each farmer (role, age, experience, education level, etc.). They discovered that social learning was positively correlated with adopting the use of combinations of bees, underlining the potentially critical roles of farmer-to-farmer networks and social learning in supporting the initial stages of adoption of innovations.

Grünbühel & Williams investigated how decisions are made when innovation about cattle management is introduced in two Indonesian areas (Grünbühel & Williams, 2016). They focused on the decision-making concept and Homo oeconomicus model of classical economic theory. They developed the decision narratives through 296 in-depth interviews collected through

snowball sampling techniques. They used SNA to assess the diffusion of knowledge and identify different stakeholders that influence the farmers' decisions. They found that it is easy for farmers located in South Sulawesi to test and adopt an innovation because the land is more plentiful in comparison to farmers located in Lombok, where land is insufficient and more dedicated for crop production. Innovation is applied and adapted by farmers through cultural rationality. Furthermore, innovation is diffused through a range of existing social networks when it is compatible with farmers' livelihood strategies.

The research of Wood *et al.* was based on innovation systems theory by investigating the significance of the networks in which New Zealand shepherds discuss scientific issues (Wood *et al.*, 2014). The authors analysed how farmers share their knowledge (pastoral farming) with scientists and other individuals, concentrating on communication and facilitation in the network. Their approach was based on ego network and sociometric analysis. The sample was gathered identifying 17 farmers who are in direct contact with five scientists, to explore the network cohesiveness and to evaluate the significance of networking. Personal interviews were carried out to collect sociometric data for the quantitative analysis. Also, free form interviews with the farmers were carried out to collect data for the qualitative analysis and using a mix of roster formats and a name generator. Using a mix of tools (NVivo, Ucinet and statistical software), they found that farmers characterised by dense ties and homogenous contacts increased their network compared to other farmers characterised by soft and dissimilar ties.

Levy & Lubell used SNA to investigate the structure of social networks between Californian wine farmers that facilitate the diffusion of the agroecological system and resolve collaboration matters (Levy & Lubell, 2018). Their approach was based on three social processes: cooperation, diffusion of innovation, and boundary-spanning. They surveyed 500 individuals (farmers and stakeholders) located in three regions to analyse their social network relationships. Farmers were selected from County Agriculture Commissioners' Pesticide Use Reports, additional farmers and stakeholders were selected through snowball methods. Surveys were mailed to interviewed people. Each interviewee was invited to list eight farmers and eight other individuals with whom he talked about viticulture management. Each individual in the networks was classified in one of the three following categories: farmer, stakeholder, or both (farmer-stakeholder). The findings reflect that both stakeholders and farmers have relatively low-betweenness centrality, while stakeholders-farmers have a high betweenness centrality in all the networks, and it was observed the presence of open structures that facilitate the diffusion of information. In all regions, results indicate a tendency for individuals to form ties with popular people, and stakeholders-

farmers have a greater tie propensity than farmers or stakeholders. Moreover, individuals who share three contacts are significantly more likely to be connected than people with non-common contacts.

Hoffman *et al*. applied SNA to study knowledge networks and social learning in Central Coast, Lodi, and Napa Valley – three American viticulture regions in California – (Hoffman *et al*., 2015). They used a different approach based on learning pathways (social, formal, and experiential), diffusion of innovation, social capital, and cultural evolution theories. These theories provided a basis to explain farmers' behaviour and understand how and why knowledge is or not assessed, accepted, and adopted by people. They collected data through an e-mail survey from 25 farmers and 12 types of stakeholders and calculated the response rates using AAPOR guidelines (AAPOR 2009). Their surveys were based on asking interviewers to rate on a scale of one to three the usefulness of 21 information resources for learning about vineyard management. Furthermore, they used conventional network data collection methods asking farmers to list the names of other farmers and stakeholders with whom they speak about vineyard management. Besides, matrices of relational data were constructed from this survey. Other surveys were addressed to farmers to investigate if they had participated in learning activities. Using a linear regression model, they finally assessed the hypothesis that farmers' position in the network is a function of their participation in learning activities. The results confirmed that empirical and social learning are more essential to get information about farm management than formal learning. Natural Resources Cooperative Extension (UCCE) and UC Agriculture are well-positioned to get and disseminate knowledge through the farmers' networks. Farmers' participation in technical activities, e.g., gathering and field trials, is essential for their knowledge-sharing relations. Moreover, UCCE and other agricultural support associations have an essential role to play in reinforcing networks.

Spielman *et al*., used SNA together with an innovation system approach to study agricultural systems in developing countries, as well as in smallholder-farming groups (Spielman *et al*., 2011). They applied SNA to examine how market-driven factors and social networks promote the diffusion of information among Ethiopian small farmers and how the network influenced farmers' decisions to innovate. They carried out twenty focus group interviews and semi-structured interviews with key actors named by the focus group members. Data collected were used to implement the SNA of each geographic site (ten areas). They discovered that public extension and administration exercise a powerful influence over smallholder networks, potentially keeping out civil society and market-based actors, and thus represent a boundary for the diffusion of innovation processes.

Quiédeville *et al.* applied SNA to study the role acted by the network, in which rice farmers and research institutes are engaged during the innovation process, specifically during the transition to organic farming in South France, Camargue (Quiédeville *et al.*, 2018). Their approach was based on social capital and SNA. They based on face-to-face interviews with nineteen individuals (rice farmers, researchers, and traders) to collect data for SNA and to analyse research outputs, the factors that facilitate or block innovation diffusion. Individuals were invited to identify their relations with other similar individuals, as well as to assess the intensity of those relations on information flows, collaboration links and finances. A workshop was organised with three researchers from the CFR (French Centre of Rice), three participants from two organic rice traders, two researchers from INRA (French National Institute of Agronomic Research), and seven organic and partially organic farmers. Participants were invited to draw the impact pathway of the research by connecting several components (e.g., the output x with the outcome y or activity z). The outcomes include changes, behaviours, actions undertaken and actors' relations. The authors calculated SNA indicators as betweenness centrality, clustering coefficient, average clustering coefficient, degree centrality, and average degree centrality. The results have shown an increasing role acted by INRA in the network and its impact on the transition to organic agriculture due to closer relationships between rice farmers and INRA. Besides, the results also indicate an increasing role acted by CIRAD (Agricultural Research Centre for International Development) thanks to an increase in relationships with growers. Moreover, the results showed a significant impact of Biosud on the transition to organic farming.

At the third step, SNA was applied with other approaches such as those reported in Spielman *et al.* their research was based on the use of SNA with the complex adaptive system (CAS), National agricultural system (NARS) and agricultural knowledge and information system (AKIS). They described that the diffusion of sustainable agricultural techniques derived by the network formed by the transfer and the exchange among producers and stakeholders (Spielman *et al.*, 2009).

Bourne *et al.* applied SNA to assess the performance of agricultural advisory systems in Kenya, Tanzania, and Rwanda (Bourne *et al.*, 2017). Their approach was based on measuring knowledge flow and capacity for collective action, considering that the improvement of these two elements is the basis of a modern advisory system. For this purpose, they applied ego network analyses in eleven sites of East Africa. Actors and network boundaries were chosen using a two-step approach. A personal interview was carried out by locally trained personnel, and SN data were collected using a list of question and code it in an adjacency matrix of binary variables. SNA was processed using UCINET and homophily, density, core-periphery,

and average degree of nodes were calculated. Core-periphery structure was measured utilising the model from Borgatti and Everett (2000) and expressed as the correlation between tested and ideal model. The research shows a limited capacity for collective action within farmer groups and communities in Rwanda and some areas of Kenyan. Also, in Tanzania, low connections with external actors were found. These results have shown that there are both a limit and a delay in the introduction of innovation within the population.

The approach of Misra *et al*. was focused on the introduction of the concept of system to describe the sustainable livelihood (SL) framework, succeed by comparing the rural living system with common attributes of the system to determine the system characteristics of rural living in which SNA was applied.

Concerning SNA they used both the whole and ego network approach to analyse the complex system of rural livelihood and the related function of rural organisations (Misra *et al*., 2014). Their approach was focused on the introduction of the concept of "system" to describe the Sustainable Livelihood framework. They collected data at the micro-level (community level) and macro-level (through focus group discussion with a set of actors) and concluded that stakeholders should make the decision for significant livelihood actions in a region and boost the innovation diffusion within the organised system.

Instead, the approach of Conley & Udry was based on the Bayesian framework and on the use of SNA to analyse communication networks between small farmers in Ghana concerning chemical fertilisers on new pineapple cultivation (Conley & Udry, 2001). They conducted investigations with 450 people in four villages in the Eastern Region of the country for more than twenty-one months. They discovered that geographical closeness did not guarantee that small farmers can get knowledge easily (adoption of new techniques by his similar). Conversely, the networks (restricted channel) in which a farmer was engaged allowed him to learn and innovate from new sources.

In the end, the approach of Fafchamps & Lund was based on Udry' approach with several variations and SNA to analyse the risk-sharing behaviour of Philippine rural households (Fafchamps & Lund, 2003). They surveyed four villages in the Cordillera mountains with 206 rural households. Three interviews were carried out with each household at three-month intervals and recorded. Everyone was asked to identify several people on whom it could be dependent in case of need or to whom the respondent gives support, and they called it the network of insurance. Data were collected on loans, gifts, and asset sales of each individual and all its network partners (household composition, cultivated area, professional skills, and age of head). They discovered that shocks have a dominant effect on informal

loans and gifts, but a weak effect on sales of grain and farm animals. The households receive support primarily through networks of families, friends, and acquaintances without a charge of interest on the loans used.

Conclusions

Starting from the note's goal, we described the SNA and its usefulness in analysing the knowledge diffusion in a social network. In our note, we decided to not focus on comparing other methods usually used in this regard, but our centre point was to shed light on SNA.

We tried to give to readers an overview concerning the origin, application, and use of SNA in the analysis of the processes that drive the diffusion of innovation in agriculture. We believe that readers can both use this note as a basis for future research and can get a comprehensive paper appropriated to the use of SNA (it could be used alone or applied as an explorative method with other methods and theoretical frameworks).

In our note, we highlighted that SNA is a process of assessing a social network, in which actors are involved, interact and exchange knowledge concerning any specific issue, and technical innovation too (Spielman *et al.*, 2011). SNA is centred on the idea that interaction is developed by relationships and the patterns created by these relationships (Scott & Carrington, 2011). Through SNA, we can understand how innovations are implemented and diffused in agriculture, and the role played by the main actors (brokers) to spread the innovation. To depict the social network structure, it is necessary to use a set of research methods, such as matrices, diagrams, and mathematical measures, etc. (Bourne *et al.*, 2017).

In the agriculture sector, most of the research – reported in our note – in which SNA was applied are conducted in developing countries. Furthermore, we noted that in a few research authors have only used SNA calculating the SNA' indicators, besides in most scientific paper's authors have used SNA with other methods, frameworks and theories. That means that SNA is a flexible tool and can be applied jointly with several approaches and theories. Other essential points are that in all research SNA was applied: a) to analyse how the existing networks can spread the diffusion of the existing innovation; b) to analyse communication networks and knowledge exchange between actors concerning an existing innovation; c) to analyse the role acted by the actors involved in the network during the diffusion of innovation and d) to identify how relations support actors to enhance both themselves and their communities.

We summarise that through SNA, we can get relevant information about the network to understand how innovation is shared, as well as to assess the role and importance of different actors involved in the network.

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The Methodology applied for the Literature Review of SNA and Diffusion of Innovation: Research Issues and Insights for Future Research:

For a better understanding of how we made a literature review concerning SNA and Diffusion of Innovation, in this section we will face deeply the following points:

a) Information data source,
b) The approach applied to select different articles,
c) The guidelines.

a) Information data source:

To find scientific papers related to the SNA and Diffusion of Innovation through Proxy service we accessed the library system of the University of Bologna, in section database, Scopus. Furthermore, using google scholar it was possible to find further articles and/or documents.

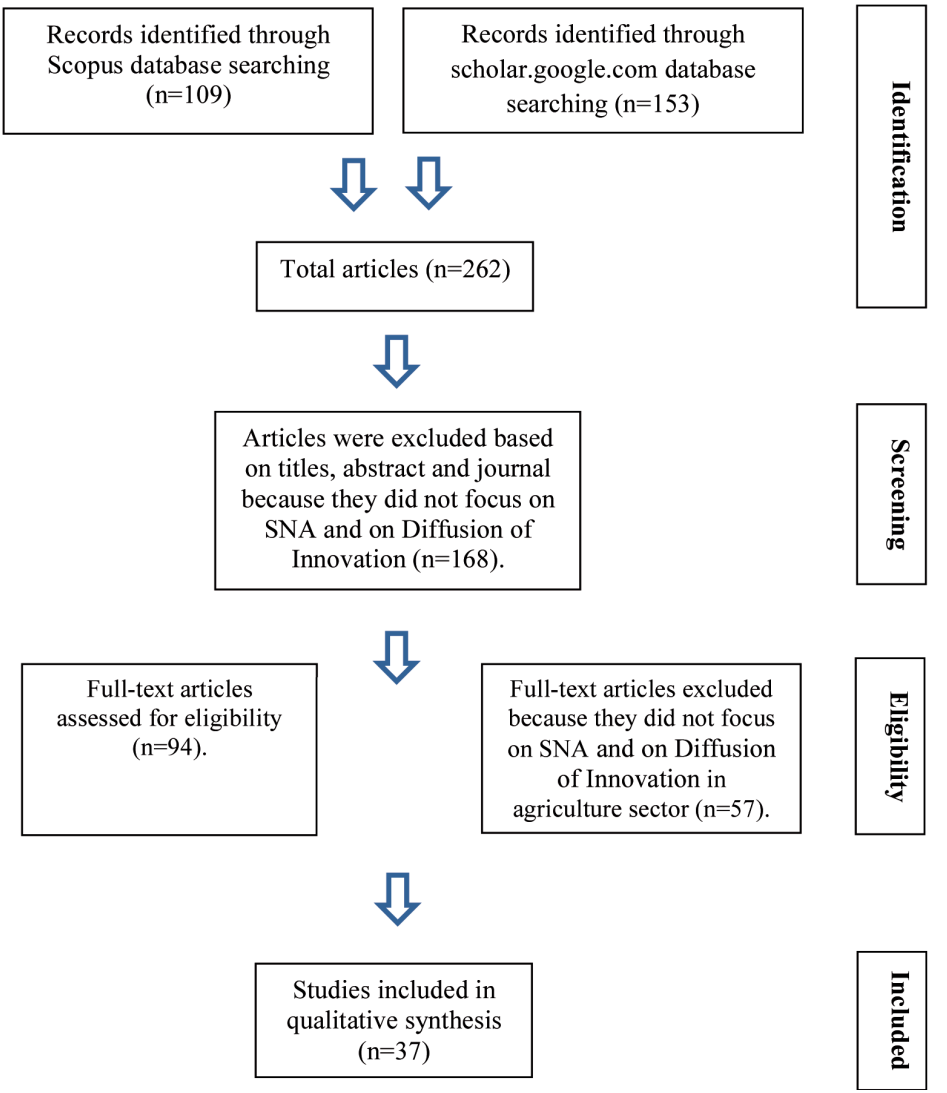
b) Approach applied to select different articles:

During the research of scientific papers, the framework adopted was based on:

– Keywords: typing Social Network Analysis; Diffusion of Innovation, Application of Social Network Analysis; Social Network Analysis in agriculture.
– Methodological approach used to select the papers:

Database	Search String
Scopus	*TITLE-ABS-KEY (social AND network AND analysis AND in AND agriculture) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA, "ECON")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBYEAR, 2019)) AND (LIMIT-TO (LANGUAGE, "English"))* *TITLE-ABS-KEY (social AND network AND analysis AND diffusion AND of AND innovation) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (SUBJAREA, "ECON")) AND (LIMIT-TO (SUBJAREA, "AGRI")) AND (LIMIT-TO (LANGUAGE, "English")).* *TITLE-ABS-KEY* (application AND of AND social AND network AND analysis) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (SUBJAREA, "ECON")) AND (LIMIT-TO (SUBJAREA, "AGRI")) AND (LIMIT-TO (DOCTYPE, "ar")). TITLE-ABS-KEY (*diffusion* AND *of* AND *innovation*) AND (LIMIT- TO (PUBYEAR, *2020*) OR LIMIT-TO (PUBYEAR, *2019*) OR LIMIT-TO (PUBYEAR, *2018*) OR LIMIT-TO (PUBYEAR, *2017*) OR LIMIT-TO (PUBYEAR, *2016*) OR LIMIT-TO (PUBYEAR, *2015*) OR LIMIT-TO (PUBYEAR, *2014*) OR LIMIT-TO (PUBYEAR, *2013*) OR LIMIT-TO (PUBYEAR, *2012*)) AND (LIMIT-TO (DOCTYPE, "*ar*")) AND (LIMIT-TO (SUBJAREA, "*ECON*")) AND (LIMIT-TO (EXACTKEYWORD, "*Diffusion Of Innovation*")) AND (LIMIT-TO (LANGUAGE, "*English*"))
Website	*https://scholar.google.com/* TOPIC: "Application of Social Network Analysis"; AND TOPIC: "Social Network Analysis in agriculture"; AND TOPIC: "Social Network Analysis and Diffusion of Innovation". Refined by: DOCUMENT TYPES: (ARTICLE) Timespan: 1995-2020. *https://scholar.google.com/* TOPIC: "Diffusion of Innovation" Refined by DOCUMENT TYPES: (ARTICLE) Timespan: 1965-2020.

c) The guidelines:



Annex A
The approach used by several authors using SNA to assess how innovation is diffused in the agricultural sector

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
Isaac, M.E.	*2012*	Agricultural information exchange and organizational ties: The effect of network topology on managing agrodiversity.	Investigate information network structures within the agrarian environment to understand the barriers to, and development of, effective farm management, specifically the management of agrodiversity.	– Social network analysis (network structure, homophily, network density).	– Ego-network analysis: personal network consists of an individual producer (ego) and their contacts (alters). – Name-generator technique: to collect network data. – Adjacency matrix: to create personal network socio-grams for each actor. – Personal network data analysis: for size (number of actors), ties (number of connections) and density (a measure of existing ties as a percentage of all possible ties).	– Cocoa cultivation.	– Extension agent from the Ministry of Agriculture. – Individuals in NGO's – Individual in local development providers	– Networks with a greater size with low organizational ties, had a lower efficiency and more redundant ties in comparison to networks with small size and high organizational ties (increase efficiency). -Individuals in open networks with few redundant ties are more likely to adopt agroforestry practices. – Farmer field schools had shown that approximately 60% of farmers continue to meet after farmer field schools (personal communication), thus creating greater self–reliance and an effective system in the adoption of sustainable agrarian practices. – The closer you are to a city and the greater the access to organizations, the more open and

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
					– Triad structures within the personal networks were analysed to assess the position of the interviewee using UCINET. – %size difference: to value the effects of the presence of an organization on network size. – Semi-structured interviews: addressed both to individuals from various organizations and to farmers. – T-tests: to test the effect of location (Site A or B) on size, number and type of ties and density values. – A correlation analysis: was conducted			diverse your informal network becomes (efficient networks, greater adoption of agroforestry).

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
					between network efficiency values and reported agrodiversity values at the plot level. – UCINET and Netdraw: to analyse and visualize the network.			
Hermans, F., Sartas, M., van Schagen, B., van Asten, P. & Schut, M.	*2017*	Social network analysis of multi-stakeholder platforms in agricultural research for development: Opportunities and constraints for innovation and scaling.	Their research aimed to investigate the ability to innovate and to explore the potential for scaling innovations in 3 multi-stakeholder platforms (MSPs) in Congo, Rwanda, and Burundi.	Their approach was based: 1) recognize in each country the long-term established partners of the CGIAR centres; 2) map the participatory stakeholders according to Humidtropics meetings for which they were invited; 3) prepare marketing materials about the program and distribute them in different areas.	Data were collected from questionnaires carrying out in each country focusing on a name generator asking participants (n. 45) to list the name of 5 organisations with whom they cooperate. The analysis of network properties and ERGM specification were carried out in R, using the statistical statnet package and the associated ergm ego package.	– Farmers. – Agro-ecological and demographic features. – Agricultural productivity. – Soil fertility. – Formulation and implementation of policy.	– NGOs (non-governmental organisations) – Private sector. – Government agencies. – Research organisations.	They found that in each country there is an imbalance between knowledge exchange, collaboration, and influence networks for the diffusion of innovation and scaling processes. For example, the private sector and NGOs are respectively under and over-represented in the MSP networks, as well as connections among local and public organisations are weak, and influential public organisations are not actively connected to other groups and are often not part of the MSP. Furthermore, they discovered that groups with a central position in the network are more appreciated for

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
				– According to the research goal, they applied SNA in combination with Exponential Random graph modelling (ERGM) to explore the knowledge exchange, structural properties of the collaborative, and influence networks of 3 MSPs.				cooperation, and the scaling of innovations is mainly among the same type of groups across various administrative levels, but not among various types of groups.
Padmaja Ravula (2012)	*2012*	Mapping the social network architecture of rural communities: Gender and technological innovations in the semi-arid tropics of India.	She focused on using social networks and mapping the network of rural farmers located in two Indian villages to identify the mean of relations (informal and formal) and	The study was focused on a transaction-based approach to record the social network architectures in the two villages, for 3 transactions (socio-cultural-political, technological,	Data were collected from Aurepalle and Kanzara villages through semi-structured questionnaires and focus group discussions. Data were processed using a quantitative analysis	– Rural farmers (men and women)	– Economic, socio-cultural and technological	She found that both villages have good levels of social capital in terms of social networks. The variation in resources (natural and financial) between the two villages has encouraged the improvement of relationships in one village and self-help communities in another. The mapping of networks

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
			associations for poor farmers. Besides, to understand how these networks can boost the diffusion of innovation (agricultural technology) and how the relations support rural people to enhance both themselves and their societies diffusion of innovation (agricultural technology) and how the relations support rural people to enhance both themselves and their societies.	and economic). To assess the relations among people "egocentric networks" based on the name generator at a micro-level was used, as well as whole networks was applied at the macro level.	software STATA to convert the raw data and using UCINET software to record the visual analysis and to calculate the centrality measurements. For deep analysis, a descriptive analysis of all network maps was utilized.			in two villages shown that rural people have demonstrated social connectedness to a larger degree. Both the degree of social connectedness and density of the networks varies within the villages and depending on the attributes of the villages.
Birkenberg, A. & Birner, R.	*2018*	The world's first carbon-neutral coffee: Lessons on certification and innovation from a pioneer case in Costa Rica.	Analyse how coopedota cames to apply the carbon neutrality certification, which challenges it.	– Social Network Analysis. – Innovation systems.	– Process Net-Map: to visualize the social networks that enable the actors to pursue the certification scheme and to	– Certification of carbon neutrality (CN). – PAS 2060.	-Coopedota cooperative (800 associate farmers). – NAMA-cafe experimental farm Hacienda Aquiares.	– Through the process, Net-Map were identified the actors involved in achieving the PAS 2060 certification. – The network shows a high diversity of actors from different sectors,

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
			faced and how the coopedota solved them. In addition, examine the social, political and institutional factors that fostered this innovation.		identify the role and importance of different types of actors. – Qualitative Research: expert interviews (30 experts), semi-structured interviews (100 farmers), focus group discussions, the Process Net-Map tool and direct personal observations (the interviews gave insights into how the PAS 2060 has been applied by the copedota). – Cradle-to-gate approach for green coffee, based on considering only the GHG emissions along the value chain up until the port in Limon (Costa Rica).			which illustrates the expert knowledge and assistance required from different groups to achieve the certification as a pioneer. Many actors can be categorized into two project groups: Institutions that assisted in calculating the CF and Institutions involved in the different emission reduction projects. -In terms of linkages between actors, only a few direct funding connections between actors were identified. Most external advice was accompanied by funding or provision of experts, in particular, to assist with the LCA required for the certification. Therefore, the same pair of actors were often linked by two different types of linkages: for example, groups in charge of the biodigester, ethanol and pulp composting advised the central actors and additionally provided financing for the

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
					– PAS 2060: internationally recognized as a standardized method for the certification process and based on: quantifying, reducing, offsetting, and declaration.			implementation. Equally, the LCA group provided advice and sent their staff to actively help with the LCA. This combination LCA linkages is referred to as double linkages. – The low density of the network indicates a rather poorly interlinked network. One reason for this observation might be the nature of the network as a project-related one, which implies limited boundaries. Only two actors, the general manager, and the CN project manager are well interlinked, which results in a centralized network that consequently displays a high degree of centrality. The degree values are consistent with the values of normalized closeness, which supports the observation that not many actors have direct connections with each other. Instead, all are connected to the two central actors of the network. The normalized

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
								betweenness values illustrate that these two central actors hold broker positions. – The Net-Map identified strong individual actors, with commitment and visions, as essential for the successful CN certification. The findings also indicate a high awareness of participants regarding the importance of obtaining reliable data from farmers during the certification process. – The Net-Map interviews also showed that funding was usually combined with advice, resulting in 'double linkages' in the Net-Map diagram.
Aguilar-Gallegos, N., Muñoz-Rodríguez, M., Santoyo-Cortés, H., Aguilar-Ávila, J. & Klerkx, L.	*2015*	Information networks that generate economic value: A study on clusters of adopters of new or improved technologies and practices among oil palm growers in Mexico	Determine the factors that influence the adoption of new or improved technologies and practices and their relationship with the generation of the economic	– Scalling-out: process of broader diffusion and adoption of innovation. – Factors influencing adoption of innovation: economic benefits, psychological	– Random sampling was applied to select palm oil farmers. – Survey to palm oil farmers – Index (INTAI): refers to the average adoption of innovation.	– Characteristic of growers – Perception of the grower. – Characteristic of the production unit (oil palm). – Adoption of innovation (plant nutrition, Plant health, Plantation	– AIM: agency for innovation management – Government organizations (GO). – Educational and research organizations (ERO), – Agro-industries and input and	– Different clusters of farmers have different rates of adoption of innovation, and higher adoption contributes to higher incomes. – The adoption of innovation (new or improved technologies and practices) is related to higher levels of production and generation of economic value.

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
			value of oil palm.	and behavioural process, the efficiency of production, formal schooling, extension agents. – Social Network Analysis: based on the study of the relationships among actors and of the social structures that emerge from the recurrence of these relationships. – Homophily concept: individuals tend to maintain links with others who are similar to them in the same cluster.	– UCINET® and NetDraw®: used to obtain information about the network indicators. – Output degrees: are the links that the grower establishes in his search for sources of information. – Input degrees: is the number of times the grower was referred to by his peers as a source of information. – Multivariate analysis: cluster analysis: squared Euclidian distance, basic characterization units (BCU) or operative taxonomic units (OTU) to indicate how similar or	management, Administration, Organization, Harvest, Reproduction, and genetics). – Information network (using UCINET® and NetDraw®). – Production and economic indicators (yield, average selling price (US$/t), gross income (US$/ha).	equipment suppliers (AEIS) – NIG: other oil palm growers (non-interviewed growers).	– Net profits are higher for advanced adopters than for farmers with lower levels of adoption of innovation. – Advanced adopters have more contact (links) with extensionists (AIM case) than those who adopt less innovation. That means the levels of adoption increase, and better productive and economic parameters are achieved -Homophily in networks can impede the flow of certain kinds of relevant information. For this reason, AIM could play an essential role in connecting homogenous networks of growers among each other and with other actors in the broader value chain and innovation system.

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
					dissimilar the growers are; Ward minimum variance used for Clustering of the BCU; Pseudostatistical tools t2 of Hotelling and the cubic grouping criteria to define the number of groups. – SAS, version 9.0, software to make multivariate analysis. – ANOVA or chi-squared: tests to measure the variance between and within the clusters. – Scheffe test: to determine where the difference exists among the means (clusters).			– Net profits are higher for advanced adopters than for farmers with lower levels of adoption of innovation. – Advanced adopters have more contact (links) with extensionists (AIM case) than those who adopt less innovation. That means the levels of adoption increase, and better productive and economic parameters are achieved -Homophily in networks can impede the flow of certain kinds of relevant information. For this reason, AIM could play an essential role in connecting homogenous networks of growers among each other and with other actors in the broader value chain and innovation system.

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
Garbach, K., & Morgan, G.P.	*2017*	Grower networks support the adoption of innovations in pollination management: The roles of social learning, technical learning, and personal experience.	– Investigate Michigan grower experience and benefits associated with pollination management practices and the influence of grower networks, which are comprised of contacts that reflect potential pathways for social and technical learning.	– Diffusion of innovation theory describes how information about innovative practices spreads throughout a community of practitioners. – Knowledge systems: comprise the actors, organizations, and resources that link information and know-how with action. – Decision-making: individual belief systems that encode people's knowledge and perceptions. -innovative management in the agricultural ecosystem:	– Quantitative survey: to investigate grower knowledge systems, communication networks, and demographic characteristics to build understanding about key actors and information sources through which growers share information about pollination management. – Social network analysis (path length, network diameter, density, direct and indirect connections, brokers). – Four-point Likert scale to evaluate growers' ratings	– 3 pollination management practices: a combination of bees cover crop and permanent habitat.	– Cooperative Extension – Beekeepers – Growers (age, year experience, educational level, farm size, and income). – Extension specialists (Michigan State University (MSU), etc.) – Commercial suppliers – Commodity groups – Government agencies – Non-profit organizations (NGOs)	– No significant difference in the frequency with which growers of different crops reported buying or renting pollinators. – No significant differences in frequency of use of pollinator types across different crops or other pollination practices. – Crop pollination was the top-rated management priority for growers (high and medium farm size). – Growers with large farms ranked the effectiveness of pollinator species as a higher priority than growers with small farms. – 65% of the current practice is represented by "Buying or renting honeybees" as a pollination management practice. – 60% of growers reported currently retaining areas of permanent habitat, (including wooded lots and farm edges, old

Author	Year	Research title	Scope	Approach used	Method used	Dependent variables	Independent variables	Results obtained
				based on communication networks that facilitate both technical and social learning. -Social learning: refers to how individuals learn from each other as well as actors with different roles and are supported by social capital and networks.	(Always, Often, Sometimes, or Never). – Analysis of variance (ANOVA) to evaluate responses followed by Tukey means separation tests. – Chi-squared analysis is used to analyse count data or frequency of responses. – Name-generator technique: to collect Network data. – Levenstein procedure was used because names of network contacts were anonymized and transformed for spelling errors. -ORA software: to visualize the resulting networks.			fields, swamps, and marshes). – 49% of growers reported using flowering cover crops to encourage pollinators and 13% of growers reported using combinations of bees. – Source of information: beekeepers are an important source of information representing 28% of connections; grower-to-grower communication represents 26% of connections; Extension represents 25% of grower networks. Commercial suppliers, commodity groups, government agencies, non-profit organizations, and other organizations were represented less frequently. – In networks of growers that adopted a combination of bees had significantly more connections to both government agencies and innovative neighbours, 18%, versus non-adopters, 2%.

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					– Regression analyses were combined with descriptions of network structures to identify influential organizations, and key organization types and roles of contacts, related to the binary response variable of adoption (yes/no) of three key practices: combinations of bees, flowering cover crop, and retaining permanent habitat areas. – Logistic regression to examine the influence of technical learning measured through connections to			– The adopters and non-adopters had similar percentages of innovative neighbours currently using cover crops (19% and 18%, respectively). -Networks of growers that adopted the practice of retaining permanent habitat did not differ significantly from non-adopters. – Connections with the Natural Resources Conservation Service (NRCS) had a significant positive correlation with adopting the use of combinations of bees and adopting flowering cover crops. – Growers' personal experience with potential benefits and concerns associated with practices to attract and retain diverse pollinators had significant positive and negative correlations, respectively, with the adoption of all three innovative practices. – Using combinations of bees (adopted by 17%

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					government and extension, and social learning on the adoption of innovative practices as measured through connection to other innovative growers.			of growers) is positively linked to government and to interact with other innovators, as well as using Internet resources. – Results suggest that different types of information brokers can be important for practices at distinct stages of adoption. Social learning through social contacts is especially important for early adopters. Michigan State University Extension and beekeepers serve as information brokers, evidenced by unusually high numbers of unique links.
Grünbühel, C.M. & Williams, L.J.	*2016*	Risks, resources and reason: understanding smallholder decisions around farming system interventions in Eastern Indonesia.	– Investigated how decisions are made and diffused when innovation (adoption of techniques for improved cattle management) is introduced in two Indonesian areas (South Sulawesi and Central Lombok).	– Decision-making concept and application of methods to measure this context, such as social networks, mental models, and communication patterns. – Homo oeconomicus model of	– Decision narratives: were developed from in-depth interviews, which explored the various steps of deciding whether or not to accept new livestock management practices. – Social Network Analysis (SNA)	– Cattle management practices (buffalo and cattle): Introduction of new forage varieties, strategic forage production, feed budgeting to improve cattle nutrition and health, controlled	– 216 interviews in South Sulawesi (Indonesia). – 80 interviews in Central Lombok (Indonesia). – Household Farmers – Neighbours, – Village heads, – Religious leaders, – Government agencies.	They found that is not complicated for farmers located in South Sulawesi to test and adopt an innovation, because the land is more plentiful in comparison to farmers located in Lombok, where land is insufficient, and more dedicated for crop production. Innovation is applied and adapted by farmers through cultural rationality. Furthermore, innovation is diffused through a range of

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				classical economic theory (an independent agent who acts rationally to maximise self-interest).	was used to examine how knowledge about new practices spread among households and communities, as well as, the type of households, relationships or institutions critical for promoting adoption. – Data for SNA was collected as part of the decision narratives and focused on capturing: Interactions and influence between households and local institutions; The spread of information; The spread of resources as concomitant to information.	mating and weaning to enable higher fertility rates.		existing social networks when it is not conflicted with farmers' livelihood strategies.

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					– The interviews were structured according to Geertz' (1975). – Sample: selected through both snowball and random techniques.			
Wood, B.A., Blair, H.T., Gray, D.I., Kemp, P.D., Kenyon, P.R., Morris, S.T. & Sewell, A.M.	*2014*	Agricultural Science in the Wild: A Social Network Analysis of Farmer Knowledge Exchange	– Investigate the networks in which farmers discuss science. – Explore how farmers' participation embed science in the complex networks of agricultural innovation systems. Investigate how farmers participate with scientists and how they share knowledge (pastoral farming) with other individuals concentrating	– Theory of agricultural innovation systems: based on open-ended interactions with heterogeneous actors and the complexity of their interaction makes the knowledge they produce unpredictable. – Ego-centric network and sociometric analysis.	– Network surveys: open-ended interviews collected farmer statements about their most valuable contacts – Ego-centric network analysis – Personal interview surveys to collect sociometric data for the quantitative analysis of knowledge exchange networks. -Free-form interviews	– Herb-based pastures – Farmers. – Farmers features (age, experience in herb pasture, farm system, etc.) – Climatic condition. – Scientists. – Local research stakeholders in agricultural science. – Herb-based pastures. – Farmers' acquaintances.	–	– Farmers exchange knowledge in densely tied and strongly organized interpersonal networks. – Low density and shortest path indicate a cohesive network (suggesting that everyone in the network is close together and that group members can communicate with each other easily), but the betweenness centralization value is 11.6%, suggesting relatively little difference between the 22 group members' ability to control the flow of knowledge. – The 17 participating farmers had discussed the farmlet with 63.2%

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			on the role of communication and facilitation in the network.		are used to collect data for qualitative analysis of the perspectives on the knowledge that inform farmer networking. – Use of a mix of name-generator and roster formats. – Ucinet software to analyse the survey data. – Qualitative data collected from the interview were coded by the sociologist using NVivo 9 software. – Linear Regression was used to measure the growth rate, the growth on density and the growth on heterogeneity.		–	of their pre-existing contacts and with 113 new individuals not previously identified. Seed merchants are in distant second place, comprising 16.0% (20) of prior farmers' contacts and 8.3% (16) of the farmers' ego networks. They are followed by a mix of other occupations at 0–10% and 1– 5% respectively. The farmers intend to make contact with their social peers more than with anyone else. – The smaller networks tended to grow more than the larger networks. – Farmers' networking was driven by sociological traits and the denser and more occupationally homogenous a network, the more it grew. – Triadic analysis shows that the 17 farmers are positioned to deliver multi-member messages more frequently than

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					– Social structure: calculating density and occupational heterogeneity (measures the diversity of information sources used by each farmer). – Occupational heterogeneity has been calculated using Blau's heterogeneity index. – Ucinet's brokerage routine was used to identify the triadic forms in the network.			the five agricultural scientists. In addition, farmers are much more likely to receive such messages than any other occupational grouping. – Farmers regularly contact numerous other people to secure the farming resources they need. This practical networking sustains wide-ranging and durable relationships that emphasize the interpersonal value of knowledge exchange. – Farmers intend to make contacts with fellow farmers and other agricultural individuals to share experience-based knowledge. – Farmers also exchange knowledge directly by visiting each other's properties and that increase the sharing of farmer experience. – Farmers seek knowledge that can be applied to their farm by contacting individuals

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								who can share the experiences of other equally individual farms (homophily concept). – Farmers move experience across farms by comparing examples.
Levy, M.A. & Lubell, M.N.	*2018*	Innovation, cooperation, and the structure of three regional sustainable agriculture networks in California.	Analyse the structure of social networks among wine grape growers in three regions of CA, USA, that have implemented sustainability partnerships.	– Social capital and social networks theories: are theorized to facilitate social processes such as learning and cooperation that enable human societies to adapt to dynamic and complex social-ecological systems. – Social processes: Diffusion of innovation theory (innovation is facilitated by networks that efficiently	– Survey data (500 growers) to measure the communication networks of growers in three viticulture regions in California. – Surveys were administered in 2011 for Lodi and 2012 for Napa and Central Coast. Growers were identified from county Agriculture Commissioners' Pesticide Use Reports, and additional eligible growers and outreach professionals	– Agroecological systems. – Sustainability partnerships.	– 500 individuals: growers, outreach professionals and outreach-grower present in three different regions.	– The survey response rate was 24% in Central Coast, 39% in Napa, and 45% in Lodi. – The Lodi's network is the smallest (447 nodes) and most dense (0.0068, fraction of possible ties present), connected (0.84, fraction of dyads with a path between them), and centralized (0.081, normalized sum of deviation of degrees from the most popular actor) of the three, and Central Coast's network is largest (785 nodes) and least dense (0.0031), connected (0.73), and centralized (0.019), with Napa's network intermediate on all measures. – Outreach professionals and Growers both have relatively low-

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				transmit information); Cooperation (facilitated by networks that allow the development of reputation and trust); boundary-spanning networks (link together specialized components of food systems, which help bring different types of expertise into the overall agricultural value chain); and structural holes (individuals whose ties span different parts of the system can access more and a greater variety of resources).	were identified through snowball methods. Surveys were issued by mail, and non-respondents were asked several times to respond. – Networks were constructed from survey questions that asked respondents to list up to eight growers and up to eight other individuals with whom they communicate about viticulture management in decreasing order of frequency of communication in Napa and Central Coast and up to four of each in Lodi.			betweenness centrality, but outreach-growers have high betweenness centrality in all three networks. – Network centralization is greatest in Lodi and least in Central Coast. The empirical networks feature a few highly popular actors, more popular than any nodes in the random graphs. In terms of distances between dyads, Central Coast has the longest average path length. In Napa and Lodi, where the observed path lengths are shorter. These results demonstrate the presence of open structures that enable the diffusion of information. In addition, Lodi is the most centralized with the lowest HMPL, while the Central Coast is the least centralized with an HMPL no different from the expectation in a random graph. In terms of clustering coefficient,

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				– Transitive triangle: relationships between individuals i–j and i–k facilitates the relationship j–k. These structures help maintain reputation and trust by enabling indirect reciprocity and social sanctions for free-riders and by providing third-party verification of cooperative or uncooperative behaviour.	– To enable comparisons across regions, only the first four individuals listed in each category for Napa and Central Coast were used. Edges are treated as undirected and dichotomous. – Each node in the networks was assigned an attribute type based on whether they are exclusively a grower, exclusively an outreach professional, or both a grower and outreach professional, based on county records and survey question responses. Network data were manually			Lodi has the greatest value, followed by Napa and Central Coast. – In all three regions, GWD estimates were significantly negative, indicating a tendency for actors to form ties with popular actors. At the aggregate level, this creates centralized networks with short paths between nodes. Furthermore, the positive coefficient estimates on GWESP indicate a strong force for triadic closure in all three regions. – In terms of the boundary-spanning role, in all three regions, outreach-growers have a greater tie propensity than growers or outreach professionals. All else accounted for, in Napa, outreach professionals are substantially less popular than Growers, while in Lodi, outreach professionals are somewhat more popular than growers.

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					cleaned to merge duplicate entries, correct misspellings, etc. – All analyses were performed in R version 3.3.3 (R Core Team 2016) using the statnet suite of packages, version 2016.4. – For each region, we simulated 1000 random graphs with uniform edge probability and the same size and density as the observed network. – For each region, have been compared the empirical value of three graph-level indices of interest to the distribution from the			– There is strong regional homophily at the zip code level in all regions. – Across the three networks, actors who share three contacts are an order of magnitude more likely to be connected than actors with non-common contacts.

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					random graphs: normalized degree centralization, harmonic-mean path length (HMPL), and clustering coefficient. – A combination of descriptive statistics, conditional uniform random graph tests and exponential random graph models (ERGMs) were used to provide empirical support for the hypotheses. – For each network, it was analysed the path length (HMPL), which accounts for disconnected dyads, and degree centralization, a measure of			

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					the absolute difference of degree of each node in the network from the highest-degree node, normalized to the maximum possible value for a network of that size. – In the ERGM context, network centralization was tested with a geometrically weighted degree (GWD) term, which measures repulsion of edges from high-degree nodes. -For closed network structures: comparison between observed levels of triadic closure to levels found in uniform random			

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					graphs of the same size and density and then via the geometrically weighted edgewise shared partners (GWESP) statistic in ERGMs to test whether there is a tendency for triadic closure above what would be expected by other tie-formation forces in the network (e.g., regional homophily). – Parameter estimates were obtained via Markov chain Monte Carlo (MCMC) maximum likelihood estimation.			

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Hoffman et al., (2015)	*2015*	Network-smart extension could catalyse social learning.	They applied SNA to study knowledge networks and social learning in Central Coast, Lodi, and Napa Valley (three American viticulture regions in California).	They used a different approach based on learning pathways (social, formal, and experiential), diffusion of innovation, social capital, and cultural evolution theories. These theories were used as a basis to explain farmers' behaviour and to understand how and why knowledge is or is not assessed, accepted, and adopted by people.	For each region from 2010 to 2012, they have collected data through an e-mail survey from 25 farmers and 12 types of stakeholders following the Dillman method, as well as they, have calculated the response rates using AAPOR guidelines (AAPOR 2009). Their surveys were based on asking interviewers to rate on a scale of 1 to 3 the usefulness of 21 information resources for learning about vineyard management. Furthermore, they used conventional network data	– Farmers. – Wine grape cultivation. – Geographical area' features. – Learning activities about vineyard management. – Agricultural techniques. – Outreach professionals. – Boundary-spanning professionals. – Agricultural support organisations.	–	The results showed that farmers confirmed that social learning and experiential are more useful to get information about farm management than formal learning. Some stakeholders are well-positioned to get and diffuse information through the farmer networks. Farmer's participation in learning activities confirmed that these activities are still a strong tool for the dissemination of knowledge.

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					collection methods asking farmers to list the names of other farmers and stakeholders with whom they speak about vineyard management. Besides, matrices of relational data were constructed from this survey. Centrality and coverage were calculated as well. Other surveys were addressed to farmers to investigate if they had participated in learning activities and using a linear regression model, they assessed the hypothesis			

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					that farmers' position in the network is a function of their participation in learning activities.			
Spielman, D.J., Davis, K., Negash, M. & Ayele, G.	*2011*	Rural innovation systems and networks: findings from a study of Ethiopian smallholders. Agriculture and Human Values.	They applied SNA to examine how Ethiopian small farmers innovate and market-driven factors, as well as how social networks promote the diffusion of information outwardness and how those outwardness influenced farmers' decisions to innovate considering the growers' agricultural practices and choices.	Their research was based on SNA used together with innovation systems approach aimed to assess how community engenders, interchange, and utilizes knowledge, as well as how these processes can induce innovation and disseminate the benefits derived from the innovation in Ethiopia.	They carried out 20 focus group interviews comprised of 5 people each. Semi-structured interviews were carried out with key actors named by the focus group members. Data collected from both interviews were used to carry out the SNA of each geographic site (10 areas).	Households – Economic activities. – Behaviours of smallholders. Geographic site. – Innovative agricultural practices. – Marketing practices.	– Bureau of Agriculture and Rural Development (BoARD). – Manager of credit and saving institutions. – Traders. – Brokers. – Staff of NGOs.	They discovered that public extension and administration exercise a powerful influence over smallholder networks, potentially keeping out civil society and market-based actors, and thus represent a boundary for the diffusion of innovation processes.

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Quiédeville, S., Barjolle, D. & Stolze, M.	*2018*	Using social network analysis to evaluate the impacts of the research: on the transition to organic farming in the Camargue.	Assess the relevance of undertaking an SNA to better understand the role played by the network of actors during innovation processes as well as validate stakeholders' views on actors' relationships in a case study on the transition to organic farming in the South of France.	– Social capital: bonding, linking and bridging links. – Social Network Analysis (SNA). – Indicators of betweenness: represents a high degree of intermediation in the network. – Clustering coefficient: to assess actors' access to relevant information and resources by calculating the level of connectivity between actors in the neighbourhood. – Degrees: account for the number of relationships among actors. – Participatory Impact Pathway Analysis (PIPA).	– Face-to-face interviews. – Social Network Analysis (SNA): identifying the relationships between actors and evaluating the intensity of those relationships. As well as, calculating indicators as betweenness centrality, clustering coefficient, average clustering coefficient, degree centrality and average Degree centrality. – Building the impact pathway: through the organization of stakeholder's workshop, in which actors were asked to draw the	– Organic rice cultivation.	– INRA: (French National Institute of Agronomic Research. – CIRAD: Agricultural Research Center for International Development. – CFR: French Centre of Rice. – Organic and partially organic farmers. – Rice traders. – CEBIOCA: Organic Cereals in the Camargue – ORPESA: Organic Rice Production in Environmentally Sensitive Areas – BIOSUD: associating a cereal cooperative and two trading companies. – France AgriMer: French public agency for agriculture. – CFR: French Centre of Rice	– 4 different groups of pathway links were obtained: PL1: CEBIOCA and ORPESA have contributed to the growing influence of INRA in the actor-network. PL2: The CEBIOCA and experimentations carried out (by INRA and CIRAD) have contributed to an increasing influence of CIRAD in the actor-network. PL3: INRA and CIRAD have become a knowledge broker in the network influencing positively innovation development and the transition to organic farming. PL4: the high selling price, the growing demand for organic rice, and the adoption of organic farming have contributed to an important and growing influence of Biosud in the network. – Through SNA tests it was demonstrated: INRA has a high centrality in the

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					impact pathway by linking the different components (e.g., the output x with the outcome y or activity z).			transition to organic farming and a high influence in the network due to an increase in relationships between its adjacent actors (farmers); an influence of FranceAgriMer and CFR on the growing role played by CIRAD alongside the development of innovations focalized on the transition to organic farming; the increasing influence of INRA and CIRAD in the network becoming knowledge broker; based on betweenness indicator the Biosud was not positioned as an obligatory crossing point and so did not facilitate much communication between actors in the network.
Spielman, D.J., Ekboir, J. & Davis, K.	*2009*	The art and science of innovation systems inquiry: Applications to Sub-Saharan	Explore methodologies that can help improve the study of agricultural innovation	– Complex adaptive systems'' (CAS): evolve through the combination of initial		–	–	– Description of different methodologies that can help to study the agricultural innovation systems to resolve matters related to (a) how agents interact in the

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		African agriculture.	processes and their role in transforming agriculture.	conditions, multiple interactions, trends, and random variations in agents and their interactions. – National agricultural research system (NARS) approach and Agricultural knowledge and information system (AKIS) approaches: emphasize the role of public-sector research, extension, and educational organizations in generating and disseminating new technologies. – Agricultural innovation system (AIS) approach: makes use				production, exchange, and use of knowledge and information within a network; (b) how agents respond individually and collectively to technological, institutional, or organizational opportunities and constraints; and (c) how policy changes can enhance the welfare effects of these interactions and responses.

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				of individual and collective absorptive capabilities to translate information and knowledge into a useful social or economic activity in agriculture. – Social network analysis – Innovation histories: method of recording and reflecting on innovation processes as part of wider institutional learning and change. – Cross-country comparisons: based on using benchmarks, scorecards, and indices. It is a useful tool				

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				for guiding innovation policy in many countries. – Game-theory modelling: illustrates the spontaneous processes of social self-organization and how public policy and organizational structures can affect these processes.				
Bourne, M., Gassner, A., Makui, P., Muller, A. & Muriuki, J.	*2017*	A network perspective filling a gap in the assessment of agricultural advisory system performance.	This research proposes a framework linking social network measures to information flow and capacity for collective action and applies it to personal (egocentric) networks in 11 sites within East Africa.	– Advisory systems: includes the entire set of organizations that support and facilitate people engaged in agricultural production to solve problems and to obtain information, skills, and technologies to improve their livelihoods and well-being.	– Network boundaries and actors were selected using a two-step approach: in each target country, an administrative unit was selected; each selected administrative unit was divided into high, medium and low elevation zones and from	– Rural agricultural advisory systems in eastern Africa. – Conservation Agriculture with Trees (CAWT) practices in East Africa (Rwanda, Tanzania, Kenya).	– Tanzania: 268 farmers. – Kenya: 433 farmers. – Rwanda: 383 farmers – Advisory provider (WWF, Government, KENDAT, FFS, World vision, etc.).	– 43% from Bugesera District (Rwanda), 34% from Mbarali District (Tanzania) and 6% from Machakos County (Kenya) said they consulted no one when asked whom they talk to about agricultural issues. The results show a low response rate for Bugesera and Mbarali districts. Respondents from Mbarali District named at least three actors. For Bugesera and Machakos most respondents named one

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				– Centralised approaches for transferring technologies such as training and visit. – Social Network Analysis: density, centrality, the existence of subgroups, levels of homophily and number of bridging or bonding ties. – Egocentric network.	each zone, an administrative sub-unit was selected. – Social Network Analysis: survey data, UCINET 6, calculation of density, the average degree of nodes, core-periphery, homophily and core-periphery structure. – Key actors: degree centrality, and key player Problem/Positive KPP-POS (is used to identify the type of actors that are most important for information dissemination and degree centrality for the most connected actors).			or no actors. The findings reflect the overall network densities, which can be considered low. – In all administrative units the number of bonding ties was higher than the number of bridging ties. In Bugesera and Mbarali, the highest numbers of bonding ties were observed with friends while in Machakos it was with neighbours. For the bridging ties, extension agents were found to be the most named actors in all administrative units. Respondents in Bugesera also named organisations as an important group of actors, whereas only in Machakos veterinary officers were named. – For Bugesera and Mbarali administrative units, farmers were more likely to name actors who were members of farmer groups served by the same advisory provider, than farmers from other groups or other

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					– Results were displayed in interactive maps through R-igraph package. – Analysis was carried out at two different levels. First level: at the administrative unit level, an overview of response rates and analysis of variation in response rates from the different questions used, as well as, the type of relationships (bonding and bridging ties and homophily) was completed. Second level: more detailed network analysis was carried out for each administrative sub-unit separately.			advisory providers (scores closer to 1 indicating homophily). In Machakos, the networks were homogeneous within the advisory approach (0.82) but more heterogeneous with farmers being more connected to actors outside of their group (0.78). – Lowest density was found for all sub-units within Bugesera, the highest density for all sub-units, except for Madibira Ward, was found in the Mbarali sub-units. The networks of the administrative sub-units in Machakos were slightly denser than in Bugesera but lower than in Mbarali. From all actors present in the networks only 24 had more than 11 connections. These 24 actors are considered central, as they are the most connected in the network. Most of these central actors (15) were extension agents. Only in Mbarali District were central actor's family members and friends.

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								-None of the networks were found to fit a core-periphery arrangement. -In terms of centrality, farmer group members were found to be the least important group for information dissemination. Instead, In Bugesera District almost all key actors were friends. In Mbarali District friends were also most key actors in most sub-units, while in Machakos County extension agents, family and neighbours were also prominent for key actors.
Sanchaye-eta Misra et al.	*2014*	Application of Social Network Analysis in Livelihood System Study	The study aims to analyse the complicated system of rural livings (small farmers) and the related function of rural organisations.	Their approach was focused on the introduction of the concept of "system" to describe the Sustainable Livelihood (SL) framework (DFID, 1999). Succeed by comparing the "rural living system" with common	Data were collected at the micro-level (community level) and macro-level (through focus group discussion with a set of actors). Data collected were processed using statistical and visual techniques.	– Small farmers.	– Natural assets, Social capital, physical capital, human capital, financial capital, vulnerabilities, policies, institutions and processes and livelihood strategies.	They deduced that stakeholders should make the decision for significant livelihood actions in a region and boost the innovation diffusion within the organized system.

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				attributes of the "system" to determine the system characteristics of rural livings, on which SNA is used.				
Conley and Udry	*2001*	Social Learning through Networks: The Adoption of New Agricultural Technologies in Ghana.	Analyse communication networks between small farmers in Ghana concerning the use of chemical fertilizers on new cultivation (pineapple).	Their approach was based on the Bayesian framework and SNA.	They conducted investigations with 450 people in 4 villages in the Eastern Region of the country for more than 21 months.	– Farmers. – Maize and Cassava cultivation. – Urban consumers. – Pineapple cultivation. – European market. – Agricultural chemicals (fertilisers). – Agents.	–	They discovered that geographical closeness did not ascertain that small farmer can get knowledge in an easy way (adoption of new techniques by his similars); conversely, it was the networks (restricted channel) in which farmer was engaged that allowed him to learn and innovate from new sources.
Fafchamps and Lund	*2003*	Risk-sharing networks in the rural Philippines.	Used a social network to analyse the risk-sharing behaviour of Philippine rural households.	Their approach was nearest to Udry' approach (1994), with numerous variations, and SNA.	They carried out a survey in 4 villages in the Cordillera mountains with 206 rural households. 3 interviews were carried out with each household at 3-month intervals and recorded.	– Household. – Informal institution. – Gift giving. – Informal credit. – Sales of livestock and grain. – Friends and acquaintances.	– Mutual insurance.	They discovered that shocks have a dominant effect on informal loans and gifts, but a weak effect on sales of grain and farm animals. The households receive support primarily through networks of families, friends, and acquaintances without a charge of interest on the loans used.

Author	**Year**	**Research title**	**Scope**	**Approach used**	**Method used**	**Dependent variables**	**Independent variables**	**Results obtained**
					Everyone was asked to identify several people on whom it could be dependent in case of need or to whom the respondent gives support (they called it the network of insurance). Data were collected on loans, gifts, and asset sales of each individual and all its network partners (household composition, cultivated area, professional skills, and age of head).			