Scientific Paper

Essential approaches in innovation and technology transference in the agricultural sector

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Abstract

Objective: To analyze some of the main approaches in innovation and technology transference and their application in the Cuban agricultural sector.

Materials and Methods: For the location of the bibliographical documents Google Scholar was used as documentary source, with the descriptors: innovation network, network extension, agricultural technology transference, agricultural extension systems in Cuba and technology transference in Cuba. Forty-two records were obtained.

Results: The characteristics of the traditional agricultural extension work model were approached from its deficiencies. The research proved that the concept of social networks has gained popularity in recent years and is frequently used in innovation processes. Another approached element was the information and knowledge sources in the context of agricultural innovation. The innovation networks were characterized, which have as principle enhancing the relations among the largest quantity of actors of an agrifood system, with emphasis on primary farmers.

Conclusions: The social network approach constitutes the methodological basis for the creation of new innovation and technology transference methods. The agricultural sector needs to boost technology transference and innovation schemes, based on scientific approaches and tools that achieve the visualization of the factors with higher incidence on the dynamics of introduction of scientific-technical-knowledge in productive scenarios.

Keywords: productivity, networks, agricultural innovation networks

Introduction

At present, it is calculated that throughout the world the absolute number of people affected by underfeeding or chronic lack of food has increased approximately from 804 to 821 million people in the period 2016-2018 (FAO *et al*., 2019).

Mankind continues searching for the mechanisms to reverse such complex situation, which is shown in the creation of several projects with regional and global approach. An example of it is Agenda 2030 for Sustainable Development, passed in September 2005 by the General Assembly of the United Nations. This Agenda established a transformative vision towards sustainability of the 193 member states that undersigned it, which will also be the reference guide for the work of the institutions, in order to work with this view for the next 15 years (Yépez *et al*., 2020).

In Cuba, the State spends significant money amounts in food import. The food importing company claimed that in 2020 the expenses increased by 25 % compared with the previous year. This implied an extra disbursement of 308 million dollars. The same source reported that Cuba acquires this way 80 % of the food consumed by the population. It also indicated that a strategy to reverse this situation is to accelerate all food import substitution projects and boost national production, an aspect that the Cuban government has qualified as of "national security" and which is prioritized in the economy plan (Avilleira-Cruz *et al*., 2021).

The Cuban agricultural sector, especially animal husbandry, needs to increase significantly the application of science, technology and innovation in all productive scenarios, which will influence significantly the increases of productivity levels (Cruz-Santos and Infante-Abreu, 2022). Innovation propitiates multiple benefits: economic growth, sustainable use of natural resources, besides creating the basis for reducing social disparities (Baumane-Vītoliņa and Dudek, 2020). In this scene, international evidence indicates that any region is economically more prosperous if its agents are integrated in network with innovative purposes (Alarcón-Pérez and González-Becerra, 2018). The last one is among the concepts that will be further approached in this review.

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The initially-enunciated situations could be improved, to some extent, with the application of different concepts that in recent years have emerged as paradigm for technology transference and extension which, when combined with other more specific approaches inherent to the agricultural activity, become effective strategic options to achieve substantive changes from the economic, social and environmental point of view in food production systems. Hence the objective of this review is to analyze some of the main approaches for innovation and technology transference and their applicability under Cuban animal husbandry conditions.

Materials and Methods

For the location of the bibliographic documents Google Scholar was used as documentary source with the descriptors: innovation network, network extension, agricultural technology transference, agricultural extension systems and technology transference in Cuba. A total of 42 records (table 1) were obtained. Those documents that were considered more suitable, regarding the component aspects of the review, were selected.

Results and Discussion

Social networks and their interaction with innovation and technology transference. Table 2 shows the main results related to social networks and their interrelation with innovation and technology transference obtained in Latin America and the Caribbean. Most of the studies were focused on researching and promoting the utilization of the social network approach in agricultural innovation processes.

Aguilar-Gallegos *et al.* (2016) analyzed the effects of direct or indirect interactions among 120 farmers from two questions: who do you learn from or to whom do you turn in order to obtain information or knowledge of technical and productive issues around your production unit? The results confirmed the importance of indirect links, because they allow farmers to reach better information from external sources.

Avendaño-Ruiz *et al.* (2017) focused on identifying the process of adoption and diffusion

Table 1. Total consulted records for writing the paper.

Record types	Absolute value	Relative value, %
Scientific journals	31,00	73,80
Doctoral theses	4,00	9,52
Textbooks	2,00	4,76
Other sources	5,00	11,90
Total	42,00	100,0

Source: Elaborated by the author

Table 2. Some antecedents related to social networks, innovation and technology transference.

Paper	Authors
Análisis de redes sociales para catalizar la innovación agrícola: de los vínculos directos a la integración y radialidad.	Aguilar-Gallegos *et al.* (2016)
Innovaciones tecnológicas en el sector hortícola del noroeste de México: rapidez de adopción y análisis de redes de difusión.	Avendaño-Ruiz *et al.* (2017)
La intervención en red para catalizar la innovación agrícola.	Aguilar-Gallegos *et al.* (2017)
Uso de herramientas informáticas para el análisis de redes sociales en pequeñas empresas agrícolas de Nayarit, México.	Sifuentes-Ocegueda y Sifuentes-Ocegueda (2017)
Estudio de la brecha tecnológica de los productores de aguacate de Cambita Garabitos, San Cristóbal, República Dominicana.	Brito *et al.* (2018)
Del análisis de redes a modelos económicos, un camino para evaluar intervenciones en sistemas agrícolas.	Prager *et al.* (2019)
Procedimiento de investigaciones extensión tecnológica para la alimentación sostenible de ovinos, resultados preliminares.	Herrera-Toscano y Carmenate-Figueredo (2021)

Source: Elaborated by the author

of innovations in export horticulture of northwest Mexico, taking into consideration the differences according to farmer size. The estimation of the adoption rate index indicated that large farmers are the ones who adopt such innovations earlier and are leaders in that activity, reason for which there is a technological gap between small and large farmers, stressed by economic limitations.

Sifuentes-Ocegueda and Sifuentes-Ocegueda (2017) analyzed the advantage of using computer tools in the development of social research, particularly for qualitative data analysis. In this case, the function of social networks as strategies for recruiting small agricultural farmers of Nayarit, Mexico, was used to explain the collective processes that are generated in their environment, especially regarding the incorporation and organization of labor force. Thus, groups of people with real connections and their expressions in terms of cohesion or exclusion were identified. The data generation was based on the application of a questionnaire and interviews linked to labor supply and demand, which was processed through the use of computer tools specialized in qualitative research.

Brito *et al.* (2018) showed the results of a survey carried out on 102 avocado farmers of the Cambita municipality, in San Cristobal, Dominican Republic, to determine the main factors that influenced the technology adoption level and the causes of technological gaps among the farmers of the zone.

Aguilar-Gallegos *et al.* (2017) stated that innovation processes occur among a heterogeneous group of actors, where social network analysis (SNA) is a promising tool for their analysis and understanding. It allows to design network-based interventions to catalyze such processes. Network interventions describe the process through which relational data are used to accelerate the information flow among the actors that make it up.

The above-cited study contributed to provide knowledge and evidence contributed to providing knowledge and evidence about the application and usefulness of SNA in the context of a network-based intervention to catalyze agricultural innovation. In addition, it allowed to add to the literature of SNA the study of a network at the beginning and end of the intervention of an extension model, showing the changes in the structure and indicators in a longitudinal way.

Data from goat farmers were used to generate baseline indicators and the intervention was later analyzed with a final line. The results support the usefulness of SNA to catalyze agricultural innovation and emphasize the importance of the selection of farmers and key actors to boost these processes. It is concluded with some methodological and public policy implications to improve and promote agricultural innovation.

Prager *et al.* (2019) elaborated a methodology that explores the link of social network analyses with other models, in order to strengthen the products and inputs for critical interventions. This document added value to the exploration of possible futures in topics such as policies, technologies, climate shocks and, in general, changes in socioeconomic trends.

Herrera-Toscano and Carmenate-Figueredo (2021) designed a procedure of research-technology extension for sustainable sheep feeding with local resources in Las Tunas province, Cuba, and reported the main results of its implementation. The procedure was designed in six stages (one of them consisted in the establishment of a local innovation network).

Main insufficiencies of traditional extension systems. According to Rendón-Medel *et al.* (2015), the traditional agricultural extension model shows five aspects that constitute important burdens for the introduction of technologies in productive scenarios. Among the main deficiencies they indicated, first, their lineal character. These authors concluded that the contact with scientists is not the only priority in the small farmer's needs, but the interrelation with all those social actors with whom the experts can form strategic alliances to define and make viable and sustainable technological and productive proposals. The extension worker should then facilitate the link of small farmers among them and with all the other actors that could contribute with their enterprise.

Rendón-Medel *et al.* (2015) also referred to the underestimation of non-scientific knowledge: traditional extension appears as only vehicle of transference of scientific knowledge. In many cases, farmers' contribution has been neglected.

The function of extension should not be linearly transferring what agronomists or technicians learn at the university to the farming universe and disregarding the farmer's traditional knowledge.

Extension was traditionally aimed at production alone, which propitiated a merely technical professional, without greater concern, or

knowledge about commercialization, organization or entrepreneurial management.

At present, farmer experimentation is very important to achieve an integration of traditional and scientific-technical knowledge and training of farmers on marketing and added value topics.

The lack of orientation towards farmers' demands and market demands and the obsession for a certain technological offer are also among the deficiencies of the traditional extension system indicated by Rendón-Medel *et al.* (2015). The technical contents of the programs based on a technological offer that, according to technicians, was adequate for the agricultural development strategy to be adopted, were defined beforehand. Then, with much inflexibility, the programs were implemented, disqualifying as resistant to change the farmers who did not want to adopt the whole package.

In a market context, much more flexibility is required in technical messages, adjustment to demand and to the farmers' capacities, as well as to the dynamic demands of the main markets.

The paternalistic approach under which the extension workers were educated made them believe that they were the sources of the true agricultural knowledge and that, thus, they did not have to lead, but to steer farmers, who were not capable of understanding by themselves, towards objectives and methods. Instead of advising the farmer, the extension worker thought of himself/herself as a teacher of an ignorant person. This not only inhibits the farmer's learning process, but also the extension worker's and thus, the fast advance towards new productive horizons.

It is necessary to remedy the almost exclusive orientation of traditional extension towards the individual farmer. At present, farmers should be able to become organized, to form exchange and inter-learning groups, agri-commercial enterprises. They should also create strategic alliances with other social actors from rural and city areas to face the hard competition for markets and natural resources.

Technological gaps. Rogers *et al.* (2009) proved that the diffusion of an innovation follows an *S*-shaped pattern, like a growth curve or a logistic function (fig. 1). The knowledge dissemination process occurs, generally before adoption and will be conditioned by the attitude assumed by farmers. Consequently, there is a delay between the moment in which a person finds out about the existence of an innovation and the moment in which he/she adopts it. This lapse is known as the "knowledge-attitude-practice gap" (KAP). Its shortening or reduction is the goal of many interventions.

To understand the agricultural innovation processes it is necessary to identify leader or reference farmers, figures that in the environment of the agricultural sector name all those farmers who stand out for their high innovation adoption capacity, and that is why they are usually the habitual clients of enterprises and organizations dedicated to the diffusion of innovations under the assumption that they are early adopters and opinion leaders.

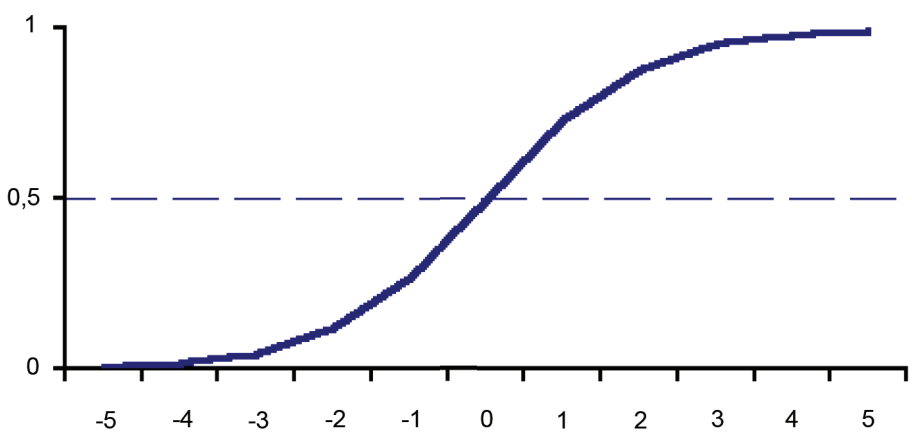

Figure 1. Curve of diffusion of innovation in the agricultural context.
Source: Valente (2005).

The KAP gap is a key concept in the theory of behavioral change, because from this it has been proven that recruiting the opinion leaders first accelerates the innovation diffusion process. In this approach, opinion leaders are a critical element and early adoption by them accelerates the diffusion of an innovation (Valente, 2005). The attempts to reach a critical mass of adopters are thus focused on recruiting opinion leaders to increase the diffusion process rate. On the contrary, the early adoption of an innovation by farmers with lower innovative capacity who, in general, are those with lower technological and economic level, would produce diffusion curves that would grow more slowly. For such reason, the critical factor in the diffusion stage lies on the method used to identify leader and reference farmers.

The approach of social network analysis and innovation networks. The concept of social networks has gained popularity in recent years and is used very frequently in innovation processes, which has allowed to understand certain phenomena with a network perspective in several areas of sciences: social sciences, physics, epidemiology, biology, among others (Olmedo-Neri, 2020). Likewise, the social network approach constitutes the methodological basis for the creation of new methods for innovation and technology transference.

The analysis of social networks allows to make emphasis on the existing relations among different entities that constitute a system (Pulgar, 2021). For example, in a social system these entities are commonly called actors or nodes. From this perspective of the social network analysis, a social environment can be represented with the use of patterns and regularities of relations established among the actors that make it up. These patterns shape what is known as structures, which in turn derive into multiple indicators of great usefulness for the analysis and evaluation of the functioning of a social network.

A network is composed by a set of actors or nodes that are joined through a group of links that represent a specific type of relation. The nodes of a network can be almost anything, although, generally, when speaking of social networks it is implicitly expected that nodes are active agents "individuals" (Aguilar-Gallegos *et al*., 2017). However, there are networks in which the nodes are represented by animals, objects, tractors, machinery, companies, cities, plant species, web pages, accounts associated to social profiles, government entities, non-governmental organizations (NGO), among others.

The nodes or actors have distinctive characteristics, commonly called attributes, which distinguish some actors from others and which explain the behavior of a set of actors, or of the network in its entirety. If the actors have attributes, the links that are established among them also have them, which allows to distinguish the level of strength or intensity of the bonds, their frequency, among others. Another important element is the type of relation that is shown from the social point of view: family, of friendship, commercial, and others.

Thus, social network analysis allows the visualization and evaluation of such bonds and of the actors that participate in the network. Precisely, the established bonds are the ones that shape networks in particular ways and where the nodes have different positions in these structures.

These characteristics of the network, of the nodes and their bonds are the primordial substrate for the social network analysis. Thus, the basic elements of any network will be the actors or nodes and the links or bonds that are established among them. This way, the presence of relational information among actors is a crucial characteristic, which also defines the network.

Besides the relational information, it is important to add a third basic element of the network, which is the directionality of the bond, for which there are non-directed and directed networks (Hanneman and Riddle, 2011). This in turn provides new elements, because through the bonds "pathways" are formed by which some type of resource can flow. In turn, these "pathways" allow to connect indirectly parts of the network that are not directly connected. Thus, resources that would seem socially distant can be reached by diverse actors.

Innovation could be defined as the partial or total changes that are introduced in the products, productive or service processes, based on scientific or practical knowledge, which generate improvements from the quantitative or qualitative point of view and propitiate advances in the economic, environmental and social aspects. Innovations can be classified into two areas: the technological ones that group product and process innovations, and the non-technological ones which comprise organizational management and marketing innovations.

The innovation network approach explicitly acknowledges that the innovation, production and

commercialization of a product cannot be carried out by only one company, but in collaboration with other agents and as result of their interaction. Network methodology, as a set of formal tools of social research, allows to know the position of actors in the network and explain, based on its relations and attributes, which are the strategic mechanisms to increase a useful participation of actors and general efficiency of the network. The study of innovation networks not only allows to diagnose the current situation of information flows among farmers, enterprises and institutions, but it also allows to place factors related to the existence of these relations, favoring the decision-making aimed at increasing such flows.

Ochoa-Ambriz *et al.* (2022) referred that the so-called network extension model (NEM) aims at utilizing the above-stated arguments, acknowledging innovation as the result of an interactive learning process that transcends the prevailing lineal vision, where research is placed as main and only means to generate innovation in the agricultural sector. This scheme can contribute to generate and strengthen the public extension model, by promoting the active participation of diverse types of actors of regional innovation systems, and has as protagonists the so-called leader farmers of innovation at local level.

Computer programs used in social network analysis. There are many computer programs used in social network analysis, which is due, among other factors, to the fact that there are increasingly more databases with high complexity level. This has allowed the extension of this type of analysis to diverse fields of science.

Some of the most used programs and the main indicators that are obtained are described below (table 3). In general, over time increase has been observed in the quantity of indicators, due to a large extent to the scientific and technological advance, which in turn will allow the performance of more integral and rigorous analyses from the scientific point of view.

Sources of information and knowledge that propitiate innovation. The information and knowledge sources in the context of agricultural innovation could be defined as the multiple objects, subjects, products and opportunities of farmers and diverse actors of an agri-food chain to acquire and transmit knowledge. Likewise, the extent of this concept comprises physical or virtual spaces, research institutes (public and private, national or international), universities or institutions specialized in technology diffusion. In this approach, all actors are important, in larger or lesser extent, to disseminate and apply knowledge (Antúnez-Saiz and Ferrer-Castañedo, 2021).

Solleir-Rebolledo *et al.* (2020) asserted that extension work is an element that facilitates the technology transference processes developed through the adoption of innovations. This activity, according to the authors is multidisciplinary, enhancer of the importance that information and knowledge have in the promotion of productive activities, and which also considers knowledge management and network management.

There are diverse information sources among which the following can be cited: enterprises, farmers, providers, buyers or competitors, research institutes (public and private, national or international), universities or institutions specialized in technology diffusion. The interactions can be materialized in joint research projects, strategic alliances, company mergers, research internships, joint patents, joint

Table 3. Programs used in social network research in the agricultural sector.

Programs	Main indicators determined	Authors
NetDraw 2.097	Nodes, relations, density, input centralization, output centralization, diffusor collector, structurers.	Cuevas-Reyes *et al.* (2016)
NetDraw v. 2.139 Ucinet v 6.0	Nodes, relations, density, input centralization, output centralization, collector diffusor, structurers, size of the largest component, network diameter, farmer-to-farmer links, degrees of input, degrees of output, radiality, integration, centralization.	Aguilar-Gallegos *et al.* (2016)
NetDraw 2.519 Ucinet v 6.617	Actors in the network, size of the network, number of links, density, loose nodes, number of components, size of the largest component.	Aguilar-Gallegos *et al.* (2017)
Ucinet	Density, degrees of centralization, centralization index.	Albán-Vallejo *et al.* (2018)

purchase or use of equipment, and both or input purchase (Velázquez-Castro *et al.*, 2018, Díaz-Canel and Delgado-Fernández, 2021).

The dynamics of an innovation system does not depend on the agents in frontier of science but on the innovation capacity of individual agents and of the system as a whole. This, in other words, means that innovation processes depend more on the existence of many agents innovating in their daily activities than on a few institutes researching in the frontier of science (Zamora, 2022).

Another interesting element approached in the research conducted by Solleir-Rebolledo *et al.* (2020) refers that for an actor who operates in the primary chain link of any product there are, at least, fifteen different information sources, besides that represented by other farmers or themselves through trial and error tests, which constitute the main innovation reference sources.

The above-cited authors also reported that, in general, farmers or ranchers resort to four learning sources: learning by doing or producing, which implies the possibility of failing and, thus, of learning; learning by interacting with input and service providers; acquiring knowledge from research institutions and, finally, from other farmers. Nevertheless, in the case of Cuba, the interaction of primary farmers with input providers is seriously restricted, mainly due to logistic limitations; in addition to the fact that this type of actor is very often an individual without juridical personality, who acts in the informal market depending on his/her interests.

In spite of the above-stated facts, Aguilar-Ávila *et al.* (2010) identified a strong preponderance of farmers as learning source and suggested that they are the basis of knowledge on which practically most of the innovation process is supported, which is also tacit, because the knowledge concerning the dexterities acquired from direct experience in productive and management activities, are not codified in publications, courses and databases with possibility of being acquired. Thus, the best way to transfer this type of knowledge is through the promotion of mechanisms of personal contact and of direct communication among the actors and the development of trust relations.

Figure 2 summarizes the main information and knowledge sources which, according to the criterion expressed by the above-cited authors, exist or could be utilized in Cuba to encourage agricultural innovation at local level. In this case, the primary farmer should be the main subject, because he/she decides what technologies are introduced or not in his/her scenarios.

In Cuba, this reasoning became more real since 2008, through the Decree-Law 259, which allowed the delivery of idle state lands in usufruct, as alternative to the their decapitalization and the imperative need to substitute food imports, permitting the increase of land in the hands of the non-state sector (Soulary-Carracedo *et al.*, 2020).

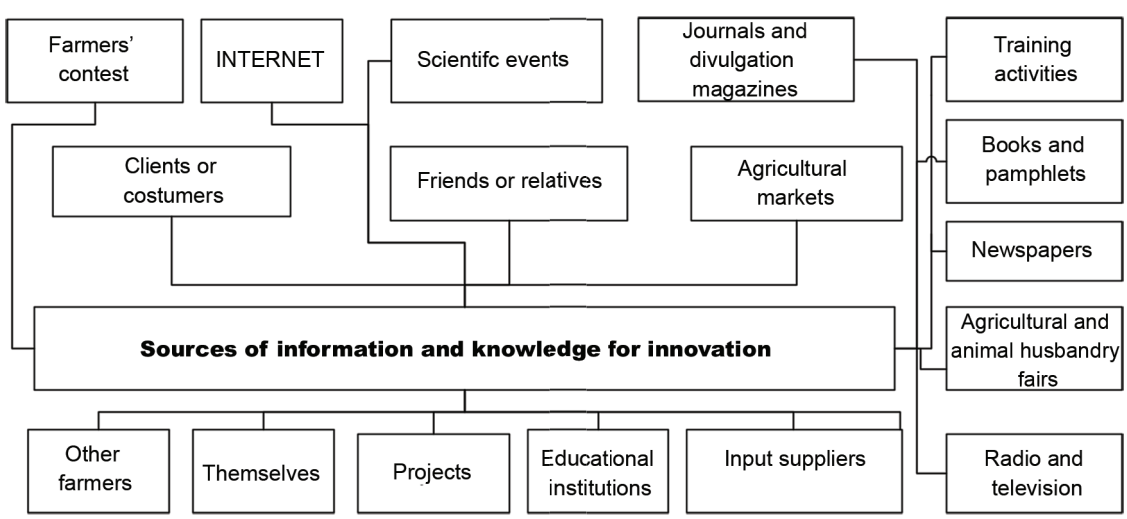

Figure 2. Available sources for agricultural innovation at local level.
Source: Elaborated by the author

Conclusions

The social network approach constitutes the methodological basis for the creation of new innovation and technology transference methods. The agricultural sector needs to promote technology transference and innovation schemes, based on scientific approaches and tools, which achieve the visualization of the factors that exert higher incidence on the dynamics of introduction of scientific-technical knowledge in productive scenarios.

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Conflict of interests

The author declare that there is no conflict of interests.

Authors' contribution

- Javier Antonio Herrera-Toscano. Conducted the documentary research about aspects related to innovation and technology transference, which, after their processing, were included in this manuscript.

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