Factors that influence the operation and communication of governmental support programs among small-scale bovine dairy farmers in central Mexico †

[Factores que influyen en el funcionamiento y comunicación de los programas gubernamentales de apoyo entre productores en pequeña escala de ganado bovino lechero en el centro de México]

Guillermo Gómez-Espinoza[1], Dalia Andrea Plata-Reyes[1], Carlos Manuel Arriaga-Jordán[1], Adolfo Armando Rayas-Amor[2] and Carlos Galdino Martínez-García[1*]

[1]Instituto de Ciencias Agropecuarias y Rurales (ICAR). Universidad Autónoma del Estado de México (UAEMéx). Campus el Cerrillo Piedras Blancas. C.P. 50090, Toluca, Estado de México, México. E-mail: cgmartinezg@uaemex.mx
[2]Universidad Autónoma Metropolitana, Unidad Lerma. División de Ciencias Biológicas y de la Salud. Departamento de Ciencias de la Alimentación. Av. De las Garzas No. 10, Colonia El Panteón, C.P. 52005. Lerma de Villada, Estado de México, México.
**Corresponding author*

SUMMARY

Background: Social networks that comprise farmers, institutions, researchers, and outreach services are strategic for rural development. It is necessary to identify factors that promote or restrict the participation of small-scale dairy farmers in governmental support programs and their dynamics in the social network in the communication and dissemination of information. **Objective:** To identity factors that influence the operation and communication of governmental support programs among small-scale dairy farmers. **Methodology:** A questionnaire was applied to 213 farmers. For identifying differences between farmers who receive governmental supports (Group 1, *n*=93) and those who do not (Group 2, *n*=120), a Mann-Whitney U test was conducted. Variables associated for obtaining governmental support were identified through a binary logistic regression analysis. The key actors in information dissemination were found through a social network analysis of the 93 farmers who receive governmental supports. **Results:** Significant differences ($P<0.05$) were found between groups. The farmers with governmental supports had larger production units, higher technology level and perceived that it was less difficult to carry out the procedures to access such programs. Variables related to total hectares, number of feeding techniques, daily sales of milk, and perception of difficulty were associated to participation in governmental support programs. **Implications:** The key actors in the social network were the farmers with the largest farms, greater availability of economic resources and links with other farmers or officials from governmental institutions and organizations; however, farmers with restricted liquidity and smaller farms, but who generate links in the network were also recognized as key actors. **Conclusions:** The participation of farmers in governmental support programs was associated to the size of the production unit, perception of simplicity or difficulty to carry out the legal procedures, in addition to links with key actors who make the legal procedures easy.
Key words: small-scale dairy farms; governmental programs; key actors.

RESUMEN

Antecedentes: Las redes sociales que integran agricultores, instituciones, investigadores y servicios de extensión son estratégicas para el desarrollo rural. Es necesario identificar los factores que promueven o restringen la participación de pequeños productores lecheros en programas gubernamentales de apoyo, así como su dinámica en la red social para la comunicación y diseminación de información. **Objetivo:** Identificar los factores que influyen en el funcionamiento y comunicación de los programas gubernamentales de apoyo entre pequeños productores lecheros. **Metodología:** Se aplicó un cuestionario a 213 productores. Para identificar diferencias entre productores que reciben apoyos gubernamentales (Grupo 1, n=93) y aquellos que no (Grupo 2, n=120), se realizó una prueba U de Mann-Whitney. Las variables asociadas a la obtención de apoyos gubernamentales se identificaron mediante un análisis de regresión

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ORCID = C.G. Martínez-García: http://orcid.org/0000-0001-9924-3376

logística binaria. Los actores clave en la difusión de información se determinaron mediante un análisis de redes sociales aplicado a los 93 productores que reciben apoyos gubernamentales. **Resultados:** Se encontraron diferencias significativas ($P<0.05$) entre los grupos. Los productores con apoyos gubernamentales tenían unidades de producción más grandes, mayor nivel tecnológico y percibieron menos dificultad para realizar los trámites de acceso a estos programas. Variables como "hectáreas totales, número de técnicas de alimentación, venta diaria de leche y percepción de dificultad" estuvieron asociadas a la participación en programas de apoyo gubernamental. **Implicaciones:** Los actores clave en la red social fueron productores con superficie de terreno más grande, mayor disponibilidad de recursos económicos y vínculos con otros productores o funcionarios de instituciones gubernamentales; no obstante, también se reconocieron como actores clave a productores con menor liquidez y predios más pequeños, pero que generan conexiones dentro de la red. **Conclusiones:** La participación de los productores en programas gubernamentales de apoyo estuvo asociada al tamaño de la unidad de producción, la percepción de facilidad o dificultad para realizar trámites legales y los vínculos con actores clave que facilitan estos procesos.
Palabras clave: pequeñas explotaciones lecheras; programas gubernamentales; actores clave.

INTRODUCTION

Bovine dairy production systems in central Mexico contribute to food security, generate full-time employment and daily income and contribute to alleviating poverty in rural families (Espinoza-Ortega *et al.*, 2007). Bovine dairy production systems represent up to 78% of farms and contribute 37% of total milk production at national level (Martínez-García *et al.*, 2021). However, despite their importance, small-scale bovine dairy production systems face several problems, i.e., small plots, low milk yield, little daily earnings, restricted access to credits, poor incorporation of new technologies (Martínez-García *et al.*, 2015), aspects that must be evaluated since agriculture and livestock farming contribute to the economic stability and growth of farmers by reducing inequalities in rural areas (Martínez-García *et al.*, 2015). Other problems in the small-scale bovine dairy production systems are regarded to the lack of valid documents to participate in the programs, and no information regarding government services (Ávila-Foucat, 2017). Farmers in the face of a high-pressure market, they perform badly and scarcely grow, lose resources, job posts and farmers may even abandon the activity (Romo-Bacco *et al.,* 2014; Salinas-Martínez *et al.*, 2020).

The characterization of small-scale bovine dairy farmers has allowed identifying technological preferences and generating strategies to improve the extension services (Martínez-García *et al.,* 2012; Martínez-García *et al.*, 2015). It has been observed that small-scale bovine dairy farmers are mainly influenced by other farmers, relatives or friends, to adopt new technologies (Martínez-García *et al.*, 2015; Plata-Reyes *et al.* 2025). The social networks that small-scale bovine dairy farmers build within their communities have an important role in communicating and disseminating information (Junjian *et al.*, 2020). Social capital favors resilience against social and economic challenges (Meij *et al.*, 2020), while social networks that comprise farmers, institutions, researchers and outreach services are strategic for rural development (Gan *et al.*, 2018).

According to de Souza *et al.* (2021) several studies (Stokes *et al.*, 2007; Gonçalves *et al.*, 2008; Heinrichs *et al.*, 2013; Ervilha & Gomes, 2017; Simões *et al.*, 2020) mention that the diffusion of information and innovation, and technical assistance is a determinant of increased production, income, competitiveness in the milk production chain; therefore, the understanding of social networks or how the interactions between farmers and within farmers and other actors affect production. The analysis of social networks as a strategy for planning and monitoring could identify the position of farmers in the network structure, and thus characterize those who are more central and those who are more peripheral in the diffusion of information, knowledge, and technologies. The analysis of social networks could be empirically used to understand the factors which influence diffusion of information, knowledge and technologies aimed at improving the efficiency in milk production (Campos *et al.*, 2020; Simões *et al.*, 2020; Valente, 2010; de Souza *et al.*, 2021). Strategies focused on enhancing the diffusion of innovations among dairy farmers could increase agricultural productivity and reduce inequalities such as lower incomes for smaller producers. Horizontal policies aiming at creating a critical mass of adopters willing to cooperate with each other in the funding of the new technology might be more effective to speed diffusion (Belik, 2015, Simões *et al.*, 2020).

Diffusion can be seen as the process which an innovation is communicated through certain communication channels over a certain period among the members of a social network (Rogers, 2003) that could be individuals, companies or governments. An Innovation is an idea, practice, or object that is new to individuals or organizations and innovations are mostly meant to improve and promote the quality of processes or products. Implementation of innovations is however always portrayed as a challenging task.

Innovation diffusion is a process where newly developed technologies or innovations are communicated to stakeholders through different channels of communication. Innovations may include technologies, processes or ideas perceived as new in the community. An Innovation is said to has successful diffusion when it begins with a persuasion to a group of individuals about the advantages of the innovation followed by adoption of the innovation by the individuals, implementation of the innovations and finally confirmation (Shahrina *et al.*, 2014).

In this context, it is necessary to identify factors that promote and restrict the participation of small-scale bovine dairy farmers in governmental support programs and key actors and their dynamics in the social network in the communication and diffusion of information. Therefore, the aim of this research was to identify factors that influence the operation and communication of governmental support programs for small-scale bovine dairy farmers.

MATERIALS AND METHODS

Study area

The research study was carried out in the Municipality of Aculco, located in the northwest (20°06'00.0"N 99°50'00.0"W) of the State of Mexico, Mexico, it presents a temperate weather, annual mean temperature of 13.2° C (4° C to 22° C), annual mean rainfall of 850 mm (700 to 1000 mm). The main economic activities of the municipality of Aculco, State of Mexico; are livestock farming, agriculture, industry, and tourism. Agriculture activities include corn, beans, fava beans, wheat, oats, and vegetables such as lettuce, carrots, radishes and fruit orchards. Industry is represented by the manufacturing of clothing, steel processing and quarry crafts. Tourism has become a relevant activity due to Aculco's designation as a *Pueblo Mágico* (Magic Town), attracts visitors to its natural and architectural attractions, such as its waterfall and colonial buildings (DATA México, 2025).

Aculco is largely characterized by small-scale bovine dairy production systems considering the land size of the farms, 95.8% of the dairy farms show up to 20 hectares per farm (INEGI, 2022a); it has 16,482 bovine dairy cattle heads (INEGI, 2022b), which place it seventh in the State of Mexico (INEGI, 2022b). Dairy production in the area started in the 1960's, and it has had high economic dynamism, boosted by governmental investment on infrastructure for irrigation, roads and improvement of forage production, and the opening of the market owing to the development of cheesemaking activities that commercialize their products in the region and in large cities in the center of the country such as Mexico City (Crespo *et al.,* 2014).

Data collection

Although the municipality of Aculco comprises 66 communities, only 26 were considered in the study. The farms into the communities with the 3 to 35 five dairy cattle heads were chosen for the study, the same criteria was applied in all 26 communities. The identification of the 213 participant farmers was carried out by means of a non-probabilistic snowball sampling method (Stivala *et al.*, 2016) in which initial participants recruit others with similar traits, resulting in a growing "snowball" sample within the social network. It is used for hard-to-reach potential participants, and the referral process is repeated until the desired sample size is reached, in our study, only 213 participants met the criteria of having a herd size of 3 to 35 dairy cows. The participant farmers in the study were divided into two groups, considering farmers with governmental support as group 1 (G1= 93) and farmers with no governmental support as group 2 (G2=120). Data collection was carried out over two phases.

Data collection; first phase

The first phase was carried out from August 31st, 2018, to February 7th, 2019. In order to gather the information a questionnaire was applied to 213 farmers. Such questionnaire was divided into four sections; the first one collected information on the framers' characteristics; the second, basic information on the farm; the third section focuses on the technological level of the farm (Table 1). The fourth and final section accounts for the farmers' perception on the usefulness of governmental support programs, difficulty to access and restrictions the farmers perceive when undertaking the legal proceedings.

Data collection; second phase

The second phase was carried out from June 19th to September 5th, 2019. Additionally, to the questionary of the first phase, a structured questionnaire was applied to the 93 farmers who have received governmental support for identifying the farmers' social network, institutions and organizations, as well as the sort of support received. The first section of the questionnaire gathered information of the links between farmers; the second phase, on institutions and individuals which take part in the operation of governmental support such as regional delegation (RD) staff, municipal town council [*ayuntamiento*] (AYTO) personnel, farmer organizations (FOR), government officials (GO), and staff of the party in power (PP). The third section, on the kind of support from governmental programs, such as: machinery and

equipment, infrastructure, heifers and semen, seeds, agrochemicals and consultancy on maize production, and veterinary advice, the fourth section, accounted for the farmers' perception of the usefulness of governmental support programs, difficulty to access and restrictions the farmers perceive when undertaking the legal proceedings. The two phases of the questionnaire were applied at the farmers' households in the time they had free after forage cutting, milking and herding.

Data Analysis

Comparison of the groups and their characteristics

The farmers (n=213) were divided into Group 1, farmers who receive governmental supports (n=93), and Group 2, farmers with no governmental supports (n=120). In order to find out the differences between groups regarding the variables that describe the characteristics of farmers, production units, technological level, usefulness and difficulty to access governmental support programs (Table 2), the nonparametric Mann-Whitney U test was performed (Ullah *et al.*, 2020), since the variables did not show normal distribution with Kolmogorov-Smirnov test (Field, 2013). Variables usefulness and difficulty were measured on a five-point Likert-type scale, from 1 = not useful to 5 = very useful, and from 1 = not difficult to 5 = very difficult, respectively (Joshi *et al.*, 2015). Variables price per milk liter and weekly income were expressed in USD; at 19.60 MXN per 1 USD dollar over the period of study, considering the exchange rate by Mexico's Central Bank (*Banco de México,* 2020).

Variables with an influence on obtaining governmental supports

To identify the variables that influence obtaining governmental supports, a binary logistic regression (Field, 2013; Martínez-García *et al.*, 2016) was carried out. The variables were identified after the following model:

$$P(Y) = 1 / 1 + e^{-(\beta 0 + \beta 1X1 + \beta 2X2 + , \ldots , + \beta nXn ,)}$$

Where:
Y: Dependent variable; $P(Y)$: probability that Y occurs; $\beta 0$: intersection Y, equivalent to the model's constant $\beta 1, \beta 2, \ldots \beta n$: unknown parameter, estimated for each explanatory variable; $X1$, $X2$, . . . , Xn: explanatory variables .

In the model, the obtaining of governmental support is dealt with as a binary variable. Therefore, the response variable (Y) corresponds to: Y=0, no governmental support, and Y=1, governmental support. The 20 explanatory variables were the same as those in group comparison (Table 2). Logistic regression analysis asks for a minimum ratio of 10 observations per each variable included in the model (Martínez-García *et al.*, 2016); however, there is a sufficient sample size (n=213) in relation to the 20 explanatory variables

Table 1. Sections and variables included in the questionnaire.

Questionnaire section	Variables included in each section
First section: farmers' characteristics	Farmers' age, schooling, experience, and the links between farmers.
Second section: characteristics of the farms	Family labor force, hired labor force, total hectares, hectares cultivated with maize, hectares with pastures, facilities (barn, machinery shed, warehouse, silage area and calf hutches), herd size, daily milk yield per cow, daily milk sales, price of milk per liter and weekly income (income from selling milk subtracting feeding costs), institutions and individuals which take part in the operation of governmental support such as regional delegation (RD) staff, municipal town council [*ayuntamiento*] (AYTO) personnel, farmer organizations (FOR), government officials (GO), and staff of the party in power (PP).
Third section: technological level of the farm	Agricultural techniques (n=14): use of manure, chemical fertilizer, native seeds, improved seeds, irrigated pastures, seasonal pastures, stub, plowing, seed drill, tiller, hammers mill, forage harvester, baler and forage chopper. Management technologies (n=7): tagging, dehorning, mechanic milking, electric fence, records on estrus, parity, and milk yield per cow. Feeding technologies (n=5): commercial concentrate, hay, silage, cut-and-carry pasture and grazing pasture. Health and reproduction technologies (n=8): veterinary services, deworming, control of brucellosis and tuberculosis, udder cleaning, nipple sealing, mastitis diagnosis and artificial insemination.

selected. The 20 explanatory variables were included in the model; however, to eliminate those variables that contribute least to the predictive capability of the model, a backward stepwise analysis using likelihood radio method was conducted. The measurements of the model goodness were the R^2 of Hosmer-Lemeshow, of Cox and Snell and Nagelkerke. (Field, 2013). To interpret the logistic regression, the value *Exp b* was used as an indicator of a change in odds resulting from a unit change in the predictor (Field, 2013). Statistical analyses of the first phase were carried out with SPSS version 22.

Analysis of the second-phase data Social network analysis (SNA)

To identify the communication network between the farmers and agencies in charge of operating governmental support programs, a Social Network Analysis (SNA) was carried out with 93 farmers. SNA allows finding out the structure, relationship and information flow between various actors (Rudnick *et al.*, 2019), and in like manner, learning how a community behaves and how it can create social and political capital (Henning *et al.*, 2019).

To analyze the communication network between the actors, a 2-mode matrix was produced; it represents connections between the various sets of actors (Carolan, 2014). The farmers were placed in the rows, whereas institutions and organizations in the columns. To produce the matrix, number "1" indicated presence, while "0", absence of link. To protect the identities of the individuals and institutions in the matrix, alphanumeric codes were created (Table 4). To identify the links and key actors, the following indicators were calculated: i) *network density*, which indicates the communication degree in the network (Carolan, 2014; Yang *et al.*, 2017); when density value approaches 1, it indicates a densely concentrated network; while if this value approaches zero, it is a disconnected network (Rudnick *et al.*, 2019). ii) *Centrality degree*, it corresponds to the number of connections with an actor and indicates whether there is domination by some nodes. iii) *intermediation degree*, it indicates that actors are mediators of relationships between actors who are not directly in contact with the network (Carolan, 2014; Yang *et al.*, 2017).

For the purpose of identifying similarity or difference between key farmers (n=11) and the rest (n=82), all of which receive governmental supports (Table 5), the mean values of the variables that describe the characteristics of farmers, characteristics of farms, technologies utilized, perception of usefulness of governmental support and difficulty of the processing were compared with the mean values of each of the key farmers (n=11). To identify the sort of governmental support the farmers receive, attribute matrices were created. For each farmer, a number was codified for the sorts of support received, while an identification figure for each node was included in the network graph (Figure 1). SNA was carried out with Ucinet 6 for Windows; the graph was generated with NetDraw.

RESULTS

First phase: comparison of farmer groups

The variables that describe the farmers' characteristics did not present significant differences between groups (P>0.05). Most of the variables (n=10) that describe the characteristics of the farm presented significant differences (P<0.05) between groups (Table 2). This way, the farmers who receive governmental supports (Group 1) had larger farms, which produce more and generate higher incomes. Farmers in Group 1 had the widest technology availability in the farms. Furthermore, significant differences (P<0.05) were observed between groups regarding perception of usefulness and difficulty. Group 2 farmers consider governmental support more important, though they notice greater difficulty to undertake the proceedings to ask for governmental supports.

Limits for processing the supports

Farmers in Group 2 indicated that they did not hear about calls (53%); they did not complete the process due to lack of time and economic resources to be able to afford the complementary funds the program requires (19%); support programs are linked to a political party (14%); they were never explained why they did not receive the support (9%); governmental agencies report insufficient funds or farmers lose documents (3%); they were unable to locate the property deed (2%); and, lack of interest in participating (2%). Furthermore, farmers in Group 2 expressed that restrictions at the moment of undertaking the processing are: inaccurate information and the period for the process is very short (38%); they need to invest time and money, not always available, and having a lot of documents (20%); discrimination, as the intervention of another person in the proceedings is fundamental (19%); supports are allotted to farmers close to authorities, institutions or parties in power (12%); and, it is exhausting to pursue these proceedings for up to four years in a row without receiving support (8%).

Variables that influence the obtaining of governmental programs

In Table 3, it is noticed that only four of the 20 analyzed variables presented significant association (P<0.05) in obtaining governmental support. The variables were total hectares, feeding technologies and

daily milk sales; however, the farmers' perception regarding difficulty to carry out the process exhibited the highest Exp *b*. The probability that farmers do not ask for governmental support increases 57 units in farmers who considered it was difficult to carry out the process.

Second phase: social network analysis

Social network in the management of governmental support programs

The communication network composed of farmers, institutions and agencies in charge of operating these support programs had a density of 0.168, which indicates it is a disconnected network, since few actors control the information inside it. Farmers J11, JTS, MRS and RHP (Table 4) showed the highest centrality degree; that is to say, they have the most connections and are in control of the information inside the network. For their part farmer JTS had the highest intermediation degree; this actor may generate links between actors who are not connected to the network. Characteristically, farmers J11, JTS, MRS and RHP are members of livestock organizations, the committee for irrigation water and inseminators in the study area; whereas the rest of the key farmers have links (a brother and a friend) who participate in livestock associations and perform administrative functions for the community (delegate), which has made it easy for them to access information on calls for governmental support programs.

As regards institutions and organizations, staff with the regional delegation (RD) that provides the support had the highest degree of centrality and intermediation, they are followed by personnel from the town council (AYTO) and the farmers' organization (FOR1) (Table 4). The actors RD, AYTO and FOR1 had the most connections and were the main actors in information communication inside the network. In like manner, they might generate links between actors not connected to the network.

Table 2. General characteristics and group comparison.

Variable	Group 1 With support (*n*=93)		Group 2 No support (*n*=120)		
	Mean	SD[1]	Mean	SD[1]	*P*[2]
Farmer's characteristics					
Age (years)	52.8	14.6	51.4	15.87	0.501
Schooling (years)	6.7	3.4	6.2	3.46	0.260
Experience (years)	31.9	16.8	27.5	16.99	0.053
Farm's characteristics					
Family labor force (n)	1.6	1.1	1.5	1.16	0.632
Hired labor force (n)	2.8	5.5	0.5	1.13	<0.001
Total hectares (ha)	8.4	11.9	2.9	3.09	<0.001
Hectares for maize	4.8	5.3	1.9	2.07	<0.001
Hectares for pasture	1.4	1.8	0.6	0.88	<0.001
Infrastructure (n)	2.9	1.4	2.0	1.36	<0.001
Herd size (head)	19.3	12.2	11.2	7.22	<0.001
Daily production per cow (L)	13.9	5.4	11.7	5.27	<0.002
Daily milk sales (L)	113.7	90.5	58.7	46.65	<0.001
Milk liter price (USD[3])	0.3	0.0	0.2	0.01	<0.001
Weekly income (USD)	97.9	151.1	47.5	77.41	<0.001
Technologies utilized					
Agricultural technologies (n)	9.1	4.1	6.9	5.17	<0.003
Management technologies (n)	3.7	1.9	2.8	2.13	<0.002
Feeding technologies (n)	4.6	1.6	3.6	1.83	<0.001
Health and reproduction technologies (n)	5.5	2.1	4.5	2.53	<0.012
Perception of governmental support programs					
Usefulness of supports[4]	4.9	0.3	4.9	0.13	<0.034
Difficulty to receive them[5]	3.7	1.3	4.8	0.49	<0.001

[1]SD=Standard Deviation, [2]*P*= Mann-Whitney U test significance (*P*<0.05), [3]1USD= 19.60 MXN., [4]Degree of usefulness: 1=not useful; 2=little useful; 3=useful; 4=quite useful; 5=very useful. [5]Difficulty degree: 1=not difficult; 2=slightly difficult; 3=difficult; 4= quite difficult; 5=very difficult.

Table 3. Variables that influence participation in governmental support programs.

Participation or not in governmental programs	B[1]	SE[2]	*P*[3]	Exp *b*	95% CI[4] for Exp *b* Lower	Upper
Constant	-3.269	0.578	0.001	0.038		
Total hectares	0.126	0.053	0.017	1.134	1.022	1.258
Feeding technologies	0.237	0.114	0.038	1.268	1.014	1.585
Daily milk sales	0.008	0.004	0.025	1.008	1.001	1.016
Difficulty to process the support	4.056	1.096	0.001	57.724	6.738	494.520

[1]B=Beta values, [2]*SE*=Standard Error, [3]*P*= Logistic regression significance ($P<0.05$), [4]CI=Confidence interval.
Note: R^2=0.396 (Hosmer and Lemeshow), 0.423 (Cox and Snell), 0.567 (Nagelkerke).

Table 4. Centrality and intermediation degree between farmers, institutions and agencies in charge of managing governmental support programs

Actors	Centrality degree (%)	Intermediation degree (%)	Observations
Farmers			
J11	71.4	12.0	A representative of FOR1[3].
JTS	57.1	45.0	Agronomist and inseminator in the region.
MRS	57.1	20.0	Member of the Committee for irrigation water.
RHP	57.1	4.5	Member of the directive board of POR1[3].
AGM	42.9	2.3	Milk farmer
JRS	42.9	2.7	Brother of the above, member of the committee for irrigation water, he helped in the process.
JP1	42.9	1.2	Friend of the staff of the government agency in charge of the support program
JER	42.9	3.3	Municipal delegate of the community.
MVR	42.9	2.3	Linked to farmers organizations and governmental institutions.
MDV	42.9	0.5	Participates in farmers organizations and is linked with personnel of a political party.
SGS	42.9	1.5	Municipal delegate of the community.
Institutions and organizations			
RD[1]	55.9	57.7	Staff with the regional delegation.
AYTO[2]	22.6	21.2	Personnel in the town council.
FOR[3]	20.4	21.5	Farmers organization.
GO[4]	14.0	9.6	Government officials.
FOR3[5]	9.7	2.0	Farmers organization.
PP[6]	8.6	2.1	Staff with the political party in power.
FOR2[7]	3.2	0.1	Farmers organization.

[1]RD=Regional delegate staff; [2]AYTO= personnel with the town council; [3]FOR1=Farmer organization; [4]GO=government officials; [5] FOR3= Farmer organization, [6]PP=Personnel with the political party in power; and, [7] FOR2= Farmer organization.

Table 5 presents the general characteristics of the 11 key farmers that communicate the information regarding governmental support programs. As regards schooling, farmers J11, AGM, JRS and JP1 only have complete and incomplete elementary, and also complete secondary, and the most experience as dairy farmers, they have larger farms and higher technological level, as indicated by the values of the variables that describe the characteristics of the farm and technologic level are above the sample mean (n=82).

The rest of the key farmers, JTS, MRS, RHP, JER, MVR, MDV and SGS, are the youngest farmers, they hold complete elementary and secondary, JTS holds university studies. The values of the variables that describe the characteristics and technological level are similar to the rest of the farmers (n=82), unlike key farmers MDV and SGS, owners of small farms, as the values of the variables that describe the characteristics of the farm are below the mean of the rest of the farmers (n=82). The 11 key farmers consider governmental support very important; however, they admit that the process to obtain support may range from not so difficult to very difficult (Table 5).

Table 5. General characteristics of key farmers who communicate information inside the network.

Variable	J11	JTS	MRS	RHP	AGM	JRS	JP1	JER	MVR	MDV	SGS	*n*=82 Mean
Farmer's characteristics												
Farmer's age (years)	64.0	49.0	50.0	46.0	46.0	59.0	76.0	47.0	44.0	39.0	54.0	53.0
Schooling (years)	3.0	17.0	6.0	9.0	9.0	6.0	1.0	9.0	6.0	9.0	6.0	6.7
Farmers experience (years)	49.0	40.0	35.0	11.0	20.0	40.0	55.0	41.0	35.0	25.0	30.0	31.55
Farm's characteristics												
Family labor force (n)	2.0	5.0	1.0	2.0	4.0	2.0	2.0	1.0	1.0	1.0	1.0	1.6
Hired labor force (n)	4.0	3.0	1.0	1.0	2.0	4.0	4.0	4.0	1.0	1.0	1.0	1.0
Total hectares (ha)	30.0	7.0	1.5	8.0	15.0	9.0	24.0	5.0	4.0	1.0	3.0	8.3
Hectares for maize (ha)	28.0	6.0	0.5	7.0	10.0	7.0	18.0	4.0	3.0	0.5	2.0	4.5
Hectares for pasture (ha)	2.0	1.0	1.0	1.0	5.0	2.0	6.0	1.0	1.0	0.5	1.0	1.5
Infrastructure (n)	4.0	3.0	3.0	2.0	4.0	4.0	4.0	1.0	2.0	1.0	2.0	3.0
Herd size (head)	35.0	12.0	16.0	19.0	27.0	32.0	35.0	22.0	12.0	8.0	7.0	19.0
Daily milk yield (L)	19.0	14.0	18.0	14.0	17.0	18.0	18.0	13.0	20.0	8.0	15.0	14.0
Daily milk sale (L)	300	100	90	170	200	300	350	175	140	30	30	106
Price per milk liter (USD[3])	0.33	0.31	0.30	0.31	0.30	0.30	0.31	0.31	0.30	0.32	0.27	0.29
Weekly income (USD)	696.4	214.3	186.4	364.3	421.4	632.1	750.0	375.0	290.0	67.5	56.8	219.3
Technologies utilized												
Agricultural technologies (n)	13.0	11.0	12.0	10.0	10.0	11.0	12.0	13.0	10.0	9.0	12.0	9.0
Management technologies (n)	7.0	4.0	6.0	4.0	5.0	5.0	6.0	6.0	3.0	1.0	3.0	4.0
Feeding technologies (n)	6.0	5.0	4.0	5.0	5.0	4.0	5.0	4.0	5.0	5.0	4.0	5.0
Health and reproduction technologies (n)	8.0	7.0	6.0	6.0	5.0	6.0	7.0	8.0	4.0	5.0	9.0	5.0
Perception of governmental supports												
Usefulness of the supports[1]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
Difficulty to process the supports[2]	4.0	5.0	4.0	3.0	5.0	3.0	3.0	2.0	3.0	5.0	2.0	3.8

[1]Usefulness degree: 1=not useful; 2= slightly useful; 3=useful; 4=quite useful; 5=very useful.
[2]Difficulty degree: 1=not difficult; 2=slightly difficult; 3=difficult; 4=quite difficult; 5=very difficult.

In Figure 1, it is noticed that 11% of the farmers that received governmental support are not linked to the network (left side nodes). The farmers expressed they are not supported by personnel in any institution or organization to process the supports and stated that obtaining supports depends on timely and duly undertake the process. The sort of supports these farmers applied the most for were related to machinery and equipment.

Eighty-nine percent of the farmers are linked to the network and obtaining governmental support has taken place by means of the operation of personnel from institutions and agencies. The farmers with the most links with institutions and organizations have obtained most of the supports; for instance, J11, RHP, AGM, JRS, JER and MVR. The supports these farmers have received is machinery and equipment, infrastructure, heifers, semen, advice on maize production and veterinary advice.

Staff with the regional delegation (RD) assisted most of the farmers, they were followed by town council personnel (AYTO). These institutions aided the farmers over the process to obtain machinery and equipment, and maize production. FOR1 also had an important role in the process to obtain infrastructure, machinery and equipment, heifers and semen, maize production and veterinary advice.

DISCUSSION

First phase: comparison of farmer groups

Farmers in both groups shared characteristics in common such as age, schooling and years of experience in dairy production; however, the farmers who receive governmental support (Group 1) commonly have a greater capitalization in terms of availability of hectares, herd size, milk yield and income from milk sales, infrastructure and technological level. Kiryluk-Dryjska *et al.* (2020) and de Roo *et al.* (2019) indicate that governmental supports are mainly allotted to farmers with greater capitalization, development and management capacity.

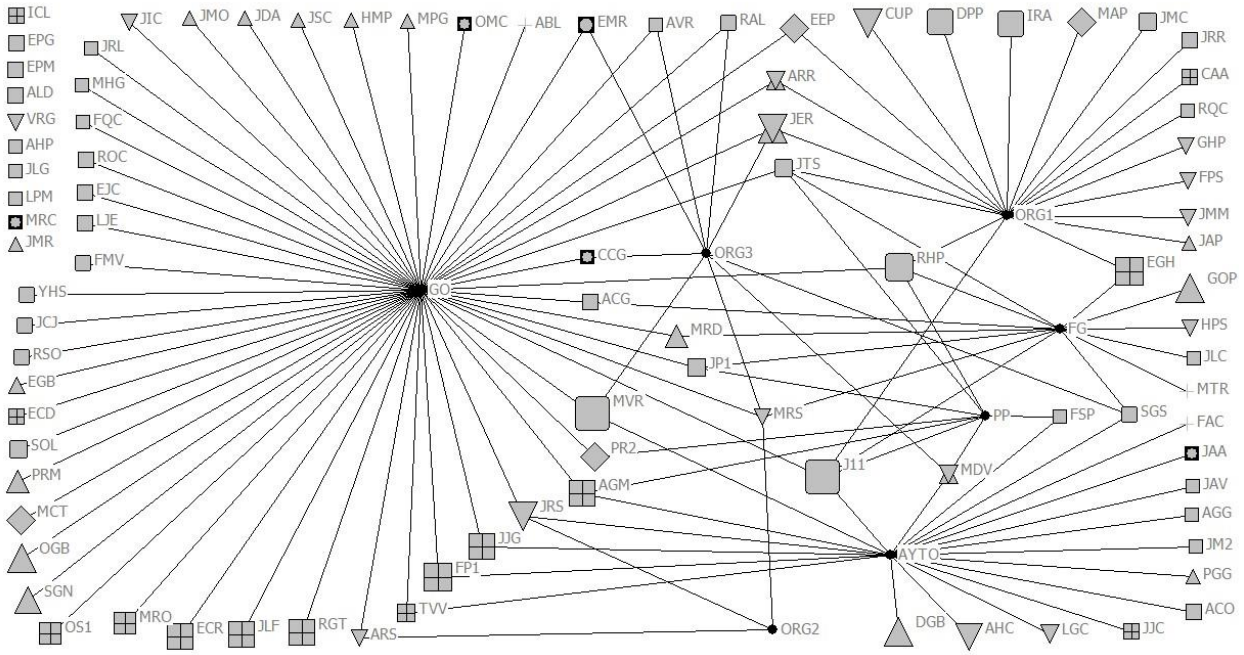

Figure 1. Social network of farmers, institutions and organizations in charge of operating governmental support programs. Institutions and organizations (black nodes). Farmers who receive support (gray nodes). Node size, proportional to the number of supports: large node 8; small, 1. Node figure, according to sort of support: machinery and equipment (square). Maize production (triangle). Machinery and equipment-maize production (crossed square). Machinery and equipment-infrastructure (inverted triangle). Infrastructure (circle in box). Machinery and equipment-infrastructure-heifers and semen-maize production (diamond). Heifers and semen (plus sign). Machinery and equipment-infrastructure-heifers and semen (opposing triangles). Various, 2 to 5 sorts in machinery and equipment, infrastructure, heifers and semen, maize production, veterinary advice (rounded squares).

Capitalization and adoption of new technologies by dairy farmers are some of the goals of the governmental programs (Martínez-García *et al.*, 2012). Therefore, the higher technological level of Group 1 may be attributed to applications for governmental supports and the greater economic liquidity that enables them to invest on new technologies (Harris, 2018; Ullah *et al.,* 2020).

Farmers in both groups stated that governmental supports are "very useful" for the farm, which encourages a better disposition in the farmers to participate (Liu *et al.,* 2019); however, the greatest difficulty perceived by farmers in Group 2 to perform the process to apply for the support may be related to not being aware of the calls, too many steps in the process, lack of experience, availability of economic resources, time requirements, political issues, lack of operators, lack of documents and disinterest of the farmers, as observed by de Roo *et al.* (2019) and Liu *et al.* (2019). Thereby, government agencies should generate more flexible mechanisms with a view to enabling the farmers' participation in the operation of the supports.

Variables with an influence on obtaining governmental support

Martínez-García *et al.* (2016) identified that variables related to age, schooling and years of experience as dairy farmer influence the adoption of agricultural and livestock technologies; however, in the case of obtaining governmental supports by farmers the contrary takes place. Likewise, Martínez-García *et al.* (2016) identified that total hectares, technological level and economic stratum of the farmer have an important role in incorporating forages into the farm; while the participation of farmers in order to receive governmental supports was associated to availability of hectares, feeding technologies, daily milk sales and the perception of the farmer regarding the difficulty to receive such supports, which was the most relevant and where institutional, political, social and personal factors were related.

Second phase: social network analysis

Social network in the management of governmental supports

A social network with multiple interrelations between farmers, organizations and authority levels is considered a governance network, in which the interchange of resources between individuals and institutions is favored (Rudnick *et al.,* 2019). However, the communication network on governmental supports identified in the present study had a low density, which corresponds to a disconnected network, where few actors have high centrality and control the information in the network; these characteristics propitiate small social networks between actors (Lombardi *et al.*, 2020; Rudnick *et al.*, 2019).

The use of social network analysis can help policymakers to identify central and most influential farmers in the community and facilitate to recognize the network topology, this analysis identified 11 key farmers; though, four actors (J11, JTS, MRS and RHP) had the highest centrality degree; that is to say, they are actors that control the dissemination of information related to governmental support programs in the network. Simões *et al.* (2020) found that the diffusion of new practices in bovine dairy systems is more likely to occur if the first people to adopt them are central to the network of the community, in our study, the four actors (J11, JTS, MRS and RHP) who participate in livestock organizations, are members of the committee for irrigation and offer insemination services in the study zone. While the rest of key farmers (n=7) showed friendship or familial bonds with farmers who participate in livestock organizations or perform administrative functions for the community (delegate). Junjian *et al.* (2020) indicate that key farmers have links with organizations that provide them with supports, subsidies or technologies. In like manner, leading farmers with links of kinship, friendship or who are representatives have better communication with other farmers and strengthen their centrality degree (Rudnick *et al.*, 2019; Plata-Reyes *et al.*, 2025). On the other hand, Simões *et al.* (2020) suggested that the adoption should be in a two-step dissemination strategy, in which broad-based educational campaigns are adopted before innovation is made available to opinion leaders.

As regards institutions and organizations, the main actors in the network were RD, AYTO and ORG1; however, RD had the highest centrality and intermediation degree. Thereby, personnel with the government agency and town council, as well as leaders from livestock organizations, played an important role in the dissemination of information on governmental support programs in the network. In this way, the empowering of the staff of leading institutions and organizations will allow the network and communication of information between the participant actors to strengthen (Yang *et al.*, 2017). According to (Shahrina *et al.*, 2014) communications are imperative in innovation diffusion to determine its success, which may involve the use of mass media or interpersonal communication channels. With the rapid development of the internet, smart hand phones, and the use of social networking tools, diffusion can be both at the interpersonal level and mass media levels. Communications allow the information about the innovation to spread allowing diffusion to take place throughout the target communities, hence identification and strengthening of communicative

networks are essential to drive the spreading of information.

Rogers (2003) and (Shahrina *et al.*, 2014) identified four main elements in the diffusion of innovations which are the *innovation, communication channels, time and the social system*. He describes innovation "as an idea, practice, or project that is perceived as new by an individual or other unit of adoption. One of the obstacles to adoption of innovations is uncertainty. To reduce the risk of rejection due to uncertainty, stakeholders should be well-informed through appropriate channels. Communication is a "process in which participants create and share information with one another in order to reach a mutual understanding", the communication channels are the means for the messages to reach the target recipients. As diffusion is a highly social process, interpersonal communication relationships and communication channels can be most influential for acceptance (cited in Sahin, 2006). Rogers (2003) asserts that time however is very important in innovation however its importance has been downplayed in many behavioral studies. As innovations are diffused within a community, the social system is one of the elements in the innovation diffusion (Shahrina *et al.*, 2014).

The four most relevant key farmers in the network, J11, AGM, JRS and JP1, are more experienced in dairy production, have larger farms and higher use of technologies. This indicates that farmers with more experience and capitalization can be considered key actors in the creation of communication networks that allow disseminating and promoting governmental supports; by contrast, results also indicate that young farmers with small production units (MDV and SGS) may be key actors in generating links, as well as communicating and disseminating information inside the network. The farmers usually follow the community leaders, as they receive resources and support from the organizations; nevertheless, farmers with no influence on the community, open to change and new knowledge, can be key actors as well (Junjian *et al.,* 2020). This way outreach services would have to be addressed to identify key farmers in the creation of social networks that favor dynamics of interaction, communication of information and that foster access to governmental supports. Social networks have been identified as key elements for outreach programs under participatory approaches to succeed (Thi *et al.*, 2010).

Social network analysis indicated that 11% of the farmers is not linked to the network. This may be due to lack of interest in establishing and developing bonds with the main actors of the network (de Roo *et al.*, 2019), which turns into lower possibilities of meeting people (Lombardi *et al.*, 2020); in any case, they were able to obtain governmental support to acquire machinery and equipment; which may be the result of timely and duly performing the process. The operation of governmental supports received by 89% of the farmers linked to the network took place via support by personnel with the institutions and agencies. de Roo *et al.* (2019) indicate that farmers who generate links with key actors in a social network find it easier to access information and governmental support. For instance, the key actors identified in the network (J11, RHP, AGM, JRS, JER and MVR) received more supports as machinery and equipment, infrastructure, heifers and semen, maize production and veterinary advice. Leading farmers strengthen the network by generating links with staff in institutions and organizations (Gan *et al.,* 2018; Lombardi *et al.*, 2020), asserting their rights, generating links between farmers, improving personal and group relationships and making the management to access the resources easier (Lang and Fink, 2019). Therefore, the link between farmers and staff in organizations and institutions plays an important role in the operation of governmental support programs.

Supports for machinery and equipment and maize production were mainly operated by personnel with RD and AYTO, who aided in document validation, assisted along the process and selected the recipients of the supports; being more likely to receive the supports those with links with staff in such organizations (de Roo *et al.,* 2019) and with the party in power (PP). In this way, the benefitted farmers commonly have higher capitalization and economic capacity to invest on supports from organizations (de Roo *et al.*, 2019; Henning *et al.*, 2019); this creates discontent and dismay in less capitalized farmers who are not benefitted (Andersson *et al.*, 2017).

Martínez-García *et al.* (2015) indicated that farmers who are members of cooperatives did not show greater technological adoption, though in the present work, the contrary was observed; farmers who were members of a famer organization (FOR1) were able to obtain support for infrastructure, machinery and equipment, heifers and semen, maize production and veterinary advice. Farmers with no governmental supports usually have small farms, while farmers who receive supports have larger farms, wider availability of technologies, higher incomes from milk sales, liquidity to carry out the process, which may be related to the generation of links with key actors inside the network, namely: farmers, friends, relatives and personnel in organizations and institutions, which enabled them to receive information timely and help in the operation of governmental supports.

CONCLUSIONS

Farmers who receive governmental support (Group 1) commonly have a greater capitalization in terms of

availability of hectares, herd size, milk yield and income from milk sales, infrastructure and technological level. The greatest difficulty perceived by farmers in Group 2 to perform the process to apply for the support may be related to not being aware of the calls, too many steps in the process, lack of experience, availability of economic resources, time requirements, political issues, lack of operators, lack of documents and disinterest of the farmers. The participation of farmers in order to receive governmental supports was associated to availability of hectares, feeding technologies, daily milk sales and the perception of the farmer regarding the difficulty to receive such supports, which was the most relevant. The analysis identified 11 key farmers; though, four actors (J11, JTS, MRS and RHP) had the highest centrality degree; that is to say, they are actors that control the dissemination of information related to governmental support programs in the network; farmers with more experience and capitalization can be considered key actors in the creation of communication networks that allow disseminating and promoting governmental supports, young farmers with small production units (MDV and SGS) may be key actors in generating links, as well as communicating and disseminating information inside the network. Concerning the institutions and organizations, the main actors in the network were RD, AYTO and ORG1.

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Compliance with ethical standards. The research present original data that are not submitted to other journal at the same time. The farmers were informed about the study, and they were agreeing to participate in the research.

Data availability. The data that support the findings of this research are available with the corresponding author at: (cgmartinez@uaemex.mx) upon reasonable request.

Author contribution statement (CRediT). G. Gómez-Espinoza – Investigation, data analyses, writing – original draft. **D. Plata-Reyes –** Review and editing the original draft. **C.M. Arriaga-Jordán –** Conceptualization, writing – review and editing. **A.A. Rayas-Amor** – Conceptualization, writing – review and editing. **C.G. Martínez-García –** Conceptualization, resources, funding acquisition, methodology, supervision, writing – review and editing.

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