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Aplicación de Modelos de Innovación Abierta en smart farms. Comparación internacional en smallholder

DOCTORANDA

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CÓRDOBA, 2022

TITULO: *Aplicación de Modelos de Innovación Abierta en smart farms. Comparación internacional en smallholder*

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POSTGRADO EN RECURSOS NATURALES Y GESTIÓN SOSTENIBLE

Aplicación de Modelos de Innovación Abierta en smart farms. Comparación internacional en smallholder

Tesis presentada por Dña. ORIANA DANIELA VILLARROEL MOLINA

para optar al grado de Doctora por la Universidad de Córdoba (España)

Vº Bº Director	Vº Bº Directora
Dr. Antón Rafael García Martínez	Dra. Carmen de Pablos Heredero

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INFORMA:

Que la Tesis Doctoral titulada ***"Aplicación de modelos de innovación abierta en smart farms. Comparación internacional en smallholder"***, que se recoge en la siguiente memoria y de la que es autora Dña. ORIANA DANIELA VILLARROEL MOLINA, ha sido realizada bajo mi dirección, cumpliendo las condiciones exigidas para que la misma pueda optar al Grado de Doctora con Mención Internacional por la Universidad de Córdoba.

Lo que suscribo como director de dicho trabajo y a los efectos oportunos, en Córdoba a 05 de septiembre de dos mil veintidós.

Fdo. Dr. Antón Rafael García Martínez

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INFORMA:

Que la tesis Doctoral titulada “***Aplicación de modelos de innovación abierta en smart farms. Comparación internacional en smallholder***”, que se recoge en la siguiente memoria y de la que es autora Dña. ORIANA DANIELA VILLARROEL MOLINA, ha sido realizada bajo mi dirección, cumpliendo las condiciones exigidas para que la misma pueda optar al Grado de Doctora con Mención Internacional por la Universidad de Córdoba.

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Fdo. Dra. Carmen de Pablos Heredero

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Salerno, November 26th, 2019

Institute of Postgraduate Studies
University of Cordoba, Spain

Dear Sir or Madam,
I am pleased to inform you that Oriana Daniela Villarroel Molina NIE Y3773160R, a Ph.D. candidate in Natural Resources and Sustainable Management at the University of Cordoba, is carrying out a research visiting period under my supervision at the Department of Political and Social Studies, University of Salerno (Italy). During this visiting period she will apply the Social Network Analysis (SNA) approach to the analysis of the dual-purpose livestock farmers database as part of her doctoral thesis.
In this period, Oriana has also attended some short courses on Multilevel and Multiplex networks at the University of Salerno (28-29 October 2019) and has participated to the Seventh International Workshop on Social Network Analysis (29-31 October 2019) at the University of Salerno.

Some activities to do during her research visiting period are described below:

- to explore the usefulness of the software UCINET to analysis the sample of farmers included in the dual-purpose livestock farmers database by using the Social Network Analysis approach;
- to consider in the analyses the farmers' attributes jointly with network data included in the affiliation and adjacency matrices;
- to calculate some SNA measures at farmer level and at network level;
- to work for a paper reporting the main results.

Your Sincerely,

Prof. Maria Prosperina Vitale
Associate professor in Social Statistics
Department of Political and Social Studies
University of Salerno (Italy)

TÍTULO DE LA TESIS:

Aplicación de modelos de innovación abierta en smart farms. Comparación internacional en smallholder

DOCTORANDA: Dña. Oriana Daniela Villarroel Molina

INFORME RAZONADO DEL LOS DIRECTORES DE LA TESIS

(se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma).

Durante el desarrollo de la Tesis la doctoranda ha profundizado en el conocimiento de las razones del bajo nivel de adopción tecnológica de los pequeños productores de Doble Propósito del trópico mexicano. Asimismo se ha indagado en cómo se produce el proceso de difusión de las tecnologías entre los pequeños productores de estas zonas marginales en países en desarrollo. Se aplicó la metodología de Análisis de Redes Sociales (ARS o SNA). Posteriormente, se identificaron los patrones de adopción tecnológica y las interacciones de los flujos de información que se producen en la cadena de valor de la Ganadería Doble Propósito. Conocimientos y metodología extrapolables al resto de áreas tropicales latinoamericanas. Asimismo, ha adquirido las habilidades y competencias necesarias para poder abordar la problemática del sector desde una perspectiva holística; por una parte, desde la orientación investigadora, con toda su secuencia metodológica y, por otra parte, la aplicada a la resolución de problemas sectoriales de modo solvente.

La Tesis plantea un objetivo novedoso y estratégico, como es el estudio del sistema bovino lechero tropical, desde el enfoque de la innovación tecnológica, la competitividad y la viabilidad de estos sistemas mixtos, con producciones múltiples y fuertes sinergias e interacciones entre procesos. Se aplica una metodología actual, para la cuantificación del nivel tecnológico y la identificación de las tecnologías y prácticas organizativas más apropiadas.

Finalmente, se proponen una serie de medidas técnicas, económicas y organizativas que favorecen la viabilidad del sistema en el largo plazo. La Tesis cierra los distintos capítulos con una discusión, donde además se desciende al nivel de tecnologías, que se evalúan de modo desagregado y con gran utilidad en el medio. La Tesis no constituye un cierre de la investigación sino un punto de inicio ya que abre la metodología de análisis a otras fases del proceso y a otras dimensiones de la empresa (ambiental, social y toma de decisiones).

La Doctoranda presenta un manuscrito con los siguientes indicadores de calidad: 2 artículos JCR, 2 artículos Latindex, 1 artículo JCR en revisión, congresos nacionales e internacionales y 1 estancia de investigación en el extranjero.

Córdoba, 05 de septiembre de 2022

Artículos de investigación:

Villarroel-Molina, O., Barba, C., Rangel, J., & García, A. (2019). Use of social networks to explore smallholder's adoption of technologies in dual purpose farms. Esic Market Economics and Business Journal (ESIC Market), 50(2), 233-257. http://dx.doi.org/10.7200/esicm.163.0502.1

Villarroel-Molina, O., De-Pablos-Heredero, C., Rangel, J., Vitale, M. P., & García, A. (2021). Usefulness of network analysis to characterize technology leaders in small dual-purpose cattle farms in Mexico. Sustainability, 13(4), 2291. https://doi.org/10.3390/su13042291

Villarroel-Molina, O., Carmen, D. P. H., Cecilio, B., Jaime, R., & Antón, G. (2021). The Importance of Network Position in the Diffusion of Agricultural Innovations in Smallholders of Dual-Purpose Cattle in Mexico. Land, 10(4), 401. https://doi.org/10.3390/land10040401

Villarroel-Molina, O., Carmen, D. P. H., Cecilio, B., Jaime, R., & Antón, G. (2022). How Does Gender impact technology adoption in dual-purpose cattle in Mexico?. *Article under review in Land*, 12/08/2022. (JCR-Q2)

Otros:

Isanta-Muñoz, F., de Tena-Fernández, A. G., Moyano-Salvago, R., **Villarroel-Molina, O.**, & Barba-Capote, C. (2020). Process management in the traceability system LeTrA Q of goat and sheep milk in Andalusia, Spain. Esic Market Economics and Business Journal (ESIC Market), 51(2), 341-359.

Publicaciones en Congresos:

Villarroel O., Rangel J., De-Pablos C., Barba C., García A. (**septiembre 2018**). Identificación de líderes en innovación tecnológica en bovino doble propósito de Veracruz. Reunión Nacional de Investigación Pecuaria Memoria. Ciencia y tecnología para una ganadería competitiva. Nayarit, México. ISSN 24485284, Año 4. Vol.1 Núm.1. Pág. 565-567.

Villarroel O., Rangel J., De-Pablos C., Barba C., García A. (**septiembre 2018**). Metodología de redes sociales para analizar la estructura de innovación tecnológica en productores de bovinos doble propósito de Veracruz. Reunión Nacional de Investigación Pecuaria Memoria. Ciencia y tecnología para una ganadería competitiva. Nayarit, México. ISSN 24485284, Año 4. Vol.1 Núm.1. Pág. 556-558.

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Villarroel O., De-Pablos C., Barba C., Angón E., Perea J., Checa C., García A. (**septiembre 2018**). Aplicación de la metodología de redes sociales (ARS) para analizar la innovación tecnológica en la conservación de razas ganaderas. XI Congreso ibérico sobre recursos genéticos animales. Murcia, España.

Villarroel O., Rangel J, De-Pablos C., Barba C., García A. (**octubre 2019**). Technology adoption behaviours of dual-purpose livestock farmers through social network analysis. Seventh International Workshop on Social Network Analysis. Salerno, Italy.

Villarroel O., Rangel J, De-Pablos C., Barba C., García A. (**febrero 2021**). An exploratory analysis of Smallholders Social Capital through Social Network Analysis. I Congreso Anual de Estudiantes de Doctorado (I CAED). Universidad Miguel Hernández (UMH) de Elche. Alicante, España. Pág. 122.

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Cursos:

Encuentro Internacional de Economías Transformadoras, 6 y 7 de **diciembre de 2018**. Real Jardín Botánico de Córdoba, Centro de Educación Ambiental.

Asistencia a two short “courses on Multilevel and Multiplex networks”. Universidad de Salerno (**October de 2019**).

Taller Hablar en Público. La experiencia de la Comunicación. Unidad de Cultura Científica y de la Innovación de la Universidad de Córdoba. 24-27 de **febrero de 2020.**

Metodología Henry Ford Entrepreneurship Academy (HFEA). Curso e-HFEA, Viaje al emprendimiento. **Mayo de 2020**. Universidad de Córdoba.

Ciclo de Talleres Alcanzando los ODS a través de la economía solidaria y la alimentación sostenible. Cátedra Cooperación al Desarrollo, Universidad de Córdoba. **Marzo de 2021.**

Estancia de investigación:

Estancia de investigación en el Departamento de Ciencias Políticas y Sociales de la ***Universidad de Salerno, Italia***, durante el periodo comprendido entre octubre 2019 a enero de 2020, con la finalidad de recibir formación y asesoría en el manejo del software UCINET.

Agradecimientos

Esta meta no la hubiera podido lograr sin el apoyo de mis directores Dr. Antón García Martínez de la Universidad de Córdoba y la Dra. Carmen de Pablos Heredero de la Universidad Rey Juan Carlos. Así como distintas Instituciones y personas entre colegas, amigos y familia, a quienes quiero dedicar mi trabajo y agradecerles por el respaldo brindado. Sin embargo, necesitaría muchas páginas para mencionar a cada uno de ellos, por lo cual también quiero agradecer a todos quienes no mencione en los siguientes párrafos.

- *Un agradecimiento especial para la Universidad de Córdoba (España), y al programa de Doctorado de Recursos Naturales y Gestión Sostenible. A la Universidad de Salerno en Italia y en su nombre a la Profesora María Prosperina Vitale, por su apoyo en el manejo de UCINET y por su disposición a enseñar y a profundizar en el manejo de la metodología de redes sociales en favor de esta tesis doctoral.*
- *Al equipo de gestión veterinaria de la UCO: Cecilio Barba, Elena Angón, Josefina Arcos y Francisco Serrano por su apoyo, gentileza y colaboración técnica durante el proceso de esta investigación.*
- *Al Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) de México, por la información proporciona, y en su nombre a Jaime Rangel Quintos, por su valiosa colaboración y apoyo tanto profesional como personal, gracias por ser el enlace que me trajo hasta este departamento de investigación en el que tanta evolución he tenido.*
- *A todos los ganaderos y ganaderas de bovino doble propósito, por su colaboración desinteresada y por su labor en el mantenimiento de este sistema ganadero tan importante para la población rural del trópico mexicano.*
- *A los amigos que he hecho en este camino y que han formado parte de mi proceso de formación: Alex, Alejandro (Parce), Merly, Owen, Ramón, Yalbeiry, Barlin, Andrea, Isa, Adela y Eli, gracias por haber sido fundamentales en estos años fuera de mi país y por ser parte de tantas memorias compartidas.*
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Finalmente, un eterno agradecimiento a mi familia por sembrar en mi la semilla de la constancia, por los valores y la buena educación, valiosas herramientas que me han permitido llegar donde estoy. Ustedes son parte de este sueño.

Oriana Villarroel Molina

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INTRODUCCIÓN

1. INTRODUCCIÓN

1.1. Justificación

El acelerado crecimiento de la población mundial plantea un desafío sin precedentes a los sistemas alimentarios y agrícolas, en virtud de que ejerce mayor presión sobre los recursos naturales necesarios para sostener la producción de alimentos y productos no alimenticios. Particularmente en lo que se refiere al sector ganadero, se prevé que en 2050 la demanda de carne y leche aumenten en un 73% y 58% respectivamente, en relación con los niveles de 2010 (FAO, 2011), paradigma que está transformando la realidad del sector. Tradicionalmente, la ganadería era un sector impulsado por la oferta, sin embargo, desde que la demanda ha pasado a impulsar de manera creciente al sector ganadero, su crecimiento se ha acelerado y ha pasado a constituirse como fuente de sustento y supervivencia para centenares de millones de pequeños agricultores (Gerber et al., 2013).

Los sistemas ganaderos tradicionales, de traspatio, de pequeña escala y familiares son los mayoritarios (Rangel et al., 2017); sin embargo, se someten a cuestionamiento permanente por su falta de competitividad, baja dimensión y escaso nivel tecnológico. Además, son penalizados en los indicadores de bienestar y sostenibilidad (Murillo et al., 2015).

Los sistemas productivos tradicionales generalmente resultan perjudicados por la falta de competitividad, infraestructura, tecnología y barreras comerciales para acceder a las cadenas de valor modernas (Gerber et al., 2013), por lo que se considera pertinente plantear esta investigación en aras de avanzar en el conocimiento de los sistemas ganaderos de doble propósito (DP) definido por Sandoval et. al, (2007) como “una alternativa comprobada para producir leche y carne a bajo costo y generar empleo en áreas rurales.

Esta actividad enfrenta una limitada competitividad, por ello, la investigación socioeconómica relacionada, requiere de estudios que permitan conocer la problemática y potencial de: a) el productor primario y sus sistemas de producción, b) la agroindustria y la cadena de valor c) los problemas relacionados con aspectos de política pública (Espinosa-García et al., 2016).

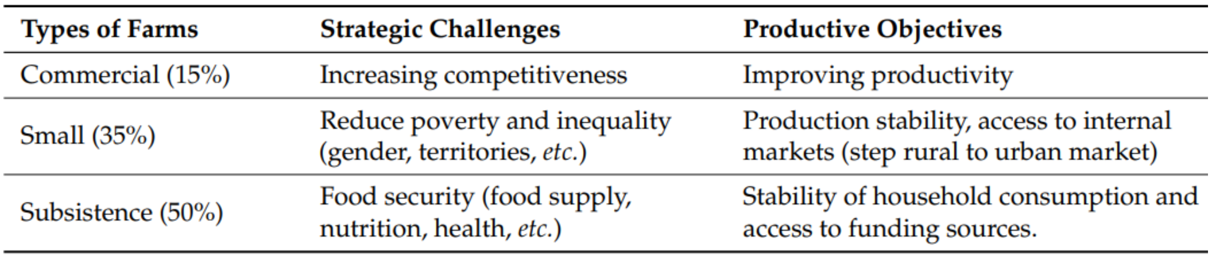
Según la Red de Investigación e Innovación Tecnológica para la Ganadería Bovina

Tropical (REDGATRO) y contrariamente a lo expuesto anteriormente, la actividad bovina que generalmente responde a producciones de pequeña escala, es clave para la seguridad alimentaria de los habitantes del trópico en términos de provisión y acceso a los alimentos, estabilidad y precios (Espinosa-García et al., 2016). En términos globales los pequeños productores generan entre el 19 y 12% de la producción mundial de carne y leche respectivamente, y fijan gran parte de la mano de obra que se ocupa en la actividad agropecuaria del trópico, y específicamente las explotaciones DP muestran elevada capacidad de resiliencia y versatilidad, alto nivel de diversificación y complementariedad con las restantes actividades; estos atributos le permiten al sistema soportar cambios climáticos y económicos como consecuencia de su bajo nivel de inversión. El DP genera ingresos directos y además promueve la sustentabilidad ambiental, a través del uso de los recursos disponibles. El ganado es un activo que favorece la reducción de la vulnerabilidad de la explotación y la pobreza, a través de una estrategia de mínimo costo, aunque con bajos niveles de eficiencia y de innovación tecnológica (Espinosa-García et al., 2016).

Los pequeños productores viven en el umbral de la pobreza, en sistemas extensivos frágiles con alto grado de marginalización. Además, este tipo de explotaciones se caracterizan por un bajo o nulo nivel de innovación tecnológica, lo que dificulta el acceso a insumos externos y gran vulnerabilidad ante desastres ambientales y turbulencias económicas (Van’t Hooft y Wollen, 2012).

Dentro del marco de planeamiento, una empresa es una unidad de decisión, que abarca uno o varios establecimientos agropecuarios o industria, que buscan la consecución ordenada de los objetivos establecidos desde la dirección o centro de decisiones. Sin embargo, en explotaciones de subsistencia, pequeños productores (smallholders) y micro emprendimientos agroalimentarios, el centro de decisión está constituido por el empresario, habitualmente a título unipersonal y cuya figura suele coincidir con el dueño de la empresa, el administrador, el gerente, etc.

La condición primordial es que en dicho centro se dispone de capacidad de decisión con respecto a los objetivos establecidos, las restricciones y las condicionantes que vayan desarrollándose en el manejo rutinario de la empresa. Como puede observarse en la Figura 1, los objetivos de los ganaderos varían según la orientación productiva; mientras que las grandes granjas comerciales buscan el incremento de la productividad, muchos de los pequeños productores se encuentran aún en la búsqueda de una producción estable que les permita acceder a grandes mercados, y los más desfavorecidos entre todos, dedicados a la producción de subsistencia buscan la estabilidad del consumo de los hogares y el acceso a recursos de financiación (García et. al, 2016). Por otro lado, en los sistemas intensivos la implementación tecnológica tiene relación directa con la mejora de los resultados productivos (carne y leche); en el caso del DP los objetivos de productores son más difusos y esto promueve la necesidad de evaluar la influencia que los lideres tecnológicos pueden tener en la adopción de tecnologías que incrementan la productividad, a partir de la identificación de patrones tecnológicos.



Types of Farms	**Strategic Challenges**	**Productive Objectives**
Commercial (15%)	Increasing competitiveness	Improving productivity
Small (35%)	Reduce poverty and inequality (gender, territories, *etc.*)	Production stability, access to internal markets (step rural to urban market)
Subsistence (50%)	Food security (food supply, nutrition, health, *etc.*)	Stability of household consumption and access to funding sources.

Figura 1. Objetivos de los productores en ganadería (García et. al., 2016).

En este contexto los sistemas doble propósito se muestran como una de las estrategias productivas más frecuentes y extendidas en las zonas tropicales de América Latina (Pérez y Díaz, 2008; Gómez-Castro et al., 2002). En México, se localizan principalmente en las áreas tropicales del país, en zonas de menos de 1600 metros de altitud, tanto del lado del Golfo de México como del Pacifico (Salas-Reyes et al., 2015; Orantes et al., 2014; PENIT, 2003; Espinosa y Wiggins, 2003).

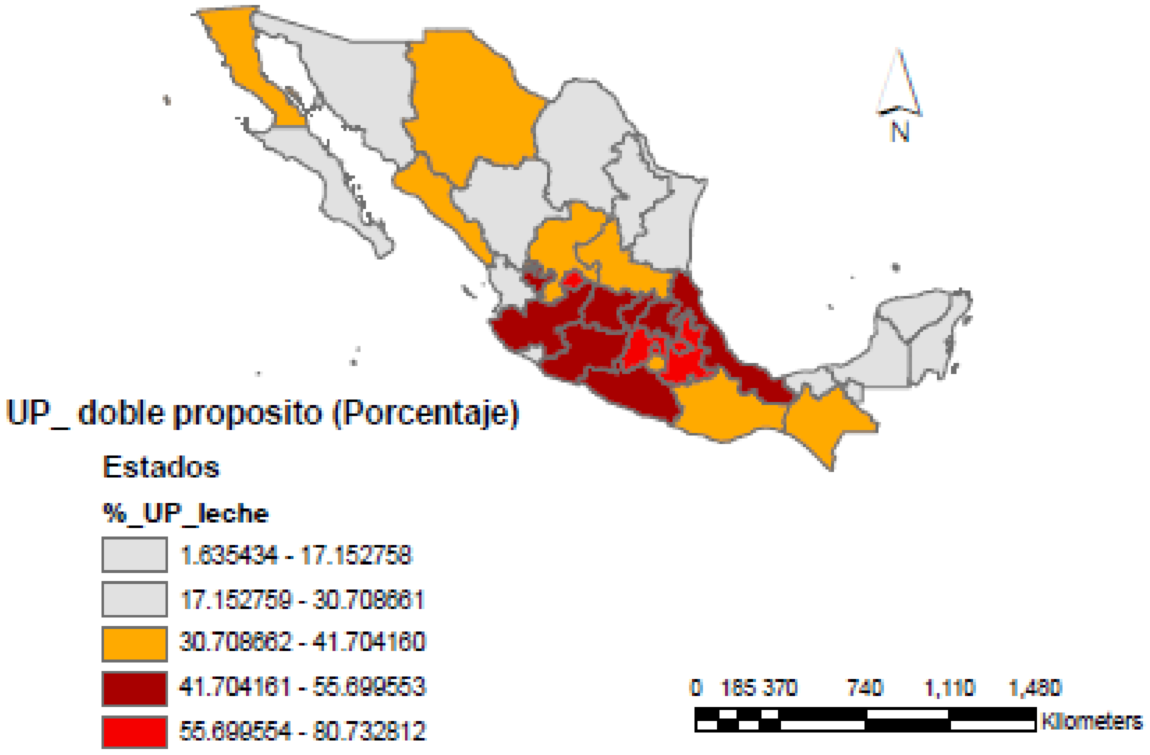


Figura 2. Unidades de producción de Doble propósito en México (INEGI, 2008).

En este ámbito se relaciona el nivel tecnológico con la metodología de redes. Partiendo de la idea de que una red, se constituye como un entramado finito de actores e instituciones diversas y relacionados entre sí.

Figura 3. Reunión de productores de Doble propósito en México (INEGI, 2008).

Los miembros de la red comparten intereses u objetivos comunes debidamente consensuados y ejecutan acciones en busca de beneficio de muy diversos tipos para cada uno de sus miembros (Zarazúa, 2009).

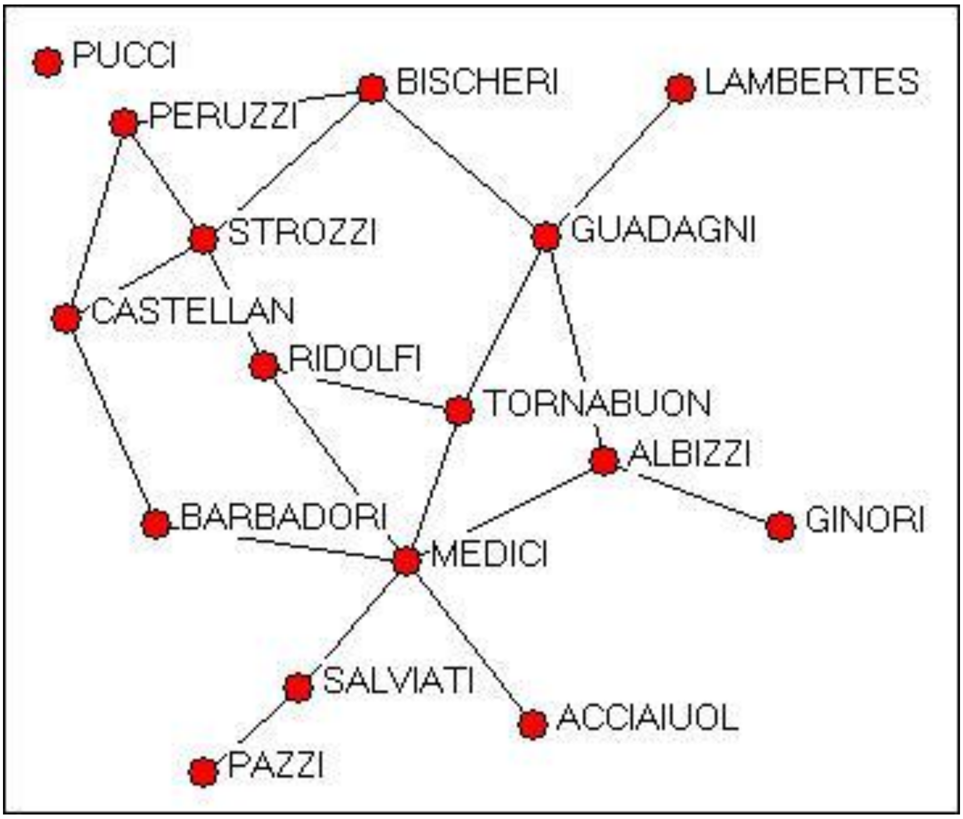


Figura 4. Estructura de red (Hanneman et al, 2005).

Se plantea un trabajo de investigación para el sector agropecuario desde la perspectiva de las redes sociales, en donde la constante se encuentra en la importancia de los flujos de conocimiento y de comunicación, realizados con base en los vínculos internos y externos de las unidades de producción establecidos por los agroempresarios.

Las redes sociales como modelo de intervención social, constituyen un espacio de confluencia de diversas disciplinas y tradiciones intelectuales bajo un enfoque interdisciplinar, para explicar los problemas planteados por la investigación social; hecho que implica un proceso de construcción permanente tanto individual como colectivo (Zarazúa, 2009).

El aporte de la perspectiva de las Redes Sociales en el sector agropecuario permite profundizar en el conocimiento de la estructura productiva de un territorio, bajo un enfoque sistémico, dado que se consideran los efectos totales de una rama económica sobre el conjunto de la economía regional, la rapidez con que una actividad se relaciona con las demás y el valor de éstas como elementos trasmisores dentro de la red.

En la presente investigación se utilizó la información obtenida por prestadores del servicio profesional pecuario (PSPP) de grupos de productores de bovinos doble propósito de once estados de la República Mexicana (Chiapas, Tabasco, Campeche, Veracruz, Sinaloa, Colima, Michoacán, Morelos, Nayarit, Oaxaca y Quintana Roo), los cuales recibieron el servicio de asistencia técnica mediante el modelo GGAVATT (Grupos Ganaderos de Validación y Transferencia de tecnología) por medio del Programa Soporte de la Secretaria de Agricultura, Ganadería, Pesca y Alimentación (SAGARPA) durante el período 2010–2011 y actualizada hasta fechas recientes en 2020 (Figura 5).

Figura 5. Asesores técnicos capacitando a pequeños productores en tecnologías ganaderas según la metodología GGAVATT.

Posteriormente se aplicó la técnica de muestreo no probabilístico para seleccionar grupos de actores relevantes a partir de 3.600 cuestionarios proporcionados por el Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) a través de su Unidad Técnica Especializada Pecuaria nacional (UTEP).

El criterio de selección utilizado fue el siguiente:

1) Todas aquellas UP (Unidades de Producción) que hayan participado en el Programa Soporte de la SAGARPA en el período 2010 – 2011.

2) Todas aquellas UP ubicadas en la región tropical de México tanto de trópico húmedo como trópico seco.

3) Consistencia y calidad de la información proporcionada en las encuentras y entrevistas aplicadas a las UP.

La información se procesó siguiendo los lineamientos de la estrategia desarrollada por el INIFAP para mejorar la competitividad en la producción y comercialización de leche, bajo el método de mapeo estratégico, el cual permite la construcción, análisis e interpretación de Redes Sociales al identificar a los actores relevantes y sus interacciones dentro de un ámbito especifico de investigación. El modelo de Mapeo Estratégico involucra tres procesos fundamentales:

[1] Perfilamiento: Identificación de actores fundamentales y su categorización a través de la investigación documental, que permitirá definir la amplitud de la Red Social de adopción tecnológica de los ganaderos de doble propósito.

[2] Relacionamiento y Perfilamiento Remoto: Una vez definida la amplitud de la red, el siguiente proceso es determinar el perfilamiento remoto (características de los actores) y su relación con los demás actores que interactúan dentro de la red. La información en este caso se obtiene directamente de los actores, mediante trabajo de campo, para lo cual se emplearon técnicas de investigación: encuestas y entrevistas.

[3] Cambio: Una vez se ha determinado el grado de relacionamiento entre actores y como se afectan unos a otros, se realiza un diagnóstico de la situación actual y se realizan proyecciones de cambios en actores y su relacionamiento.

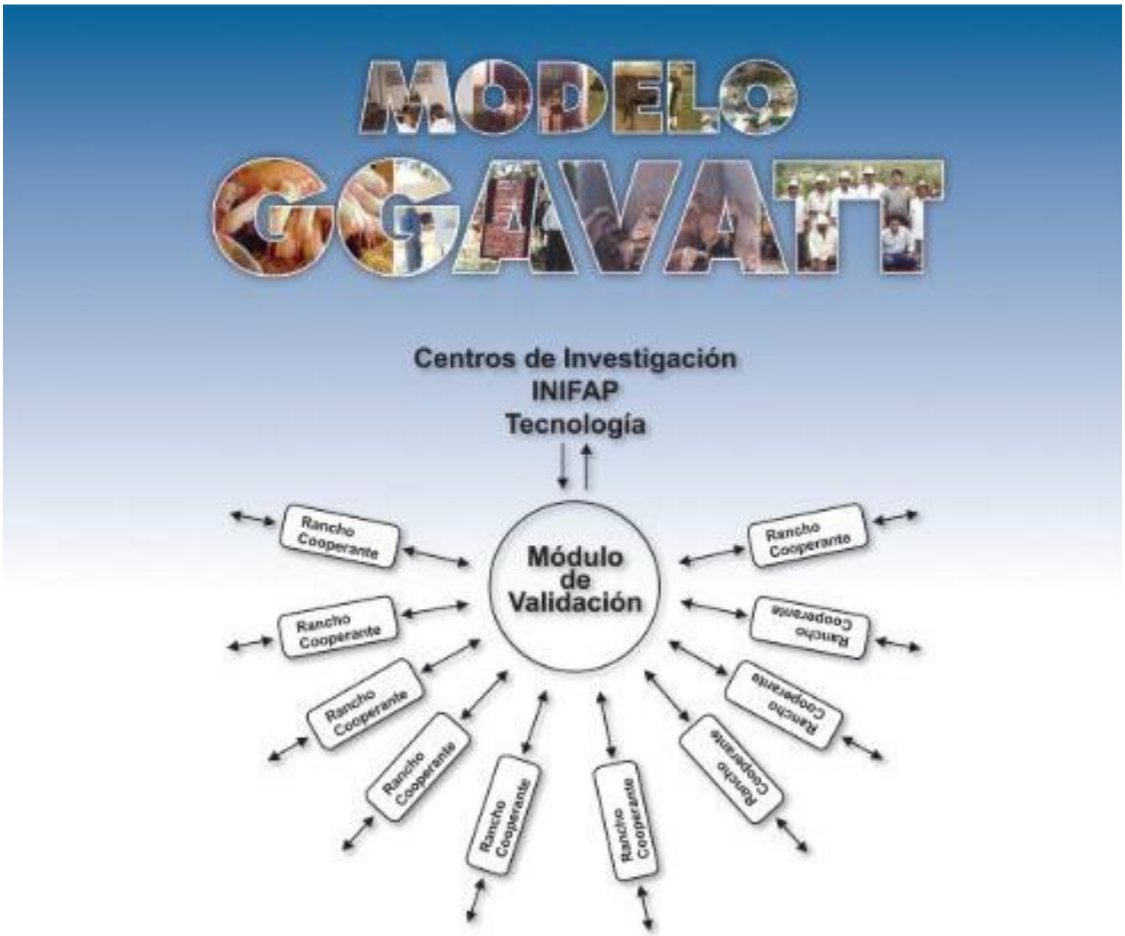


Figura 6. Lineamientos del GGAVATT. (INIFAP, 2002).

En esta investigación el elemento de relación fundamental entre actores es la adopción tecnológica. Es decir, la decisión de adoptar o no una determinada tecnología entre un paquete de tecnologías, es un rasgo distintivo de un ganadero. En economía esto se relaciona con la “***Teoría de la Elección Racional***”, una perspectiva teórica general de las ciencias del comportamiento humano, su ámbito es el de la interacción humana y se refiere a toda clase de situaciones sociales (Vidal, 2008). La interrogante detrás de esta teoría fue: ¿en base a qué criterios los actores toman las decisiones en sus explotaciones? En este caso, sí lo normal entre los ganaderos es no adoptar (baja tasa de adopción tecnológica), ¿qué caracteriza a aquellos ganaderos que se salen de la norma y deciden adoptar tecnologías que otros ganaderos dentro del sistema han decidido no adoptar? Por otro lado, estas decisiones de adopción pueden ser representadas visualmente a través del Análisis de Redes Sociales. El ARS constituye por tanto una forma de mapear el comportamiento humano.

Las tecnologías utilizadas en esta investigación fueron aquellas seleccionadas por Rangel et al. (2016), para la ganadería de doble propósito, agrupadas en áreas de utilidad internacional y fincas de pequeña escala (Tabla 1 y 2).

Tabla 1. Tecnologías con definiciones (Rangel et al., 2016)

A1. Management	**Information system of management and the direct use of resources by grazing**
1. Animal identification	0. Individual animals identification was not done; 1. Individual animals identification was done (ear tags, hot iron, tattooing, neck chains, *etc*.)
2. Record system	0. Record systems were not utilized; 1. Record systems were utilized to make decisions into the farm operation
3. Breeding management	0. There was not a specific management breeding planning; 1. There was a specific management breeding planning
4. Grazing native pasture	0. Cattle did not graze in native pasture lands; 1. Cattle grazed in native pasture lands; *Paspalum, Panicum, Bouteloua*; *etc*.
5. Grazing planting	0. Cattle did not graze in planted pasture lands; 1. Cattle grazed in planted pasture lands (*Panicum máximum, Brachiaria brizantha, Andropogon gayanus, Hyparheina rufa, Clitoria ternatea, Leucaena leucocephala*)
6. Grazing of crop residues	0. Grazing of crop residues was not done; 1. Grazing of crop residues was done *i.e.*, maize *Zea mais*, sugar cane *Saccarum officinarum*, oat *Sativa L. etc*.
7. Milking season	0. Cows are not regularly milked; 1. Cows are regularly milked; the farm is oriented to milk production
8. Type of milking	0. Hand milking was utilized; 1. Mechanical milking was utilized mainly
A2. Feeding	**Strategies for animal feeding applied by smallholders including three kinds of foods: Roughage, concentrated feeding and supplements**
Roughage	
9. Green fodder	0. Green fodders were not used; 1. Green fodders were cultivated, cut and provided directly to cattle.
10. Silage	0. Feeding with silages was not utilized; 1. Feeding with silages was utilized, *i.e.*, grass, maize, others.
11. Hay making	0. Cattle were not fed with haymaking or stubble; 1. Cattle were fed with haymaking or stubble, *i.e.*, corn, sorghum, oats, other
Concentrated feeding	
12. Processed feed	0. Cattle were not fed with processed feed; 1. Cattle were fed with processed feed including compound feed
13. Concentrate making	0. Cattle were not fed with concentrate-making feed; 1. Cattle were fed with concentrate-making feed (home-made concentrate) includes all types of grains, cereals, *etc*.
Supplements	
14. Molasses/urea	0. Cattle were not supplemented with molasses/urea; 1. Cattle were supplemented with a mix of molasses/urea
15. Grains and oilseeds	0. Grains and oilseeds were not added to cattle diet; 1. Grains and oilseeds plants were added to cattle diet (Maize, Sorghum, soya, other)
16. Multi nutritional blocks processed	0. Cattle were not supplemented with multi nutritional blocks processed; 1. Cattle were supplemented with multi nutritional blocks processed

17. Manufacture of multi nutritional blocks	0. Cattle were not supplemented with manufactured multi nutritional blocks; 1. Cattle were supplemented with multi nutritional blocks processed (home-made)
18. Common salt	0. Cattle were not supplemented with NaCl; 1. Cattle were supplemented with NaCl
19. Mineral salts	0. Cattle were not supplemented with mineral salts; 1. Cattle were supplemented with mineral salts (common salt plus Ca, P and other minerals).
20. Mineral blocks	0. Cattle were not supplemented with mineral blocks; 1. Cattle were supplemented with mineral blocks
21. Vitamin provided	0. Vitamins were not used; 1. Vitamins were provided, as A, D, E, B complex
22. Agro-industrial by-products	0. Agro-industrial by-products were not used; 1. Agro-industrial by-products awerere used, *i.e.*, dry grain such as bran; wet grain such as brewers grains; and pulps such as beet, citrus, and others
A3. Genetics	**Technologies to improve productive parameters through the preservation of the breed, and the resistance of the animals to the tropical climate and to ectoparasites**
23. Using male breeds	0. Male breeds were not utilized; 1. Male breeds were incorporated
24. Using male crosses	0. Male crosses were not utilized; 1. Male crosses were incorporated
25. Using female breeds	0. Female breeds were not utilized; 1. Female breeds were incorporated
26. Using female crosses	0. Female crosses were not utilized; 1. Female crosses were incorporated
27. Use of genetically tested bulls	0. Genetically tested bulls were not utilized; 1. Genetically tested bulls were utilized to identify morphofunctional and genetics characteristics
28. Calves selection criteria	0. Calves selection criteria were not used; 1. Calves selection criteria were used (gain weight, high weight for age, high and faster growth or others)
29. Female selection criteria	0. Female selection criteria were not used; 1. Female selection criteria were used, as milk production of the mother, the behavior of the mother, breed, udder conformation and resistance to mastitis, others
30. Sire selection criteria	0. Sire selection criteria were not used: 1. Sire selection criteria were used as productive progenitor, body conditions, performance testing, lifetime, pedigree, progeny testing, sib performance, others
31. Crossbred system	0. Crossbreed planning was not utilized; 1. Crossbreed planning was utilized: simple, sire crossbred, absorbent crossbred, others
A4. Reproduction	**Technologies oriented to improve reproductive efficiency parameters**
32. Evaluation in bulls	Breeding soundness evaluation in bulls 0. No evaluation of the reproductive capacity of bulls or no sire on the farm; 1. Evaluation of the reproductive capacity of bull is done
33. Semen evaluation	Semen fertility evaluation 0. Sperm viability was not done; 1. Sperm fertility was evaluated
34. Female evaluation	0. Evaluation of female body condition was not done; 1. Evaluation of female body condition was done before mating
35. Oestrus detection,	0. Estrus detection was not done; 1. Estrus detection was done

36. Pregnancy Diagnosis	0. Pregnancy diagnosis was not done; 1. Pregnancy diagnosis was done as rectal palpation, ultrasound scanning, others
37. Mating	0. Seasonal mating; 1. Continuous mating was done
38. Breeding policy	0. Control of the mating was not done; 1. Planning mating control.
A5. Animal Health	**Technologies geared to health, welfare, quality of the milk production and the incorporation of a sanitary milking program**
39. Health planning	0. Animal health planning was not done; 1. Animal health planning was done, includes voluntary or compulsory measures and protocols to prevent the spread of local and transboundary animal diseases
40. Vaccination program	0. Planning of vaccines and bacterins was not done; 1. Application of vaccines and bacterins was done, to prevent diseases such as *Clostridium chauvel, brucellosis, tuberculosis, derriengue, pasteurelosis, leptospirosis*, others
41. Parasite diagnosis	0. Diagnosis analysis was not utilized to identify types of parasites in feces; 1. Diagnosis analysis was used to identify types of parasites in feces
42. Internal deworming control	0. Internal deworming was not used; 1. Internal deworming was used in different kinds of animals in the herd
43. External parasite control	0. External parasite control was not used; 1. External parasite control was used
44. Mastitis diagnosis	0. Mastitis diagnosis was not done; 1. Mastitis diagnosis was done.
45. Sanitary milking program	0. A sanitary milking program was not done; 1. Sanitation practices in milking were done: cleaning and drying of the udder and teats, calf stimulation, utilization of disposable materials, control of health hazards, others.

Tabla 2. Tasa de adopción de tecnología en fincas de doble propósito (Rangel et al., 2016).

Technological packages	Code	Mean ± SE (CV, %)
Management 60.67 ± 10.64 (9.05)	T1. Animal identification	87.99 ± 1.66 (10.60)
	T2. Record system	48.56 ± 2.56 (25.04)
	T3. Breeding management	81.20 ± 2.00 (15.30)
	T4. Native pastures	83.29 ± 1.91 (13.95)
	T5. Grazing planting	39.69 ± 2.50 (24)
	T6. Grazing of crop residues	56.14 ± 2.54 (24.69)
	T7. Milking season	86.16 ± 1.77 (11.95)
	T8. Type of milking	2.35 ± 0.78 (2.30)
Feeding 27.21 ± 6.29 (5.14)	T9. Green fodder	29.50 ± 2.33 (20.85)
	T10. Silage	24.54 ± 2.20 (18.57)
	T11. Hay	50.13 ± 2.56 (25.07)
	T12. Processed feed	32.11 ± 2.39 (21.86)
	T13. Concentrate making supplements	8.62 ± 1.44 (7.89)
	T14. Multinutritional blocks processed	1.83 ± 0.69 (1.80)
	T15. Manufacture multinutritional blocks	14.10 ± 1.78 (12.14)
	T16. Molasses/urea	9.66 ± 1.51 (8.75)

	T17. Grains and oilseeds	8.36 ± 1.42 (7.68)
	T18. Common salt	61.62 ± 2.49 (23.71)
	T19. Mineral’s salt	62.14 ± 2.48 (23.59)
	T20. Mineral blocks	20.37 ± 2.06 (16.26)
	T21. Vitamins	55.87 ± 2.54 (24.72)
	T22. Agroindustrial By-products	4.44 ± 1.05 (4.25)
Genetics 61.91 ± 10.60 (8.99)	T23. Using male breeds	37.34 ± 2.47 (23.46)
	T24. Using male crosses	55.87 ± 2.54 (24.72)
	T25. Using female breeds	22.45 ± 2.13 (17.46)
	T26. Using female crosses	71.28 ± 2.31 (20.53)
	T27. Use of genetically tested bulls	20.10 ± 2.05 (16.10)
	T28. Calves’ selection criteria	49.87 ± 2.56 (25.07)
	T29. Female selection criteria	89.56 ± 1.56 (9.38)
	T30. Sire selection criteria	90.34 ± 1.51 (8.75)
	T31. Crossbred system	95.82 ± 1.02 (4.01)
Reproduction 15.45 ± 3.76 (9.21)	T32. Mating	96.61 ± 0.93 (3.29)
	T33. Evaluation in bulls	11.49 ± 1.63 (10.20)
	T34. Semen evaluation	2.61 ± 0.82 (2.55)
	T35. Oestrus detection	21.41 ± 2.10 (16.87)
	T36. Female evaluation	15.40 ± 1.85 (13.07)
	T37. Pregnancy diagnosis	29.50 ± 2.33 (20.85)
	T38. Breeding Policy	12.27 ± 1.68 (10.79)
Animal Health 71.41 ± 14.72 (12.99)	T39. Health planning	79.37 ± 2.07 (16.41)
	T40. Vaccination program	95.30 ± 1.08 (4.49)
	T41. Parasite diagnosis	24.54 ± 2.20 (18.57)
	T42. Internal deworming	98.96 ± 0.52 (1.04)
	T43. External parasite control	98.43 ± 0.64 (1.55)
	T44. Sanitary milking program	85.12 ± 1.82 (12.70)
	T45. Mastitis diagnosis	26.11 ± 2.25 (19.34)

Asimismo, en la propuesta de modelos y discusión de resultados, se consideraron los trabajos previos elaborados por el equipo de investigación AGR 267 Economía Agroalimentaria y Gestión de sistemas sostenibles en el ámbito del doble propósito en diferentes países.

En este caso, Rangel et al., (2016), encontraron un efecto de la zona ecológica sobre el nivel de adopción tecnológica de los ganaderos. En este trabajo se señala que aquellas fincas ubicadas en el trópico seco presentaron los niveles más altos de adopción tecnológica en las áreas tecnológicas de manejo, alimentación y salud animal, mientras que las fincas ubicadas en el trópico húmedo mostraron mayor nivel de adopción tecnológica en el área de reproducción. Además, Rangel et al. (2016) realizaron una comparación entre tecnologías en fincas muy pequeñas y medianas y encontraron que las fincas muy pequeñas presentaban diferencias en la alimentación y salud de los animales. Las fincas del trópico seco promovieron tecnologías de forrajes y alimentos concentrados como henificación, forrajes verdes, ensilaje, alimentos procesados, granos y oleaginosas. En las fincas de trópico seco, para la salud animal, las tecnologías más importantes fueron el control de parásitos, el programa de vacunación y el programa de ordeño sanitario. Las Fincas Pequeñas ubicadas en el trópico húmedo mejoraron las tecnologías asociadas al manejo reproductivo, particularmente la evaluación del semen tanto de hembras como de toros, diagnóstico de preñez, detección de celos y política de crianza. En las fincas medianas ocurrió una situación similar, aunque la detección de celos fue menor y las diferencias en el diagnóstico de gestación fueron mayores. Este trabajo se complementó con otros desarrollados en el intervalo 2012-2020.

A tenor de lo expuesto se planteó un objetivo general y varios específicos o parciales.

1.2. Objetivo General

El objetivo general de la presente investigación fue profundizar en el conocimiento del proceso de adopción y difusión de la tecnología entre los pequeños productores de Doble Propósito del trópico mexicano. Esta investigación se realizó mediante la metodología de Análisis de Redes Sociales (ARS o SNA, por sus siglas en inglés). Posteriormente, se identificaron las interacciones de los flujos de información que se producen en la cadena de valor de la Ganadería Doble Propósito.

1.3. Objetivos Específicos

Los objetivos específicos de esta investigación son:

1. Comparar los diferentes softwares de análisis de redes sociales y seleccionar el más adecuado para esta investigación.
2. Evaluar con el análisis de redes sociales (ARS) los patrones de adopción para los diferentes paquetes tecnológicos.
3. Evaluar con el análisis de redes sociales (ARS) la influencia del posicionamiento de los lideres tecnológicos.
4. Evaluar los patrones de adopción tecnológica y la difusión de innovaciones desde la perspectiva de género.

Todos los objetivos propuestos nos ayudarán al desarrollo de un análisis prospectivo de los sistemas ganaderos de doble propósito en el trópico mexicano, favoreciendo el diseño estratégico de políticas públicas de transferencia de tecnología y recomendaciones de actuación.

REVISIÓN BIBLIOGRÁFICA

2. REVISION BIBLIOGRÁFICA

Introducción

La revisión bibliográfica se ha elaborado a partir del siguiente artículo, así como del material presentado en diferentes congresos. De acuerdo con la normativa del Instituto de Postgrado de la Universidad de Córdoba que regula la redacción y estructura de una tesis con mención internacional se ha procedido a exponer este capítulo tanto en inglés como en español.

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En los países en desarrollo el ganado sustenta gran parte de la población rural, proporcionando bienes y servicios (McDermott et al., 2010; Robinson et al., 2011; FAO, 2018). Los ganaderos de pequeña escala representan casi el 20% de la población mundial y ofertan una parte importante de los alimentos de alto valor nutricional en el trópico (McDermott et al., 2010; FAO, 2019). Los activos ganaderos muestran gran heterogeneidad en los países en desarrollo, fluctuando desde sistemas pastoriles extensivos con pequeños productores y producción de subsistencia hasta sistemas de producción industrial comercialmente orientados a la producción a gran escala (Cadena-Iñiguez et al., 2016; Herrero et al., 2013; Robinson et al., 2011; McDermott et al., 2010). No obstante, la mayor parte de los productores viven en el umbral de la pobreza, con alto grado de marginación y desarrollan su actividad en sistemas ecológicos muy frágiles (García-Martínez et al., 2016; Rangel et al., 2017).

Además, los pequeños productores de los países en desarrollo presentan muy bajo nivel de adopción tecnológica, la difusión de la innovación es lenta y con escasa vertebración en la zona. A pesar de ello la innovación y la tecnología constituyen herramientas estratégicas para el desarrollo y el aumento de la competitividad y viabilidad de las explotaciones (Williams, 2015; Aguilar-Gallegos et al., 2016; Rangel et al., 2017; Roldán-Suárez et al., 2018; Flores-Trejo et al., 2016). Frecuentemente se ha explicado el proceso de adopción tecnológica desde un enfoque individualista (Escobal, 2017). Hoy en día se analiza la adopción tecnológica desde una visión holística, donde se vincula estrechamente a factores sociales; tales como las características de los productores, su entorno y el tipo de relaciones que establecen entre sí (Díaz-José et al., 2013; Espejel-García et al., 2014). Por otra parte, Borgatti y Molina (2003) remarcan la importancia del aprendizaje tecnológico, ya sea «aprender haciendo» y «aprendizaje por imitación». Deroian (2002), afirma que la adopción lenta de la innovación se justifica por la incertidumbre intrínseca, lo que conlleva a la observación de la adopción en los productores próximos (vecinos) para alcanzar una experiencia acumulada de modo retardado. A este efecto, producto de la interacción de grupos sociales, se le denominó efecto influencia.

Los agentes de cambio y los líderes de opinión desempeñan un papel importante en la adopción y difusión de la innovación (Kempe et al., 2003; Wasserman y Faust, 2013). El Análisis de Redes Sociales (ARS) permite estudiar patrones de difusión e identificar unidades de análisis que están conectadas de manera frecuente e intensa dentro de una red (Rendón-Medel et al. 2007; Borgatti y Li, 2009; Martínez et al., 2009; Opsahl et al., 2010; Dawson et al., 2011; Warner et al., 2012; Díaz-José et al., 2013; Espejel-García et al., 2014; Flores-Trejo et al., 2016). Su carácter distintivo radica en el hecho de que sitúa a las relaciones en el foco de su atención, en contraposición al análisis habitual centrado en el examen de los atributos o características de los actores (García y Méndez, 2004).

El incremento de la adopción tecnológica requiere un conocimiento en profundidad de las relaciones y los lazos entre actores para transferir la innovación (Ter-Wal y Boschma, 2009; Wasserman y Faust, 2013). Cross et al. (2002) indican que su conocimiento proporciona una manera de hacer visible lo invisible y tangible lo intangible. Por otra parte, Hartwich y Scheidegger (2010), indicaron que la aplicación de Redes Sociales (ARS) en los pequeños productores de los países en desarrollo facilita la comprensión de los procesos de innovación rural con respecto a los siguientes aspectos:

(a) afina el enfoque de las capacidades disponibles de los agricultores para abordar con éxito la innovación,

(b) desafía la adopción de tecnología lineal que sugiere que las innovaciones se trasmiten desde la investigación y la extensión a los agricultores, sin considerar otras rutas y

(c) cambia el enfoque hacia el fortalecimiento de las capacidades dinámicas de los agricultores a través de procesos de aprendizaje colectivo (Roldán-Suárez et al., 2018).

La fuerza de los vínculos con otros agricultores y agentes que promueven la innovación, así como la complementariedad y el gradiente de conocimiento entre ellos, determina en qué medida las personas absorben las innovaciones (Hartwich y Scheidegger, 2010). Una premisa de esta perspectiva es que los comportamientos y resultados de los individuos, se ven afectados significativamente, por la forma en que ese individuo está vinculado a una red superior con un mayor número de conexiones sociales (Van den Bossche y Segers, 2013).

El objetivo de la revisión realizada fue exploratorio, respecto al proceso de adopción y difusión tecnológica a partir del Análisis de Redes Sociales (ARS) y se valoró si la utilización de esta metodología es apropiada para los ganaderos de muy pequeña escala situados en zonas tropicales de Latinoamérica, denominados de doble propósito. Esta aportación promoverá posteriores desarrollos cuantitativos que permitan identificar las tecnologías viables en cada zona, la secuencia de adopción, el modo de difusión y los líderes tecnológicos.

La revisión recoge la aplicación del ARS en la difusión de la innovación; a nivel general (Tabla 3), en la gestión de los recursos naturales (Tabla 4), y en los pequeños productores agropecuarios (Tabla 5), destacando los escasos trabajos existentes en ganadería (Tabla 6) y en los sistemas ganaderos bovinos de doble propósito (carne y leche) de los países tropicales (Tabla 7). Finalmente, derivado de la revisión, se muestra la propuesta del análisis tecnológico en ganadería de doble propósito en zonas tropicales (Figura 7).

Metodológicamente se ha realizado una revisión sistemática de la bibliografía existente en ARS en el sector agroalimentario. Para ello se han utilizado diferentes buscadores, plataformas y bases de datos; tales como, Google Scholar, Web of Science WOS, Science Direct, etc. Se ha establecido como intervalo de búsqueda el periodo 2009-2019 y se han utilizado palabras clave: ARS, análisis de redes sociales, UCINET, Pajek, ganadería de doble propósito, difusión de la innovación, transferencia tecnológica, difusión del conocimiento, sector agroalimentario, ganadería, innovación, tecnología, etc.

La búsqueda se realizó con estas palabras clave, ya sea de modo individual o combinado, a fin de filtrar las salidas de registros de acuerdo al objetivo del trabajo. Se usaron palabras clave en castellano y en inglés. Una vez seleccionados los manuscritos de interés se procedió a su análisis individual, evaluación y síntesis cuantitativa. Para ello se confeccionó una base de datos que recogía: la referencia de la autoría del trabajo y el país; tipo de bibliografía (científica JCR, SCI, investigación, divulgación); sector donde se aplicó; software utilizado; metodología aplicada y medidas de centralidad; muestra (unidades y tamaño muestral).

Análisis de Redes Sociales (ARS) en el sector agroalimentario

El ARS se ha utilizado en diferentes sectores y fases de la cadena agroalimentaria; destacando el análisis de los sistemas de gobernanza y la acción colaborativa en comunidades agroproductivas (Prota et a., 2018; Marín y Berkes, 2010; García-Amado et al., 2012; Alexander et al., 2015; Markantonatou et al., 2016), el análisis de la planificación de la conservación (Mills et al., 2014; Muñoz et al., 2018), la conectividad social de hogares pobres y la resiliencia al cambio climático (Cassidy y Barnes, 2012) y la profundización del conocimiento en la sostenibilidad de la producción porcina a partir de palabras clave (Schodl et al., 2017).

En las Tablas 3 y 4 se muestran las distintas áreas en las que se ha utilizado el ARS con distintos fines: para potenciar las dinámicas de aprendizaje colectivo y en la promoción de métodos agroecológicos (Arora, 2012), en la identificación de áreas de mejora de aprendizaje en comunidades rurales (Molano y Polo, 2015), la cuantificación del potencial creativo (Dawson et al., 2011), la relación entre la cohesión de equipo y su rendimiento (Warner et al., 2012), la evaluación de la productividad científica en ciencias pecuarias (Cerón-Muñoz et al., 2011), la transferencia de conocimiento tecnológico (Bond et al., 2008; Weiss et al., 2012; Bressan y Matta, 2015; López-Cruz y Obregón, 2015) y la influencia de los contactos informales en las redes de difusión del conocimiento (Reagans y McEvily, 2003; Levin y Cross, 2004; Morrison y Rabellotti, 2005; Allen et al., 2007); estos últimos estudios se apoyan en la teoría de la fuerza de los lazos débiles de Granovetter (1985).

Las redes sociales están constituidas por un centro de vínculos fuertes y una periferia de vínculos débiles. Según Granovetter (1985) la innovación y las oportunidades surgen frecuentemente en los vínculos débiles; ya que se mueven un contexto distinto donde se utiliza información y tecnología diferente a la disponible en el entorno próximo.

En la tabla 3 se recoge bibliografía previa donde se aplica ARS para la difusión del conocimiento y la innovación.

Tabla 3. Aplicaciones del ARS en la difusión del conocimiento y la innovación

Referencia	País	Medidas de centralidad utilizadas	Tamaño de la muestra (Software)[1]
Weiss et al. (2012)	Australia	Densidad; Centralización de la red; Centralidad del actor	30 informantes claves (U)
Arora (2012)	India	Grado	212 Pequeños agricultores (P)
Bressan y Matta (2015)	Argentina	Densidad	33 Fabricantes de productos electrónicos (U)
Molano y Polo (2015)	Colombia	Densidad; Centralización; Grado de entrada; Grado de salida; Intermediación; Distancia geodésica; Coeficiente de clúster	35 Miembros de CENDES (U)
Dawson et al. (2011)	Australia	Grado; Cercanía	76 Estudiantes de medicina (SNAPP)
Cerón-Muñoz et al. (2011)	Colombia	Grado	559 Investigadores (U)
López-Cruz y Obregón (2015)	Colombia	Centralidad del Grado de entrada; Centralidad del vector propio	Empresas manufactureras (U)
Bond et al. (2008)	UK	Centralidad de la red; Intermediación	183 Miembros de organizaciones (U)
Morrison y Rabellotti (2005)	Italia	Cliques; Estructura centro–periferia; Densidad; Centralidad; Grado; Centralidad del vector propio; Intermediación; Índice de heterogeneidad	26 Bodegas de vino (P)
Allen et al. (2007)	UK	Grado	Trabajadores del Grupo ISIC (U)
Schodl et al. (2017)	Austria	Intermediación; Análisis de cluster	329 Publicaciones científicas (P)
Levin y Cross (2004)	USA	Fuerza de los lazos	400 Empleados de grandes empresas (RGM)

[1] Software: U. Ucinet; P. Pajek; SNAPP. Social Networks Adapting Pedagogical Practice; RGM. Regresión Jerárquica Múltiple

Tabla 4. Aplicaciones del ARS en la conservación de recursos naturales

Referencia	País	Medidas de centralidad utilizadas	Tamaño de la muestra (Software)[1]
Markantonatou et al. (2016)	Italia	Diámetro; Densidad; Distancia promedio; Grado promedio; Centralización, Fuerza de los lazos	56 Stakeholders (U)

Mills et al. (2014)	Islas Salomón	Grado de entrada; Intermediación; Centralidad	23 Organizaciones ambientalistas (U)
Marín y Berkes (2010)	Chile	Centralidad; Densidad; Grado	38 Organizaciones de pescadores (U)
García-Amado et al (2012)	México	Centralización; Intermediación; Análisis de clúster; Distancia geodésica; Grado de entrada; Grado de salida; Cercanía	66 Jefes de hogar (U, SPSS y R)
Cassidy y Barnes (2012)	Botsuana	Centralidad; Intermediación	145 Hogares (U)
Alexander et al. (2015)	Jamaica	Cohesión; K-reach; Densidad; Grado de centralidad	380 Pescadores (U, G)

[1] Software: U. Ucinet; P. Pajek; SNAPP. Social Networks Adapting Pedagogical Practice; RGM. Regresión Jerárquica Múltiple

ARS en la difusión de la innovación en sistemas agroganaderos

En la difusión de innovación de pequeños productores agroalimentarios (Tabla 5); ARS se ha utilizado en la identificación de actores claves y favorecer la adopción de nuevas tecnologías a través de sus redes de contacto (Pérez, 2011; Mayoral et al., 2012; Hernández, 2015; Ricciardi, 2015), en el estudio de la influencia de las interacciones sociales en el comportamiento de los pequeños productores respecto a la adopción tecnológica y la innovación (Diez, 2008; Hartwich et al., 2010; Rodríguez-Modroño, 2012; Núñez-Espinoza et al., 2014; Gómez-Carreto, 2015; Aguilar-Gallegos et al., 2016; Stojcheska et al., 2016; Cárdenas-Bejarano et al., 2016; Avendaño-Ruiz et al., 2017; Espejel-García et al., 2017; Roldán-Suárez et al, 2018; Vishnu et al., 2018), en la valoración de la confianza en las relaciones de negocios entre productores (Figueroa-Rodríguez et al., 2012; Pérez-Hernández et al., 2017), en la evaluación de los factores que limitan o favorecen la gestión de la innovación en pequeños productores (Zarazúa-Escobar et al., 2011; Espejel-García et al., 2014), identificación de redes de innovación rural en agroecosistemas con papaya (Cano-Reyes et al., 2015), análisis de las coberturas obtenidas en estrategias de gestión de la innovación (Solleiro-Rebolledo et al., 2015; Roldán-Suárez et al., 2018), en el análisis la cadena de valor de los productos lácteos (Baker et al., 2013) y la evaluación del sistema de trazabilidad de la carne (Naeaes et al., 2015).

Tabla 5. Aplicaciones del ARS en la difusión de innovación en pequeños productores

Referencia	País	Medidas de centralidad utilizadas	Tamaño de la muestra (Software)[1]
Hartwich et al. (2010)	Honduras	Densidad; Grado de entrada; Intermediación;	79 Productores de café (U)

		Centralidad del vector propio	
García et al. (2017)	México	Grado de entrada; Grado de salida; Densidad	63 Productores y seis agentes técnicos (U)
Cano-Reyes et al. (2015)	México	Rango, Intermediación; Cercanía	55 Productores de papaya (U)
Stojcheska et al. (2016)	Macedonia, Serbia, Bosnia	Densidad; Reciprocidad; Intermediación	895 Agricultores (U)
Figueroa-Rodríguez et al. (2012)	México	Grado	39 Productores de hortalizas (U)
Avendaño-Ruiz et al. (2017)	México	Densidad; Centralidad	58 Horticultores y 32 instituciones de la región. (U)
Mayoral et al. (2012)	Argentina	Fuerza de los lazos	21 Empresas de tecnología (U)
Ricciardi (2015)	Ghana	Grado; Intermediación; Centralidad armónica; Índice de Jaccard	91 Familias de subsistencia agrícola (U)
Baker et al. (2013)	Tanzania y Uganda	Grado	Productores, comerciantes y extensionistas (P)
Naeaes et al. (2015)	Brasil	Densidad; Centralidad; Cercanía; Intermediación; Coeficiente de agrupamiento; Distancia geodésica; Cliques; N-cliques	3 Sistemas de trazabilidad de la carne (U)
Nuñez-Espinoza et al. (2014)	México	Grado; Intermediación	Proyectos de desarrollo rural exitosos (U)
Rodríguez-Modroño (2012)	España	Densidad; Centralidad; Cercanía	607 Empresas andaluzas (U)
Zambada-Martínez et al. (2013)	México	Densidad; Cercanía	18 Representantes de organizaciones (U)
Gómez-Carreto (2015)	México	Densidad; Índice de centralización; Grado de entrada; Grado de salida	71 Empresas de productores de jitomate (U)
Solleiro-Rebolledo et al. (2015)	México	Densidad; Centralidad; Grado de entrada normalizado; Grado de salida normalizado	34 Especialistas (U)
Roldán-Suárez et al. (2018)	México	Densidad; Cercanía	457 Actores del sistema del maíz (U)
Diez (2008)	Argentina	Densidad; Centralidad; Grado de entrada; Grado de salida; Cercanía; Intermediación	33 Instituciones de apoyo a la producción. (U)
Ortiz-Rosales y Ramírez-Abarca, (2017)	México	Densidad; Centralidad; Grado de entrada; Grado de salida; Cercanía, Intermediación	442 Almacenes. (U)
Zarazúa-Escobar et al. (2011)	México	Grado; Densidad; Centralización;	130 Actores clave en la producción de fresa. (U)

Muñoz et al. (2018)	Colombia	Densidad; Grado de entrada; Grado de salida; Actores clave	100 Profesionales interesados en la conformación de la red. (U)

[1] Software: (U): Ucinet, (P): Pajek

En el caso de los sistemas ganaderos (Tabla 6), el ARS se ha utilizado ampliamente en economía de la salud animal para evaluar los patrones de contagio de agentes infecciosos, mediante la identificación de las rutas de movimientos de ganado entre fincas (Christley et al., 2005; Ortiz-Peláez et al., 2006; Bigras-Poulin et al., 2006; Baptista et al., 2008; Drewe, 2009; Dube et al. 2010; Smith et al., 2013; Koene y Ipema, 2014; Büttner et al., 2015; Lichoti et al., 2016; Marquetoux et al., 2016; Poolkhet et al., 2016; VanderWaal et al., 2016; VanderWaal et al., 2017; Crabb et al., 2018; de Sa et al., 2018; Kim et al., 2018; Nicolas et al., 2018).

En este caso el análisis de redes sociales ha sido una técnica útil para identificar individuos, poblaciones y regiones importantes en términos de riesgo de introducción, prevalencia, propagación y diseminación de enfermedades en los sistemas ganaderos (Martínez et al., 2009); este enfoque permite mediante la trazabilidad de animales procedentes de una granja infectada, identificar nodos u operaciones de ganado en la red que están en riesgo de infectarse y transmitir la infección (Dubé et al., 2009).

Tabla 6. Aplicaciones del ARS en economía de la salud animal

Referencia	País	Medidas de centralidad utilizadas	Tamaño de la muestra (Software)[1]
Christley et al. (2005)	Inglaterra	Grado promedio; Intermediación; Cercanía	141 Granjas (P, U)
Ortiz-Peláez et al. (2006)	Inglaterra	Intermediación; Análisis de Clúster	653 Granjas, mercados y distribuidores (P)
Bigras-Poulin et al. (2006)	Dinamarca	Clúster	460.615 Movimientos individuales de ganado (P)
Baptista et al. (2008)	Portugal	Grado; Centralidad; Intermediación; Cercanía; Densidad, Clúster	1.031 Granjas, mercados, subastas (P)
Dubé et al. (2010)	Canadá	Grado de entrada; Grado de salida;	171 Granjas (U)
Smith et al. (2013)	UK	Distancias euclidianas; Grado; Intermediación; Coeficiente de clúster; Centralización; Índice (E – I)	1.633 Granjas (U)

Lichoti et al. (2016)	Kenia y Uganda	Distancia geodésica media; Densidad; Coeficiente de clúster; Modularidad	683 Productores de cerdo (N)
Marquetoux et al. (2016)	Nueva Zelanda	Grado de entrada; Grado de salida; Intermediación; Coeficiente de clúster	180 Granjas (P)
Poolkhet et al. (2016)	Camboya	Grado; Intermediación; Densidad; Coeficiente de clúster	365 Productores e intermediarios (U)
VanderWaal et al. (2017)	Uruguay	Grado; Fuerza de los lazos; Cercanía; Intermediación; Densidad; Centralización.	62.767 Productores (I)
Crabb et al. (2018)	Australia	Distancia geodésica; Grado; Intermediación; Grado de entrada; Grado de salida; Cercanía; Densidad; Clúster	593 Movimientos de pollos (G)
de Sa et al. (2018)	Brazil	Grado de entrada; Grado de salida; Intermediación	27.517 Certificados de tránsito animal, 579 certificados comercio internacional. (P)
Kim et al. (2018)	Mayotte	Densidad; Coeficiente de cluster, Distancia euclidiana; Intermediación; Cercanía	3505 Movimiento de ganado (I)
Nicolas et al. (2018)	Mauritania	Grado de entrada; Grado de salida; Intermediación; Coeficiente de clúster; Densidad, Centralización; Centralidad del Eigenvector	2.219 Movimientos comerciales (U)

[1] Software: (U): Ucinet, (P): Pajek, (I): Igraph, (N): NodeXL, (G): Gephi

En los países en desarrollo de Latinoamérica (ALC) predomina el sistema de producción bovino de doble propósito (DP). El DP está conformado por explotaciones de muy pequeña escala, muy bajo nivel tecnológico y alto grado de marginalización. Aunque, por otra parte, contribuyen de modo muy importante al mantenimiento de los modos de vida tradicionales en el sector agrario y favorecen la cohesión social de los territorios; son capaces de generar ingresos directos, contribuyen a la sustentabilidad ambiental y muestran gran potencial para mitigar emisiones de gases de efecto invernadero (Rangel et al., 2017; García Martínez et al., 2016).

El DP se desarrolla en mayor proporción en las regiones agroecológicas tropicales (Hernández et al, 2011). Es un sistema multifuncional y flexible de producción mixta, es decir, favorece la complementariedad entre la ganadería (carne y leche), la agricultura tropical, el uso de pastizales, las actividades forestales, las actividades de transformación de alimentos como queso y otras externas (servicios fundamentalmente) (Rangel et al., 2017).

El sistema de producción es tradicional y de pastoreo extensivo en condiciones de rusticidad. Se utilizan recursos de bajo costo de oportunidad, lo que favorece que sea una actividad sostenible con mayor flexibilidad y eficiencia en el uso de los recursos (Díaz et al., 2011).

En esta área de conocimiento, México es pionero en el uso del ARS en ganado bovino de DP (Tabla 7), con trabajos promovidos por el INIFAP (García-Amado et al.,2012; Espejel-García et al., 2014; García et al., 2017; Cano-Reyes et al., 2015; Cárdenas-Bejarano et al., 2016; Figueroa-Rodríguez et al., 2012; Roldán-Suárez et al., 2018; Avendaño-Ruiz et al., 2017; Espejel-García et al., 2017; Nuñez-Espinoza et al., 2014; Pérez-Hernández et al., 2017; Zambada-Martínez et al., 2013; Gómez-Carreto, 2015; Solleiro-Rebolledo et al., 2015; Roldán-Suárez et al., 2018; Zarazúa-Escobar et al., 2011; Pérez, 2011), enfocados principalmente a mejorar el extensionismo agrario y los programas de capacitación agrícola. La mayoría de estos trabajos se han realizado a través de encuentros directos con los productores.

Tabla 7. Aplicaciones del ARS en la difusión de la innovación en DP

Referencia	País	Medidas de centralidad utilizadas	Tamaño de la muestra (Software)[1]
Espejel-García et al. (2014)	México	Densidad; Centralidad; Actores clave	66 Productores de leche (U)
Hernández (2015)	Chile	Densidad, Centralización, Intermediación, Grado de entrada, Grado de salida	18 Productores de leche (U)
Vishnu et al. (2018)	India	Grado, Intermediación, Cercanía, Densidad	320 Productores de leche (U)
Cárdenas-Bejarano et al. (2016)	México	Densidad, Grado, Intermediación	18 Productores del modelo GGAVATT (U)
Espejel-García et al. (2017)	México	Centralidad; Actor clave; Actor difusor	126 Productores bovinos (U)
Villarroel-Molina et al. (2018)	México	Grado; Centralidad; Intermediación; Cercanía, Cutpoints; Eigenvector	262 Productores (U)
Pérez (2011)	México	-	34 Productores bovinos de carne (U)
Perez-Hernandez et al. (2017)	México	Grado; Intermediación	11 Organizaciones de producción de ovinos (U)

[1]Software: (U): Ucinet

Sin embargo, son escasos los trabajos que han hecho uso del ARS para estudiar el proceso de difusión de la tecnología en DP (Rendón-Medel et al., 2007 y Espejel-García et al., 2014) (Tabla 7).

Rendon-Medel et al (2007) utilizó la metodología ARS para identificar actores claves en la red de producción ovina del Estado de Querétaro, con la finalidad de inducir un proceso de adopción de siete innovaciones y desarrollar capacidades de comercialización entre los productores. Este autor realizó un estudio comparativo entre dos grupos de productores. Por una parte, los seleccionados por la Agencia para la Gestión de la Innovación (AGI) en base a criterios de liderazgo, solvencia moral, disponibilidad a participar en un proceso de innovación y simpatía. Por otra parte, un panel de actores clave seleccionados por el software de análisis de redes, a partir del cálculo de indicadores de difusión y estructuración. El modelo ARS sustituyó a una parte importante de los productores considerados inicialmente por la AGI y se logró un incremento de la cobertura de la red en un 22%. La tasa de adopción promedio de los productores propuestos por la AGI era del 56%, mientras que para el grupo propuesto por el algoritmo de KeyPlayer fue de 25%. En tanto que los seleccionados mediante ARS mostraron mayor capacidad de difusión de la innovación. Lo que sugiere que los asesores de la AGI tienden a seleccionar a los productores con mayor nivel tecnológico, pero, su vez, mostraron baja capacidad de influencia entre sus pares, dada su reducida propensión a comunicar sus conocimientos (Rendón-Medel et al., 2007).

Espejel-García et al. (2014) utilizaron ARS para identificar los factores que limitan o favorecen la gestión de la innovación en la cadena de bovinos de leche del Valle del Mezquital, Hidalgo (México) y determinaron la articulación del sistema regional de innovación y conocimiento entre los actores y encontraron un bajo grado de articulación e integración, con una densidad muy baja entre productores (4,4%). En este trabajo el 49,5% de los productores son autodidactas y aprenden de familiares y de otros productores (conocimiento tácito). Solamente un 19,5% de la innovación proviene de técnicos especialistas; un 18,4% de proveedores de insumos y un 10,2% lo hace de la Comisión Estatal de la Leche (conocimiento codificado). Estos hallazgos refuerzan la hipótesis de que los lazos débiles son potenciales mecanismos de difusión de conocimiento tácito, es decir, un conocimiento producto de la experiencia, mientras que los lazos fuertes con agentes especializados promueven la trasmisión de conocimiento codificado (Granovetter, 1985).

Respecto al modo de difusión de la tecnología, se han logrado mapear redes de innovación a través de encuestas directas a los actores, para detectar patrones de relaciones (Rendón-Medel et al., 2007; Arora, 2012; Mayoral et al., 2012; Espejel-García et al. 2014). Señalan a las personas o instituciones con quién tiene relación, generando una lista de nombres. Este tipo de muestreo genera una matriz de adyacencia de Modo 1, que permite el cálculo de los indicadores a través de análisis de redes sociales. Sin embargo, existe otra forma de análisis, menos frecuente, para el estudio de la adopción tecnológica en ganadería y es aquella información que proviene directamente de los patrones de adopción de cada ganadero.

En este caso, la red se construye a partir de la siguiente pregunta: ¿Adopta o no adopta la tecnología?; lo que genera una matriz de adyacencia de Modo 2. Este segundo análisis incorpora la teoría de la elección, incluyendo comportamientos, actitudes, creencias, etc. Busca una mayor aproximación a la realidad y remarca elecciones similares entre pares de nodos, referido en la literatura como homogeneidad social (Everett y Borgatti, 2013; Borgatti, 2009).

En resumen, en ganadería el ARS permite profundizar en el conocimiento de la difusión tecnológica a través de las encuestas directas a los productores, preguntando las relaciones; donde el productor señala las personas o las instituciones con quien se relaciona, así como el modo de aprendizaje de la innovación, su adopción y su difusión (Rendón-Medel et al., 2007; Arora, 2012; Mayoral et al., 2012; Espejel-García et al. 2014) (Matriz de adyacencia Modo 1). Aunque también se abre otra vía de gran interés que ayuda a conocer los patrones de adopción a partir de las tecnologías implementadas en cada explotación de acuerdo a la adopción o no de la tecnología (Matriz de adyacencia Modo 2) (Everett y Borgatti, 2013; Borgatti, 2009).

Villarroel-Molina et al. (2018a, 2018b) organiza la información en una matriz de adyacencia Modo 2 (Tabla 8). La matriz está compuesta por los productores, en las filas y los diferentes tipos de tecnologías que utilizan en las columnas de la matriz. Donde (1) significa que si adoptan la tecnología y el valor nulo que no la adoptan (0). Para analizar esta información, se transforma la matriz Modo 2 (Tabla 8) en una matriz de Modo 1 (Tabla 9) usando el comando de afiliación de UCINET. El resultado muestra cuántas tecnologías comparten cada par de ganaderos.

Tabla 8. Tecnologías por productor Matriz Modo 2 (Villarroel-Molina et al., 2018).

	Tecnologías evaluadas (en Rangel et al., 2017)[1]						
Productor	Uso de registros	Programa de cría	Pastoreo en pastos nativos	Pastoreo en praderas cultivadas	Pastoreo en rastrojos y residuos agrícolas	Tipo de ordeño	Hasta n=45
Farmer$_1$	0	0	0	0	0	0	0
Farmer$_2$	0	0	0	0	0	0	0
Farmer$_3$	1	1	1	1	0	0	1
Farmer$_4$	1	1	1	1	1	1	1
Farmer…$_n$	1	1	1	1	1	0	0

[1] Donde: (1) significa que si adoptan la tecnología y (0) que no adoptan esa tecnología.

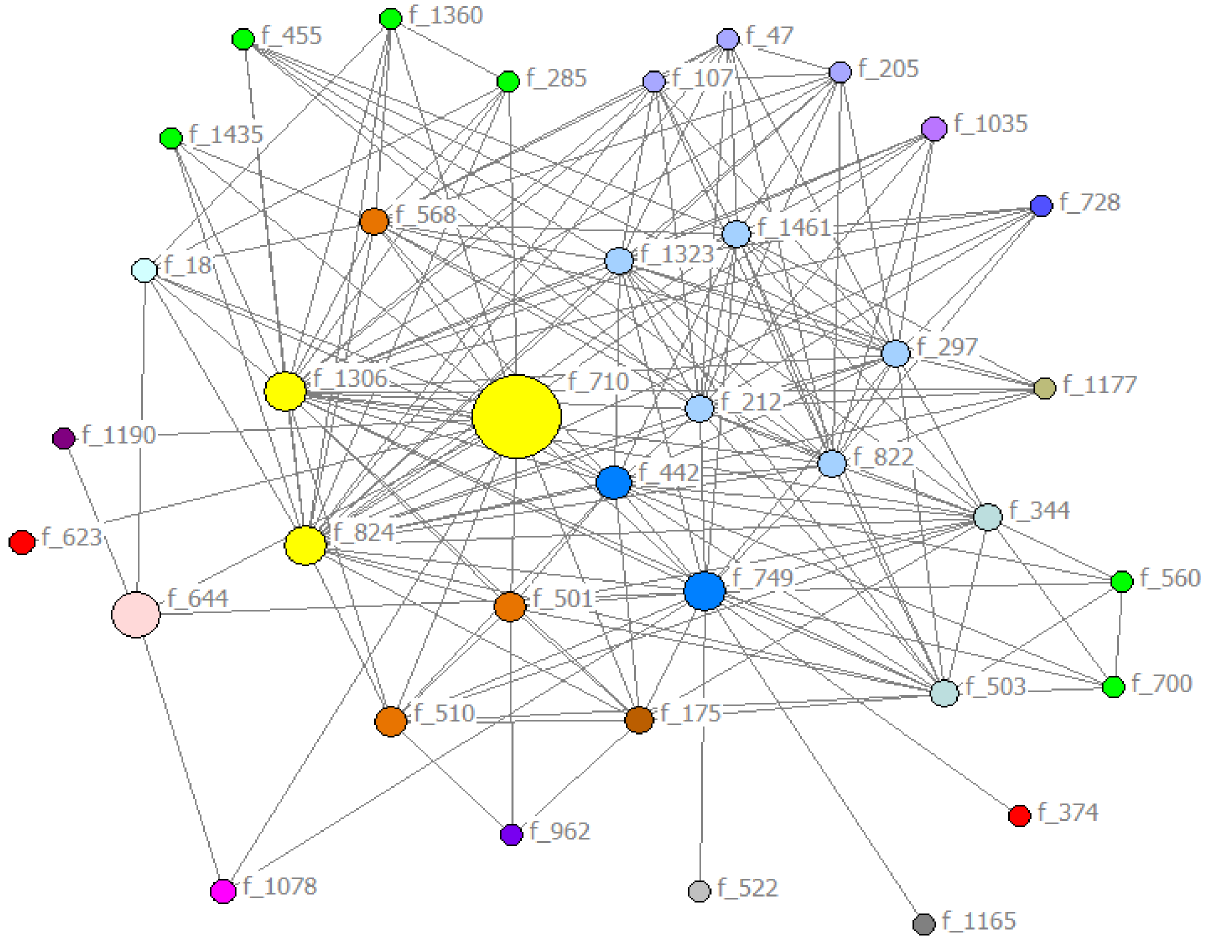
La aplicación de ARS Farmer vs Farmer recogida en la Matriz Modo 1 (Tabla 9) y en la red expresada en la Figura 7; también se podría implementar desde la orientación de Tecnología vs Tecnología lo que suministraría información relativa a los patrones de adopción de tecnologías. Esta aproximación metodológica con Matrices de adyacencia de Modo 2 es fiable, sencilla de obtener, fácil de implementar y facilita un diagnóstico de la situación real existente, que promueve la disminución del riesgo al fracaso en la adopción tecnológica por parte de los pequeños productores (García et al., 2016).

Tabla 9. Tecnologías compartidas entre productores, Matriz Modo 1 (Villarroel-Molina et al., 2018).

	Productores[1]							
Productores	Farmer$_1$	Farmer$_2$	Farmer$_3$	Farmer$_4$	Farmer$_5$	Farmer$_6$	Farmer$_7$	Farmer$_{\ldots n}$
Farmer$_1$	**24**	20	20	18	12	16	15	15
Farmer$_2$		**26**	25	17	10	16	15	16
Farmer$_3$			**27**	17	10	16	15	17
Farmer$_4$				**20**	12	16	16	14
Farmer$_5$					**20**	19	19	16
Farmer$_6$						**19**	15	12
Farmer$_7$							**21**	12
Farmer$_{\ldots n}$								**20**

[1] Número de tecnologías comunes a dos productores. En el eje diagonal, en negrita, las tecnologías adoptadas por cada productor.

Finalmente, mediante la aplicación de UCINET, Villarroel-Molina et al. (2018) muestran en la Figura 7 el patrón de adopción y difusión tecnológica en el área de genética y reproducción de los pequeños productores de doble propósito del trópico mexicano. En amarillo aparecen los ganaderos con mayor grado de centralidad e intermediación.



*El tamaño y color del círculo hacen referencia a la intermediación y al grado de centralidad.

Figura 7. Red de adopción tecnológica en el área de genética y reproducción (Villaroel-Molina et al., 2018)

Previamente a la utilización de ARS, Rangel et al. (2017), García et al. (2016), Herrero et al. (2013) y Robinson et al. (2011), recomiendan el desarrollo de una tipología de explotaciones que explique la mayor parte de la variabilidad existente en el sistema.

La tipología incorpora los factores estructurales, de dimensión, económicos y ambientales; generando clúster con gran homogeneidad dentro del grupo y gran heterogeneidad con los restantes grupos de explotaciones. Esta metodología multivariante permite desarrollar patrones de difusión de la innovación, que son específicos para productores similares. Su conocimiento favorece a posteriori el desarrollo de políticas públicas específicas para cada grupo.

2.1. Introduction

Livestock feed a great part of the rural people from developing countries, supplying goods, and services (FAO, 2018; Robinson et al., 2011; McDermott et al., 2010). Cattle smallholders represent almost 20% of the world's population, they offer an important part of the highest nutritional value of foods. Cattle production structures show a great heterogeneity in developing countries. There are extensive pastoral systems, subsistence systems settled by smallholders to high industrial systems based on large scale economy (McDermott et al., 2010; Robinson et al., 2011; Herrero et al., 2013; Cadena-Íñiguez et al., 2016). However, most part of the producers live under the poverty threshold, in high degree marginalized and fragile ecological territories. Besides the smallholders in developing countries show a very low level in technology adoption, the spreading of the technologies is very slow into the territories. However, both innovation and technology are strategic tools for the development and the increase of the competitiveness and viability of the farms (Williams, 2015; Aguilar-Gallegos et al., 2016; Flores-Trejo et al., 2016; Rangel et al., 2017; Roldán-Suárez et al., 2018). Frequently, the technological adoption process has been explained as the individualist approach (Escobal, 2017).

Currently, technological adoption is analysed by a holistic point of view, linking closely social factors as producers' characterization, their setting, and the type of relation between themselves (Díaz- José et al., 2013; Espejel-García et al., 2014). Borgatti and Molina (2003) reaffirm the importance of technological learning, learning by doing and learning by imitation. Deroian (2002.) indicates that the adoption of the innovation is low due to intrinsic uncertainty. That address to adoption by observation among producer's neighbour in order to reach an accumulated experience in a delayed manner. This effect produced by an interaction between social groups is called "***influence effect***".

Technical advisors and local leaders play an important role in technological adoption and innovation diffusion (Kempe et al., 2003; Wasserman and Faust, 2013). Social networks analysis (SNA) defines patterns of diffusion and identify units of analysis frequently connected into an intensive network (Rendón-Medel et al. 2007; Borgatti y Li, 2009; Martínez et al., 2009; Opsahl et al., 2010; Dawson et al., 2011; Warner et al., 2012; Díaz-José et al., 2013; Espejel-García et al., 2014; Flores-Trejo et al., 2016). The distinctive point is that the relationships are the central focus, opposite to the standard analysis, where an exam of attributes or of the stakeholder's characteristics is addressed. The growth of technology adoption requires deepest knowledge of relationships and links amongst stakeholders to transfer innovation (Ter-Wal y Boschma, 2009; Wasserman y Faust, 2013). Cross et al. (2002) indicate that the knowledge of relationships provides visibility to the invisible and tangibility to intangible.

Furthermore, Hartwich and Scheidegger (2010) mention that the application of SNA in smallholders from developing countries facilitates the compression of the rural processes of innovation regarding these items: (a) Improving the approach of the available capabilities of the farmers to address the success of innovation, (b) Challenging the lineal technological adoption suggested, where the innovations are transferred from the research to farmers extension, without considering other ways and (c) Changing the approach to enhance the dynamic capabilities of the farmers through learning collective processes (Roldán-Suárez et al., 2018).

Establishing links with other farmers and advisors promotes the innovation, also the complementarity and the gradient of the knowledge among themselves (Hartwich y Scheidegger, 2010). A precondition of this perspective is that the knowledge and results of individuals are significantly impacted by how the individual is linked to a superior net composed by a greater number of social connections (Van den Bossche and Segers, 2013).

The objective of this review was exploratory regarding the adoption and diffusion of the technology process by applying SNA methodology and was assessed if the marginal dual-purpose cattle smallholders from a very low scale were appropriated and located in Latin-American tropics. This contribution will promote subsequent quantitative developments that allow identifying viable technologies in each area, the sequence of adoption, the mode of dissemination and technological leaders.

The review includes the application of the SNA methodology in the dissemination of innovation; at a general level (Table 10), in the management of natural resources (Table 11), and in small agricultural producers (Table 12), highlighting the few existing papers in livestock (Table 13) and in dual-purpose cattle systems (beef and milk) from tropical countries (Table 14). Finally, derived from the review, the proposal of the technological analysis in dual-purpose livestock in tropical areas is shown (Figure 8).

A systematic review of the existing literature on SNA in the agri-food sector has been carried out as a methodology. For this, different search engines, platforms, and databases have been used; such as Google Scholar, Web of Science WOS, Science Direct, etc. The 2009-2019 period has been established as a search interval and keywords have been used: SNA, social network analysis, UCINET, Pajek, dual-purpose cattle, dissemination of innovation, technology transfer, knowledge dissemination, agri-food sector, livestock, innovation, technology, etc. The search was carried out with these keywords, individually or in combination, in order to filter the record outputs according to the purpose of the paper. Keywords were used in Spanish and English. Once the manuscripts of interest were selected, their individual analysis, evaluation and quantitative synthesis were carried out. For this, a database was compiled. The database collected the following items: the reference of the authorship of the work and the country; type of bibliography (scientific JCR, SCI, research, dissemination); the sector where it was applied; Software used; Applied methodology and centrality measures; Sample (units and sample size).

2.2. SNA in agri-food sector

SNA was used in different sectors and agri-food links chain, the analysis of the governance systems and collaborative action in agroproductive settlements (Prota et a., 2018; Marín y Berkes, 2010; García-Amado et al., 2012; Alexander et al., 2015; Markantonatou et al., 2016), the analysis of conservation planning (Mills et al., 2014; Muñoz et al., 2018), the social connectivity of poor households and resilience to climate change (Cassidy and Barnes, 2012) and the deepening of knowledge in the sustainability of pig production from keywords (Schodl et al., 2017). Tables 10 and 11 show how the dissemination of knowledge in SNA has been used for different purposes: to enhance the dynamics of collective learning and in the promotion of agroecological methods (Arora, 2012), in the identification of areas for improvement of learning in rural communities (Molano and Polo, 2015), the quantification of creative potential (Dawson et al., 2011), the relationship between team cohesion and performance (Warner et al., 2012), productivity evaluation scientific in live- stock sciences (Cerón-Muñoz et al., 2011), the transfer of technological knowledge (Bond et al., 2008; Weiss et al., 2012; Bressan and Matta, 2015; López-Cruz and Obregón, 2015) and the influence of informal contacts on knowledge dissemination networks (Reagans and McEvily, 2003; Levin and Cross, 2004; Morrison and Rabellotti, 2005; Allen et al., 2007); these latter studies are supported on the theory of the strength of weak ties of Granovetter (Granovetter, 1985). Social networks are composed by a center of strong ties and a periphery of weak ties. According to Granovetter (1985), innovation, and opportunities often arise in weak ties; since they move into a different context where information and different technology from that available in the near environment is used.

Table 10. SNA Applications in the dissemination of knowledge and innovation

References	Country	Centrality measures	Size of sample (Software)[1]
Weiss *et al.* (2012)	Australia	Density; network centralization; Node centrality	30 Key informants (U)
Arora (2012)	India	Degree	212 Samallholders (P)
Bressan and Matta (2015)	Argentina	Density	33 Electronics products manufacturers (U)
Molano and Polo (2015)	Colombia	Density; Centralization; In-degree; Out-degree; Betweenness; Geodesic distance; Clustering coefficient	35 Members of CENDES (U)
Dawson *et al.* (2011)	Australia	Degree; Closeness	76 Medicine students (SNAPP)
Cerón-Muñoz *et al.* (2011)	Colombia	Degree	559 Researchers (U)
López-Cruz and Obregón (2015)	Colombia	In-degree; Eigenvector centrality	Manufacturing companies (U)
Bond *et al.* (2008)	UK	Network centralizarion; Betweenness	183 Members of organizations (U)
Morrison and Rabellotti (2005)	Italia	Cliques; Core periphery structure; Density; Centralization; Degree; Eigenvector centrality; Betweenness; Heterogeneity index	26 Wine cellars (P)
Allen *et al.* (2007)	UK	Degree	Workers of the group ISIC (U)
Schodl *et al.* (2017)	Austria	Betweenness; Clustering coefficient	329 Scientific Publications (P)

Levin and Cross (2004)	USA	Tie strength	400 Employers of big firms (RGM)

[1] Software: U. Ucinet; P. Pajek; SNAPP. Social Networks Adapting Pedagogical Practice; RGM. Multiple Hierarchical Regression.

Table 11. SNA Applications in natural resources conservation

References	Country	Centrality measures	Size of sample (Software)[1]
Markantonatou *et al.* (2016)	Italy	Diameter; Density; Average distance; Average degree; Centralization, Tie strength	56 Stakeholders (U)
Mills *et al.* (2014)	Solomon Islands	In-degree; Betweenness; Centralization	23 environmental organizations (U)
Marín and Berkes (2010)	Chile	Centralization; Density; Degree	38 fishers Organizations (U)
García-Amado *et al.* (2012)	Mexico	Centralization; Betweenness; cluster analysis; Geodesic distance; In-degree; Out-degree; Proximity	66 households (U, SPSS y R)
Cassidy and Barnes (2012)	Botswana	Centralization; Betweenness	145 Households(U)
Alexander *et al.* (2015)	Jamaica	Cohesion; K-reach; Density; Degree centrality	380 Fishers (U, G)

[1] Software: U. Ucinet; G. Gephi; P. Pajek; SNAPP. Social Networks Adapting Pedagogical Practice; RGM. Multiple Hierarchical Regression.

2.3. SNA in the dissemination of innovation in agrolivestock systems

In the diffusion of innovation of agri-food smallholders (Table 12); SNA has been used in the identification of key actors and to analyse the capability of adoption of new technologies through their contact networks (Pérez, 2011; Mayoral et al., 2012; Hernández, 2015; Ricciardi, 2015), in the study of influence of social interactions on the behavior of smallholders regarding technological adoption and innovation (Diez, 2008; Hartwich et al., 2010; Rodríguez-Modroño, 2012; Núñez-Espinoza et al., 2014; Gómez-Carreto, 2015; Aguilar-Gallegos et al., 2016; Stojcheska et al., 2016; Cárdenas-Bejarano et al., 2016; Avendaño-Ruiz et al., 2017; Espejel-García et al., 2017; Roldán-Suárez et al., 2018; Vishnu et al., 2018), in the assessment of trust of the business relationships between producers (Figueroa-Rodríguez et al., 2012; Pérez-

Hernández et al., 2017), in the evaluation of factors that limit or favour the management of innovation in smallholders (Zarazúa-Escobar et al., 2011; Espejel-García et al., 2014), identification of rural innovation networks in agroecosystems with papaya (Cano-Reyes et al., 2015), analysis of the coverage obtained in innovation management strategies (Solleiro-Rebolledo et al., 2015 ; Roldán-Suárez et al., 2018), in the analysis the value chain of dairy (Baker et al., 2013) and the evaluation of the traceability system of meat (Naeaes et al., 2015).

Table 12. SNA Applications in the dissemination of innovations in smallholders

References	Country	Centrality measures	Size of sample (Software)[1]
Hartwich *et al.* (2010)	Honduras	Density; In-degree; Betweenness; Eigenvector centrality	79 coffee producers (U)
García *et al.* (2017)	Mexico	In-degree; Out-degree; Density	63 Producers and six technical advisors (U)
Cano-Reyes *et al.* (2015)	Mexico	Degree, Betweenness; Proximity	55 Producers of papaya (U)
Stojcheska *et al.* (2016)	Macedonia, Serbia, Bosnia	Density; Reciprocity; Betweenness	895 Agriculture farmers (U)
Figueroa-Rodríguez *et al.* (2012)	Mexico	Degree	39 horticulture producers (U)
Avendaño-Ruiz *et al.* (2017)	Mexico	Density; Centralization	58 Horticulture producers and 32 local institutions (U)
Mayoral *et al.* (2012)	Argentina	Tie strength	21 Technology companies (U)
Ricciardi (2015)	Ghana	Degree; Betweenness; Harmonic centrality; Jaccard Index	91 agriculture subsistence families (U)
Baker *et al.* (2013)	Tanzania and Uganda	Degree	Producers, traders, and technical advisors (P)
Naeaes *et al.* (2015)	Brazil	Density; Centralization; Proximity; Betweenness; Clustering coefficient; Geodesic distance; Cliques; N-cliques	3 Meat traceability systems (U)
Nuñez-Espinoza *et al.* (2014)	Mexico	Degree; Betweenness	Successful Rural development projects (U)
Rodríguez-	Spain	Density; Centralization;	607 Andalusian

Modroño (2012)		Proximity	companies (U)
Zambada-Martínez *et al.* (2013)	Mexico	Density; Proximity	18 organizations leaders (U)
Gómez-Carreto (2015)	Mexico	Density; Centralization Index; In-degree; Out-degree	71 Tomato producer companies (U)
Solleiro-Rebolledo *et al.* (2015)	Mexico	Density; Centralization; In-degree; Out-degree	34 Specialists (U)
Roldán-Suárez *et al.* (2018)	Mexico	Density; Centralization	457 Corn system actors (U)
Diez (2008)	Argentina	Density; Centralization; In-degree; Out-degree; Proximity; Betweenness	33 Institutions for supporting production (U)
Ortiz-Rosales and Ramírez-Abarca, (2017)	Mexico	Density; Centralization; In-degree; Out-degree; Proximity, Betweenness	442 warehouses (U)
Zarazúa-Escobar *et al.* (2011)	Mexico	Degree; Density; Centralization	30 key stakeholders in strawberry production (U)
Muñoz *et al.* (2018)	Colombia	Density; In-degree; Out-degree; Keyplayer	100 Professionals interested in network shaping (U)

[1] Software: (U): Ucinet, (P): Pajek.

In the livestock systems (Table 13), the SNA has been widely used in animal health economics to assess the patterns of infection of infectious agents, by identifying the routes of movement of cattle between farms (Christley et al., 2005; Ortiz-Peláez et al., 2006; Bigras-Poulin et al., 2006; Baptista et al., 2008; Drewe, 2009; Dube et al. 2010; Smith et al., 2013; Koene and Ipema, 2014; Büttner et al., 2015; Lichoti et al., 2016; Marquetoux et al., 2016; Poolkhet et al., 2016; VanderWaal et al., 2016; VanderWaal et al., 2017; Crabb et al., 2018 ; de Sa et al., 2018; Kim et al., 2018; Nicolas et al., 2018). In this case, the analysis of social networks has been a useful technique to identify individuals, populations and important regions in terms of risk of introduction, prevalence, spread and dissemination of diseases in livestock systems (Martínez et al., 2009); This approach allows the traceability of animals, from an infected farm, identifying nodes or livestock operations in the network that are at risk of becoming infected and transmit the infection (Dubé et al., 2009).

Table 13. Applications of SNA in Animal health economy

References	Country	Centrality measures	Size of sample (Software)[1]
Christley *et al.* (2005)	England	Average degree; Betweenness; Proximity	141 farms (P, U)
Ortiz-Peláez *et al.* (2006)	England	Betweenness; Cluster Analysis	653 Farms, markets and delivers (P)
Bigras-Poulin *et al.* (2006)	Denmark	Cluster	460.615 individual movements of cattle (P)
Baptista *et al.* (2008)	Portugal	Degree; Centralization; Betweenness; Proximity; Density, Cluster Analysis	1.031 Farms, market, auction (P)
Dubé *et al.* (2010)	Canada	In-degree; Out-degree	171 Farms (U)
Smith *et al.* (2013)	UK	Euclidean distance; Degree; Betweenness; Clustering coefficient; Centralization; E-I index	1.633 Farms (U)
Lichoti *et al.* (2016)	Kenia and Uganda	Average geodesic distance; Density; Clustering coefficient; Modularity	683 Pig producers (N)
Marquetoux *et al.* (2016)	Nueva Zealand	In-degree; Out-degree; Betweenness; Clustering coefficient	180 Farms (P)
Poolkhet *et al.* (2016)	Cambodia	Degree; Betweenness; Density; Clustering coefficient	365 intermediaries' producers (U)
VanderWaal *et al.* (2017)	Uruguay	Degree; Tie strength; Proximity; Betweenness; Density; Centralization	62.767 Producers (I)
Crabb *et al.* (2018)	Australia	Geodesic distance; Degree; Betweenness; In-degree; Out-degree; Proximity; Density; Cluster	593 Movements of poultries (G)
de Sa *et al.* (2018)	Brazil	In-degree; Out-degree; Betweenness	27.517 Certificates of animal trade, 579 veterinaries certificates. (P)
Kim *et al.* (2018)	Mayotte	Density; Clustering coefficient, Euclidian Distance; Betweenness; Proximity	3505 Movements of cattle (I)

Nicolas *et al.* (2018)	Mauritania	In-degree; Out-degree; Betweenness; Clustering coefficient; Density, Centralization; Eigenvector centrality	2.219 Commercial movements (U)

[1] Software: (U): Ucinet, (P): Pajek, (I): Igraph, (N): NodeXL, (G): Gephi.

The dual-purpose bovine production system (DP) predominates in the Latin American developing countries (LAC). The DP is made up of farms of very small scale, very low technological level, and a high degree of marginalization. They contribute to the maintenance of traditional ways of life in the agricultural sector and favour the social cohesion of the territories; they can generate direct income, contribute to environmental sustainability, and show great potential to mitigate greenhouse gas emissions (García Martínez et al., 2016, Rangel et al., 2017). DP is developed in greater proportion in tropical agroecological regions (Hernández et al., 2011). It is a multifunctional and flexible system of mixed production, that is, it provides the complementarity between livestock (meat and milk), tropical agriculture, the use of pastures, forestry activities, food processing activities such as cheese and other external (services primarily) (Rangel et al., 2017). The production system is traditional and extensive grazing under conditions of rusticity. Low-cost opportunity resources are used, which favours a sustainable activity with greater flexibility and efficiency in the use of resources (Díaz et al., 2011).

In this area of knowledge, Mexico is a pioneer in the use of SNA in DP cattle (Table 14), with researches promoted by INIFAP (García-Amado et al., 2012; Espejel-García et al., 2014; García et al., 2017; Cano-Reyes et al., 2015; Cárdenas-Bejarano et al., 2016; Figueroa-Rodríguez et al., 2012; Roldán-Suárez et al., 2018; Avendaño-Ruiz et al., 2017; Espejel-García et al., 2017; Nuñez-Espinoza et al., 2014; Pérez-Hernández et al., 2017; Zambada-Martínez et al., 2013; Gómez-Carreto, 2015; Solleiro-Rebolledo et al., 2015; Roldán-Suárez et al., 2018; Zarazúa-Escobar et al., 2011; Pérez, 2011), mainly focused on improving agricultural technical advisors programs and agricultural training programs. Most of these works have been carried out through direct meetings with the producers.

Table 14. Applications of SNA in the dissemination of dual-purpose cattle innovations

References	Country	Centrality measures	Size of sample (Software)[1]
Espejel-García *et al.* (2014)	México	Density; Centralization; Keyplayer	66 Dairy producers (U)
Hernández (2015)	Chile	Density, Centralization, Betweenness, In-degree, Out-degree	18 Dairy producers (U)
Vishnu *et al.* (2018)	India	Degree, Betweenness, Proximity, Density	320 Dairy producers (U)
Cárdenas-Bejarano *et al.* (2016)	México	Density, Degree, Betweenness	18 GGAVATT (Cattle producers groups) (U)
Espejel-García *et al.* (2017)	México	Centralization; Keyplayer; Diffusor actor	126 Bovines producers (U)
Villarroel-Molina *et al.* (2018)	México	Degree; Centralization; Betweenness; Proximity, Cutpoints; Eigenvector	262 Producers (U)
Pérez (2011)	México	-	34 Cattle producers (U)
Perez-Hernandez *et al.* (2017)	México	Degree; Betweenness	11 Sheep producer organizations(U)

However, there are few studies performed by the SNA to study the process of diffusion of technology in DP (Rendón-Medel et al., 2007 and Espejel-García et al., 2014) (Table 14). Rendon-Medel et al. (2007) used the SNA methodology to identify key players in the ovine production network of the State of Querétaro in Mexico, in order to induce a process of adopting seven innovations and develop marketing capabilities among the producers. This author conducted a comparative study between two groups of producers. On the one hand, those selected by the Innovation Management Agency (AGI) based on leadership criteria, moral solvency, willingness to participate in a process of innovation and sympathy. On the other hand, a panel of key players selected by the network analysis software, from the calculation of broadcast and structuring indicators. The SNA model replaced a significant portion of the producers initially considered by the AGI and achieved an increase in network coverage by 22%. The average adoption rate of producers proposed by the AGI was 56%, while for the group proposed by the KeyPlayer algorithm was 25%. Those selected by SNA showed greater capacity to disseminate innovation. This suggests that AGI advisors tend to select the producers with the highest technological level, but, in turn, they showed low capacity for influence among their peers, given their reduced propensity to communicate their knowledge (Rendón-Medel et al., 2007).

Mirror-García et al. (2014) used SNA to identify factors that limit or provide the management of innovation in the Mosque Valley milk cattle chain, Hidalgo, Mexico. It determined the articulation of the regional system of innovation and knowledge among actors; they found a low grade of articulation and integration, with a very low density among producers (4.4%). In this work 49.5% of producers are self- taught and learn from family and other producers (tacit knowledge). Only 19.5% of innovation comes from specialist technicians; 18.4% of suppliers of supplies and 10.2% from the State Milk Commission (codified knowledge). These findings rein- force the hypothesis that weak ties are potential mechanisms for disseminating tacit knowledge, i.e., a knowledge of experience, while strong ties with specialized agents promote the transmission of coded knowledge (Granovetter, 1985).

Regarding the mode of diffusion of technology, innovation networks have been mapped through direct surveys of actors, to detect patterns of relationships (Rendón-Medel et al., 2007; Arora, 2012; Mayoral et al., 2012; Espejel-García et al. 2014). They point to the people or institutions with whom they are related, generating a list of names. This type of sampling generates an adjacency matrix of one-mode, which allows the calculation of the indicators through social network analysis. However, there is another form of analysis, less frequent, for the study of technological adoption in livestock and it is that information that comes directly from the patterns of adoption of each farmer. In this case, the network is built on the following question: Do they adopt or do not adopt the technology? what does generate an adjacency matrix of two-mode. This second analysis incorporates the rational choice theory; including behaviours, attitudes, beliefs, etc. It seeks a closer approach to reality and highlights similar choices between pairs of nodes, referred to in the literature as social homogeneity (Everett and Borgatti, 2013; Borgatti, 2009).

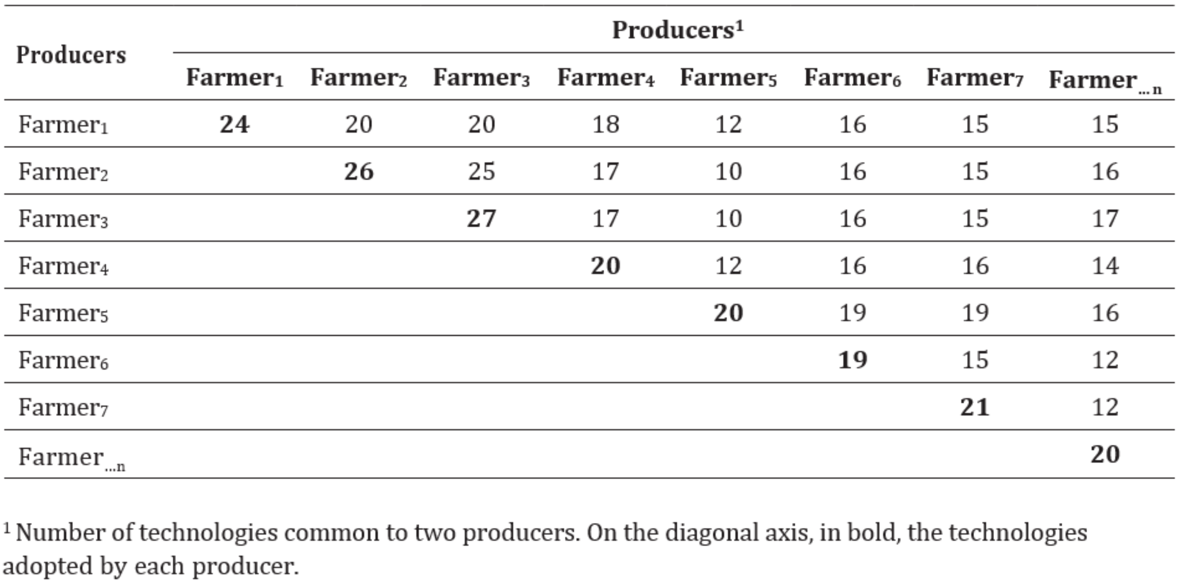
To sum up, in livestock, the SNA allows deepening the knowledge of technological diffusion through direct surveys of producers, asking about relationships; Where the producer indicates the people or institutions with whom he relates, as well as the way of learning innovation, its adoption and its dissemination (Rendón-Medel et al., 2007; Arora, 2012; Mayoral et al., 2012; Espejel-García et al. 2014) one-mode adjacency matrix. Although, it also opens another route of great interest that helps to know the adoption patterns from the technologies implemented in each farm according to the adoption or not of the technology (Adjacency Matrix Mode 2) (Everett and Borgatti, 2013; Borgatti, 2009).

Villarroel-Molina et al. (2018) organized the information in a two-mode matrix (Table 15). The matrix is composed of the producers, in the rows and the different types of technologies that they use in the columns, where (1) means that if they adopt the technology and the null value, they do not adopt it (0). Analysing this information, the two-mode matrix is transformed into a one-mode matrix (Figure 9) using the UCINET affiliation command. The result shows how many technologies are shared in each pair of farmers. The application of SNA Farmer vs. Farmer is collected in a one-mode matrix (Figure 9) and in the network expressed in Figure 8; it could also be implemented from the Technology vs. Technology orientation, which would provide information regarding technological leadership. This methodological approach with a two-mode matrix is reliable, simple to obtain, easy to implement and facilitates a diagnosis of the real situation, which promotes the reduction of the risk of failure in technological adoption by small producers (García et al., 2016).

Table 15. Technologies for producer, two-mode matrix (Villarroel-Molina et al., 2018).

Producer	Record system	Breeding management	Grazing native pasture	Grazing planting	Grazing of crop residues	Type of milking	Until n=45
$Farmer_1$	0	0	0	0	0	0	0
$Farmer_2$	0	0	0	0	0	0	0
$Farmer_3$	1	1	1	1	0	0	1
$Farmer_4$	1	1	1	1	1	1	1
Farmer…n	1	1	1	1	1	0	0

* (1) means technology adopted and (0) Non-adopted technology.



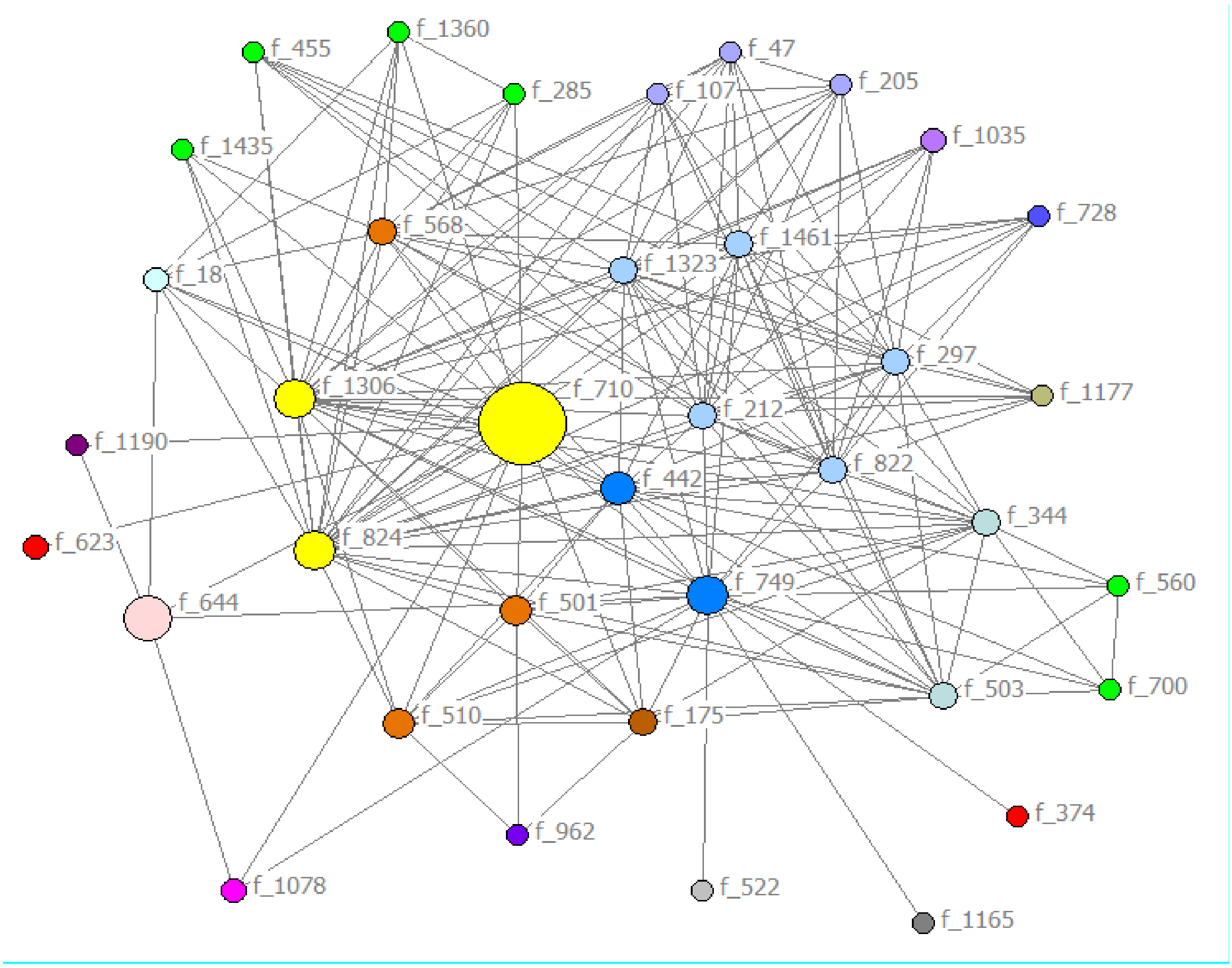
Producers	Producers[1]							
	Farmer$_1$	**Farmer$_2$**	**Farmer$_3$**	**Farmer$_4$**	**Farmer$_5$**	**Farmer$_6$**	**Farmer$_7$**	**Farmer$_{\dots n}$**
Farmer$_1$	**24**	20	20	18	12	16	15	15
Farmer$_2$		**26**	25	17	10	16	15	16
Farmer$_3$			**27**	17	10	16	15	17
Farmer$_4$				**20**	12	16	16	14
Farmer$_5$					**20**	19	19	16
Farmer$_6$						**19**	15	12
Farmer$_7$							**21**	12
Farmer$_{\dots n}$								**20**

[1] Number of technologies common to two producers. On the diagonal axis, in bold, the technologies adopted by each producer.

Figure 8. Technologies shared between producers, one mode matrix (Villarroel-Molina et al., 2018).

Finally, through the application of UCINET, Villarroel-Molina et al. (2018) show in (Figure 8) the pattern of adoption and technological diffusion in the areas of genetics and reproduction of dual-purpose smallholders in the Mexican tropics. In this case, node size refers to those farmers with the highest betweenness degree.

Previously to the use of SNA, Rangel et al. (2017), García et al. (2016), Herrero et al. (2013) and Robinson et al. (2011), recommend the development of a typology of farms for explaining most of the variability in the dual-purpose cattle system. The typology incorporates structural, dimension, economic and environmental factors; generating cluster with great homogeneity within the group and great heterogeneity with the other groups of farms. This multivariate methodology allows the development of innovation diffusion patterns, which are specific for similar producers. Their knowledge contributes to promote a posteriori the development of specific public policies for each group.



* The node size refers to betweenness degree.

Figure 9. Technology adoption network in the areas of genetics and reproduction (Villarroel-Molina et al., 2018).

MATERIAL Y METODOS

3. MATERIAL Y METODOS

3.1. Aplicación de redes sociales en sistemas ganaderos

El Análisis de Redes Sociales (ARS) es una técnica de análisis basada en la teoría de grafos, donde se dibujan las relaciones entre los diferentes actores para profundizar en su comportamiento. La red está conformada por nodos (ganaderos) y sus conexiones (segmentos). Las interacciones pueden ser dirigidas o no dirigidas y marcan el sentido de la interacción. De acuerdo con https://sergiojimenez.net/sna/, el ARS tiene un marcado carácter relacional, y se centra en la comprensión de las interacciones entre los actores de una red, así como de la estructura de la red misma. El análisis de redes incorpora atributos en las relaciones entre actores con características propias, denominándose medidas de centralidad de la red.

3.1.1. Conceptos clave en el ARS y su utilidad en sistemas ganaderos

Red: Una red es una colección de unidades de interés que pueden o no estar conectadas. Las unidades de interés normalmente se llaman nodos o vértices en física y matemáticas, mientras que en las ciencias sociales se les conoce como actores (Borgatti & Halgin, 2011; Dube et al., 2009; Borgatti & Foster, 2003). En una red de innovación ganadera sencilla, es decir sin tomar en cuenta a las instituciones quienes también pueden ser actores importantes a nivel macro, cada ganadero sería un nodo en la red con atributos individuales que los caracterizan, como el tipo de explotación, la ubicación geográfica, nivel tecnológico y el tamaño en términos de número de animales. Estos nodos están vinculados entre sí a través de una relación de algún tipo. En el caso de las redes de innovación tecnológica, la adopción de una determinada tecnología sería un atributo de vinculación entre los ganaderos que pone de manifiesto un patrón de comportamiento. La pregunta detrás de esta relación es: ¿qué lleva a un ganadero a adoptar o rechazar una tecnología o grupo de tecnologías determinadas entre las diferentes tecnologías disponibles en la región donde desarrolla su actividad productiva?

La relación que se pretende estudiar en el contexto de la adopción tecnológica viene determinada por la siguiente matriz de adyacencia, y representa una de las tantas posibilidades de relación entre los actores (Tabla 16).

Tabla 16. Matriz de adyacencia de adopción tecnológica

	Tecnología						
Ganadero	Identificación de ganado	Uso de registros	Ordeño mecánico	Inseminación artificial	Detección de celos	Vacunación	Diagnóstico de mastitis
Juan	0	1	0	1	1	0	1
Pedro	1	0	0	1	1	0	1
Luisa	0	1	0	1	0	1	0
Andrés	0	1	0	0	0	0	1
Raúl	1	0	1	1	1	1	0
María	1	0	0	1	0	0	1

1 = Adopta la tecnología; 0 = No adopta la tecnología

3.1.2. Interpretación de las Medidas de Centralidad en ganadería

El primer uso de la centralidad en las ciencias sociales fue estudiar la eficiencia de las diferentes redes de comunicación (Bonacich, 2018), estas medidas se describen comúnmente como índices de prestigio, prominencia, importancia y poder (Wasserman y Faust, 2013); y se consideran muy importantes en el contexto de cualquier tipo de red de difusión (Valente y Fujimoto, 2010). En el análisis de redes se utilizan comúnmente cuatro medidas de centralidad: grado de centralidad, cercanía, intermediación y la centralidad del vector propio (Borgatti, 2005; Brandes et al., 2016). La centralidad siempre ha sido de interés primordial para los analistas de redes sociales y es posiblemente la técnica más comúnmente aplicada al analizar datos de red.

Grado de centralidad: En el caso del estudio de la adopción tecnológica en sistemas ganaderos, el grado de centralidad de un ganadero, se determina por el número de tecnologías que este ha adoptado dentro de todas las tecnologías existentes en la población de estudio, y en referencia a los demás ganaderos dentro de la red. Es decir, a mayor número de tecnologías adoptadas, mayor grado de centralidad. Supuesto que la probabilidad de adopción de una tecnología es una función de la cantidad de amigos o contactos que han adoptado esa tecnología; el grado de centralidad se interpreta como un índice de la probabilidad de que otros ganaderos cercanos a su red adopten la innovación y como una medida del riesgo (o la oportunidad) de recibir lo que fluye a través de la red (Borgatti, 2006, 2009; Opsahl et al., 2010; Labun y Wittek, 2014; Brandes et al., 2016; Bonacich, 2018).

Intermediación: La intermediación refleja el potencial de control de la comunicación y se ha definido como la medida en que un actor tiene el control sobre el acceso de otros actores a varias regiones de la red (Labun y Wittek, 2014). La intermediación se enfoca menos en el acceso a la información para un actor focal, y se concentra en el poder resultante de estar en el camino más corto entre otros. Tener una alta intermediación puede generar poder e influencia porque uno es un intermediario entre otros en la red (Bonacich, 2018; Agneessens et al., 2017; Burt, 2009).

Cercanía: el concepto de cercanía es un poco más complejo ya que su interpretación viene determinada por la pregunta de investigación. En este sentido, la cercanía hace referencia a que tan cerca o lejos se está del fenómeno en estudio. En el caso de la adopción tecnológica, si el problema de investigación es la "no adopción tecnológica", y esto constituye el comportamiento más común dentro de la red en estudio, aquellos ganaderos con una tasa de adopción tecnológica muy baja tendrán puntajes muy altos en la medida de cercanía. Por lo tanto, esta medida es inversa a la centralidad, ya que un valor mayor indica un actor menos central, mientras que un valor menor indica un actor más central. Sin embargo, la limitación principal de la cercanía es la falta de aplicabilidad a redes con componentes desconectados: dos nodos que pertenecen a diferentes componentes tienen una distancia indefinida o infinita entre ellos (Borgatti, 2009; Opsahl et al., 2010). En el contexto de la trasmisión de conocimiento o difusión de la innovación, esta medida vendría a ser un índice del tiempo esperado de que lo que está fluyendo dentro de la red, como por ejemplo la comunicación de una nueva tecnología, llegue a un nodo determinado.

Centralidad del vector propio: Es una variante del grado que mide la influencia de un nodo dentro de la red. Bonacich (1972) sugirió que el vector propio podría ser una buena medida de la centralidad de la red, ya que, a diferencia del grado, que pondera cada contacto por igual, el vector propio asigna valor a los ganaderos de acuerdo a la centralidad de sus contactos. Esta medida permite distinguir situaciones en las que estar conectado a otros con muchos contactos (otros poderosos) es ventajoso para un actor focal (Labun y Wittek, 2014); ya que captura cierto aspecto de centralidad que no es capturado por otras medidas, como el estatus de un actor, determinado por aquellos con quienes está en contacto (Bonacich y Lloyd, 2001). En el caso de la red de innovación tecnológica, la centralidad del vector propio de un ganadero es proporcional a la suma de las centralidades de los nodos a los que está conectado. Por lo tanto, a un ganadero que está conectado con muchos ganaderos que están bien conectados se le asigna un puntaje alto, pero a uno que está conectado solo con aislamientos cercanos se le asigna un puntaje bajo, incluso si tiene un alto grado de centralidad. Así, los ganaderos más centrales en este sentido son buenos candidatos para difundir información y conocimiento.

3.1.3. Formas de abordar el Análisis de Redes Sociales

En el estudio de redes sociales es muy importante la pregunta de investigación a partir de la cual se recogen los datos en el caso de que antes de iniciar la recolección de datos se haya establecido como metodología de análisis el ARS. Por otro lado, también se debe tener muy claro el objetivo que se persigue y hasta donde se quiere llegar al aplicar esta metodología.

De esta manera, existen dos formas de abordar el análisis, una proviene de realizar preguntas cómo ¿Quién te ha enseñado esta nueva técnica?, ¿De quién recibes información novedosa?, ¿De quién ha aprendido, se ha asesorado o ha preguntado, es decir, a quién recurre para obtener información y conocimiento para implementar las prácticas, tecnologías e innovaciones que realiza en su unidad de producción?, etc. (para más ejemplos de preguntas generadoras de nombres utilizadas en el ARS, aplicado a la agricultura, ver Aguilar-Gallegos et al. (2016).

Este tipo de preguntas generan una serie de nombres que se irán repitiendo, según la influencia de los actores en la comunidad que darán origen a una matriz de modo 1. Sin embargo, no siempre se cuenta con datos de este tipo, por lo que muchas veces resulta necesario estimar las relaciones y el nivel de influencia entre actores de una misma comunidad a partir de sus decisiones o comportamiento.

En este caso, la adopción tecnológica dentro de un sistema que por lo general se caracteriza por una tasa de adopción baja, es una característica distintiva que da origen a una red de modo 2. Las redes de modos dos son poco comunes en el ARS y no todas las medidas de centralidad o indicadores pueden aplicarse a este tipo de red. Sin embargo, ofrecen una aproximación más cercana a la realidad al abordar la problemática de la baja tasa de adopción tecnológica en los sistemas ganaderos y agroalimentarios a partir de decisiones previamente hechas por los propios agricultores, es decir el análisis no se basa en intenciones de adopción.

3.1.4. Diferencias entre One-mode and Two-Mode Network

Una matriz es de modo 1 si las filas y columnas se refieren al mismo conjunto de entidades, como por ejemplo una matriz de ganadero por ganadero (Figura 10). Por el contrario, una matriz de 2 modos (Figura 11), es una matriz (bidimensional) donde las filas y columnas indexan diferentes conjuntos de entidades (por ejemplo, las filas pueden corresponder a personas mientras que las columnas corresponden a organizaciones, o en este caso, tecnologías).

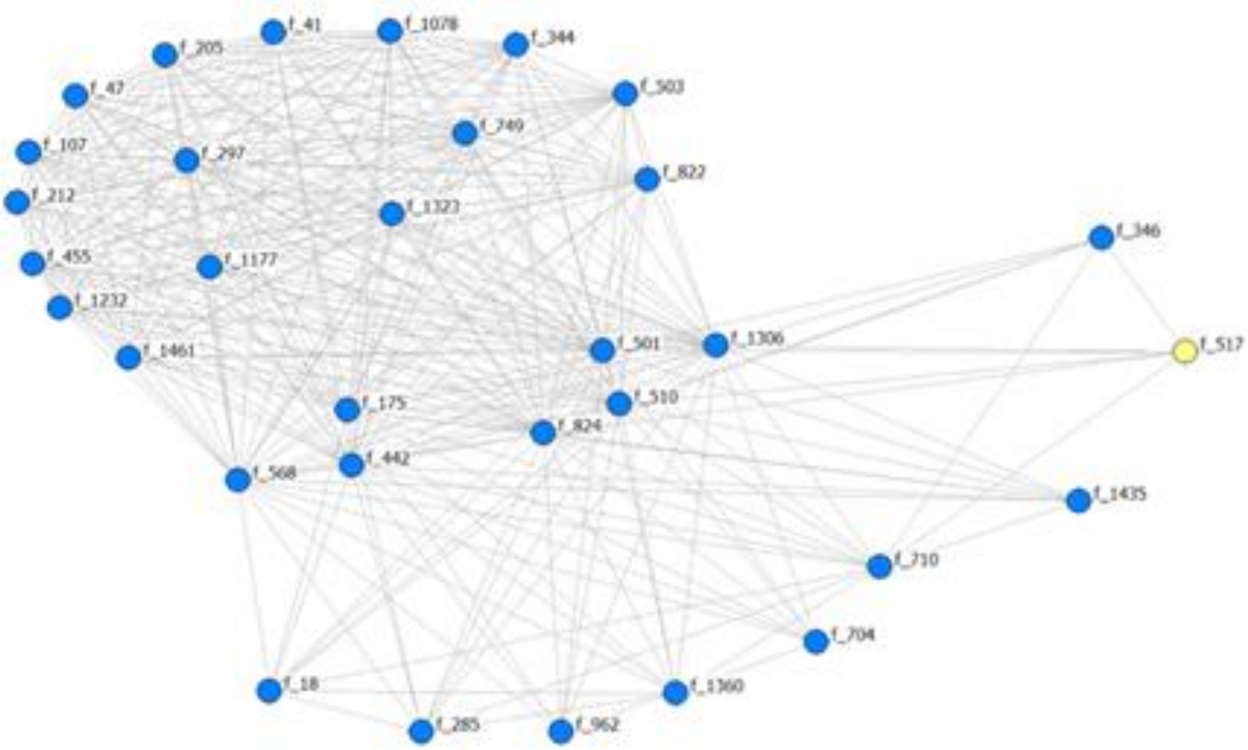


Figura 10. One-mode network visualization of farmers. ● Ganadero.

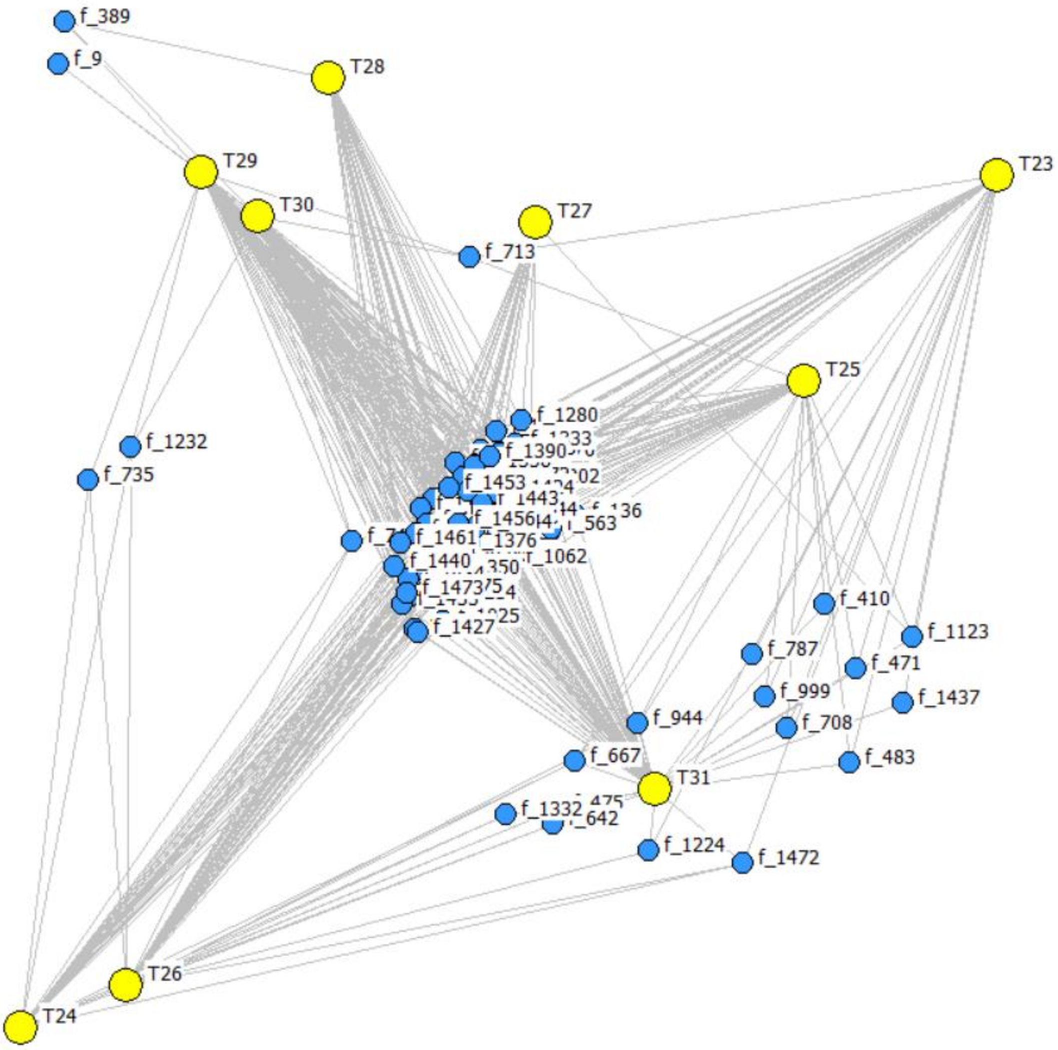


Figura 11. Two-mode network visualization of farmers and technologies. ○ Tecnologías; ● Ganaderos.

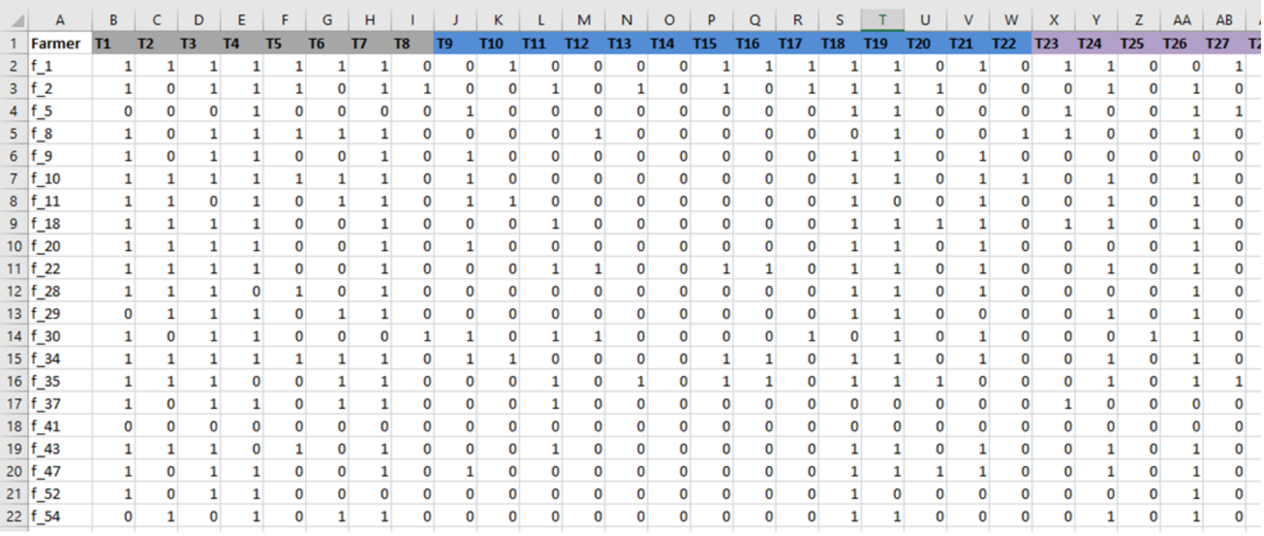
3.1.5. Cálculo de indicadores

A continuación, se describen las formas básicas para manejar los datos de red. Una vez capturados los datos de red en Excel, éstos fácilmente se pueden copiar y pegar en el Editor de matrices (Matrix spreadsheet editor) de UCINET (Tabla 18).

Es conveniente mencionar que los datos deben estar en formato UCINET, es decir, deben tener extensión ##h., para que puedan ser analizados por el programa. Lo primero para analizar datos de carácter relacional como los patrones de adopción tecnológica entre un conjunto de ganaderos a partir de datos binarios, donde 1 significa que el ganadero ha adoptado la tecnología y 0 significa que el ganadero no ha adoptado la tecnología, es transformar esta matriz inicial de modo 2 (Tabla 17) en una matriz de modo 1 (Tabla 18).

En la Tabla 17 se muestra en las columnas los ganaderos y en las filas las tecnologías que han adoptado.

Tabla 17. Matriz de Modo 2. Ganaderos por Tecnologías.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	Farmer	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20	T21	T22	T23	T24	T25	T26	T27
2	f_1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	1	1	1	1	1	0	1	0	1	1	0	0	1
3	f_2	1	0	1	1	1	0	1	1	0	0	1	0	1	0	1	0	1	1	1	1	0	0	0	1	0	1	0
4	f_5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	1
5	f_8	1	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0
6	f_9	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
7	f_10	1	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	1	0	1	1	0	1	0	1	0
8	f_11	1	1	0	1	0	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0
9	f_18	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	1	1	0	1	0
10	f_20	1	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0
11	f_22	1	1	1	1	0	0	1	0	0	0	1	1	0	0	1	1	0	1	1	0	1	0	0	1	0	1	0
12	f_28	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0
13	f_29	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0
14	f_30	1	0	1	1	0	0	0	1	1	0	1	1	0	0	0	0	1	0	1	0	1	0	0	0	1	1	0
15	f_34	1	1	1	1	1	1	1	0	1	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	1	0
16	f_35	1	1	1	0	0	1	1	0	0	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1	0	1	1
17	f_37	1	0	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
18	f_41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	f_43	1	1	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	1	0	1	0
20	f_47	1	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	1	0
21	f_52	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
22	f_54	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0

Where: (1) means that the technology has been adopted and (0) that the technology has not been adopted.

Para el análisis que se persigue en este caso, es necesario transformar esta matriz inicial de modo 2 en una matriz de modo 1 con la ayuda del programa UCINET, siguiendo la ruta Data>Affiliations (2-mode to 1-mode).

El resultado será una matriz donde se expresa el número de tecnologías que los ganaderos han adoptado de forma conjunta (Tabla 18), esto hace referencia a una similitud en los patrones de adopción, y por tanto es un atributo de relacionamiento.

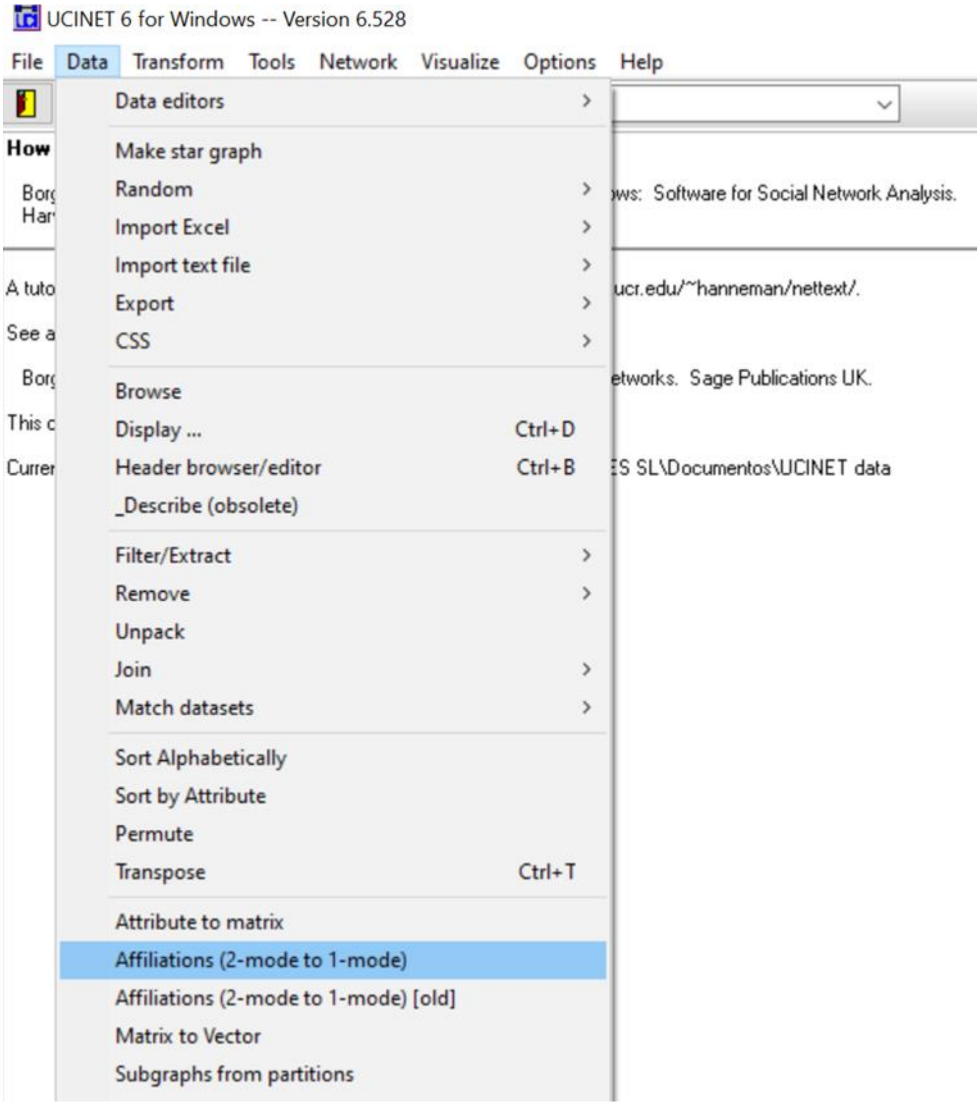
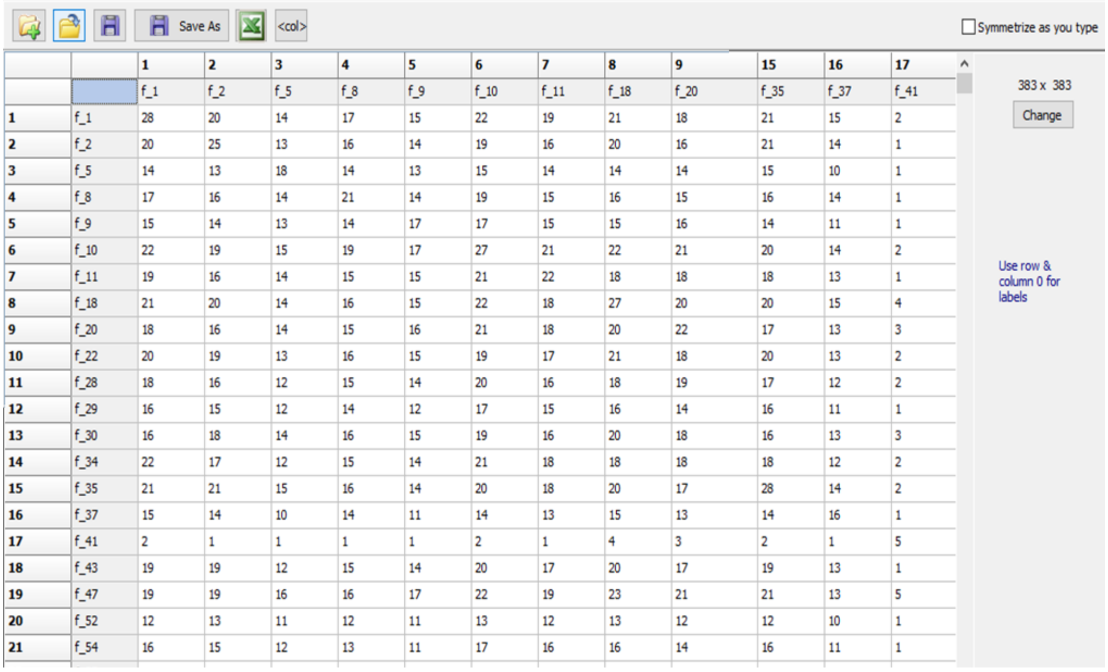


Figura 12. Transformar Matriz de Modo 1 a Matriz de Modo 2.

Por ejemplo, en la Tabla 18, de las 45 tecnologías disponibles los ganaderos f_1 y f_10, han adoptado 22 tecnologías en común. Por lo tanto, estos ganaderos están muy relacionados por la forma en la que desarrollan su actividad productiva, esto también se conoce como un vínculo fuerte (Granovetter, 2000). En este tipo de análisis se busca identificar elementos comunes entre ganaderos con perfiles tecnológicos similares para diseñar estrategias de intervención, capacitación o extensionismo agrícola. En este sentido es importante señalar que para el tipo de datos que usamos (datos de modo 2 o datos de afiliación), las centralidades tanto de los ganaderos como de las tecnologías están relacionadas entre sí. Por lo tanto, la centralidad de la tecnología depende de la centralidad del ganadero que la ha adoptado (Everett and Borgatti, 2013, Grassi et al., 2019).

Tabla 18. Matriz de Modo 1



		1	2	3	4	5	6	7	8	9	15	16	17
		f_1	f_2	f_5	f_8	f_9	f_10	f_11	f_18	f_20	f_35	f_37	f_41
1	f_1	28	20	14	17	15	22	19	21	18	21	15	2
2	f_2	20	25	13	16	14	19	16	20	16	21	14	1
3	f_5	14	13	18	14	13	15	14	14	14	15	10	1
4	f_8	17	16	14	21	14	19	15	16	15	16	14	1
5	f_9	15	14	13	14	17	17	15	15	16	14	11	1
6	f_10	22	19	15	19	17	27	21	22	21	20	14	2
7	f_11	19	16	14	15	15	21	22	18	18	18	13	1
8	f_18	21	20	14	16	15	22	18	27	20	20	15	4
9	f_20	18	16	14	15	16	21	18	20	22	17	13	3
10	f_22	20	19	13	16	15	19	17	21	18	20	13	2
11	f_28	18	16	12	15	14	20	16	18	19	17	12	2
12	f_29	16	15	12	14	12	17	15	16	14	16	11	1
13	f_30	16	18	14	16	15	19	16	20	18	16	13	3
14	f_34	22	17	12	15	14	21	18	18	18	18	12	2
15	f_35	21	21	15	16	14	20	18	20	17	28	14	2
16	f_37	15	14	10	14	11	14	13	15	13	14	16	1
17	f_41	2	1	1	1	1	2	1	4	3	2	1	5
18	f_43	19	19	12	15	14	20	17	20	17	19	13	1
19	f_47	19	19	16	16	17	22	19	23	21	21	13	5
20	f_52	12	13	11	12	11	13	12	13	12	12	10	1
21	f_54	16	15	12	13	11	17	16	16	14	16	11	1

Sin embargo, en este punto es importante destacar que después de haber probado las diferentes formas de abordar el análisis de la matriz de modo 2 en los procesos de innovación ganadera (Villarroel-Molina et al., 2021, 2019), se señala que la transformación de la matriz de modo 1 a una matriz de modo bipartido arroja resultados de las medidas de centralidad más significativos para el análisis (Figura 15). En Hanneman y Riddle (2005), se profundiza en las formas de analizar matrices de modo 2. Por lo que, si lo que se persigue es identificar ganaderos clave a través de sus medidas de centralidad, o establecer diferencias en el rendimiento o la productividad mediante análisis benchmarking como en Villarroel-Molina et al. (2021), será conveniente calcular las medidas de centralidad a través de una matriz de adyacencia bipartita. En la Figura 13 se muestra cómo se realiza la transformación en UCINET, con la ruta Transform>Graph Theoretic>Bipartite.

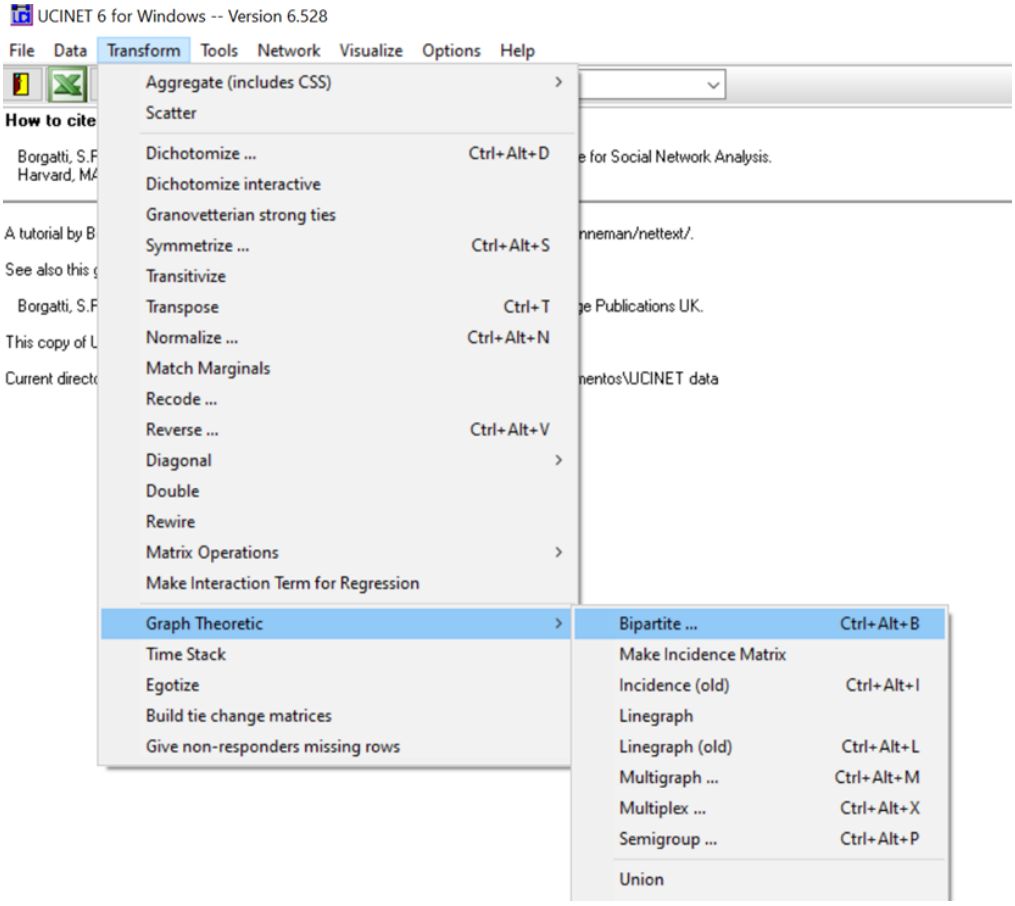


Figura 13. Transformación de la matriz a gráfico bipartito.

Una vez se ha convertido la matriz inicial de modo 2 en una matriz de adyacencia bipartita, se procede al cálculo de las medidas de centralidad a través de UCINET en la ruta Network>Centrality and Power>Multiple measures (Figura 14).

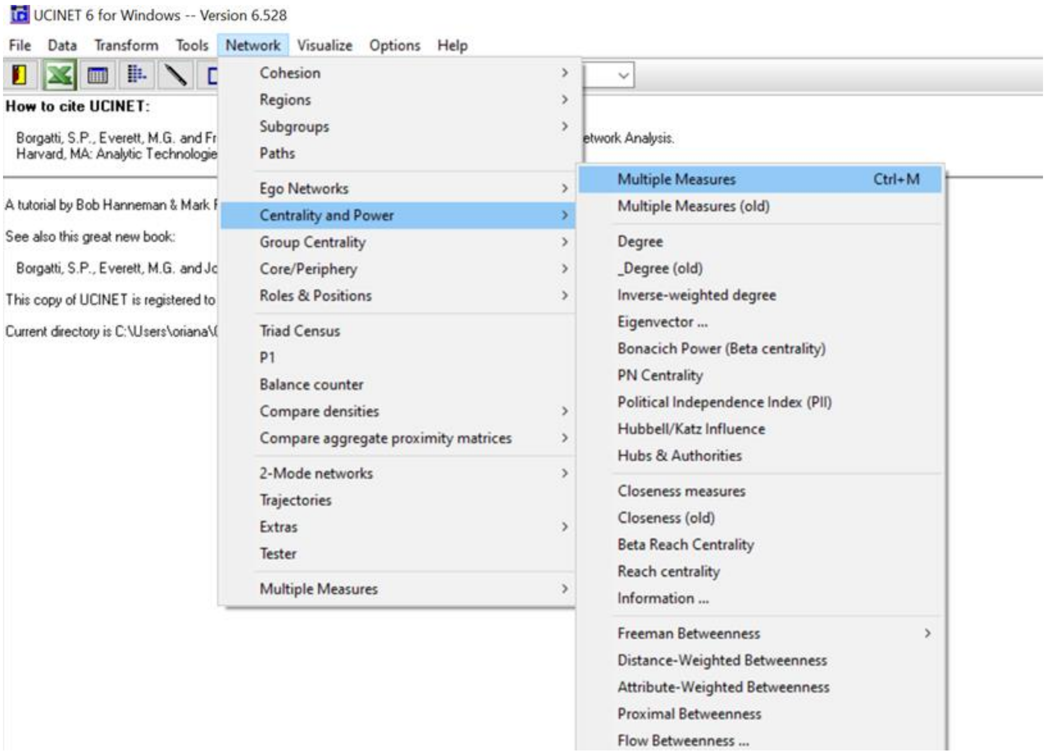
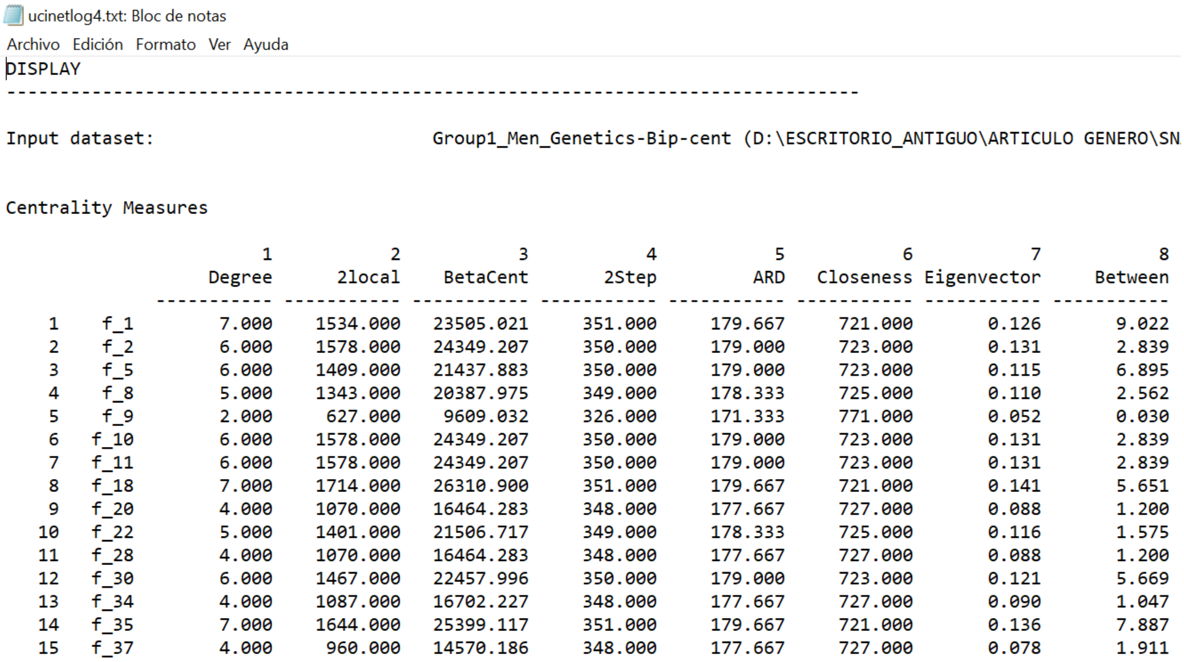


Figura 14. Cálculo de las medidas de centralidad.



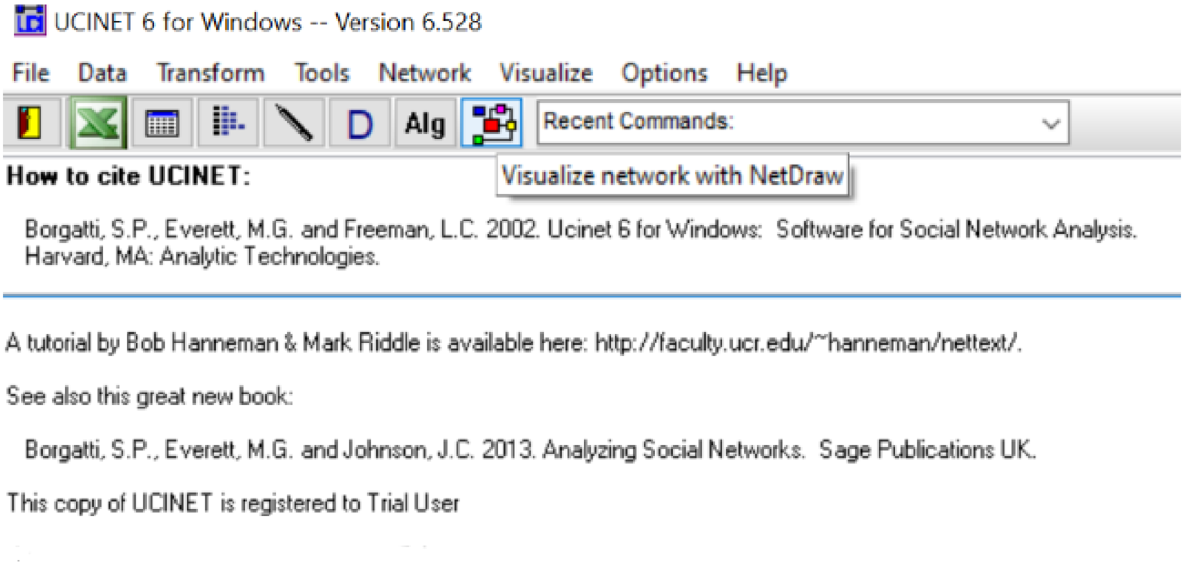
```
DISPLAY
--------------------------------------------------------------------------------

Input dataset:                        Group1_Men_Genetics-Bip-cent (D:\ESCRITORIO_ANTIGUO\ARTICULO GENERO\SN

Centrality Measures

                             1           2           3           4           5           6           7           8
                        Degree      2local    BetaCent       2Step         ARD   Closeness Eigenvector     Between
                   ----------- ----------- ----------- ----------- ----------- ----------- ----------- -----------
   1    f_1          7.000    1534.000   23505.021     351.000     179.667     721.000       0.126       9.022
   2    f_2          6.000    1578.000   24349.207     350.000     179.000     723.000       0.131       2.839
   3    f_5          6.000    1409.000   21437.883     350.000     179.000     723.000       0.115       6.895
   4    f_8          5.000    1343.000   20387.975     349.000     178.333     725.000       0.110       2.562
   5    f_9          2.000     627.000    9609.032     326.000     171.333     771.000       0.052       0.030
   6   f_10          6.000    1578.000   24349.207     350.000     179.000     723.000       0.131       2.839
   7   f_11          6.000    1578.000   24349.207     350.000     179.000     723.000       0.131       2.839
   8   f_18          7.000    1714.000   26310.900     351.000     179.667     721.000       0.141       5.651
   9   f_20          4.000    1070.000   16464.283     348.000     177.667     727.000       0.088       1.200
  10   f_22          5.000    1401.000   21506.717     349.000     178.333     725.000       0.116       1.575
  11   f_28          4.000    1070.000   16464.283     348.000     177.667     727.000       0.088       1.200
  12   f_30          6.000    1467.000   22457.996     350.000     179.000     723.000       0.121       5.669
  13   f_34          4.000    1087.000   16702.227     348.000     177.667     727.000       0.090       1.047
  14   f_35          7.000    1644.000   25399.117     351.000     179.667     721.000       0.136       7.887
  15   f_37          4.000     960.000   14570.186     348.000     177.667     727.000       0.078       1.911
```

Figura 15. Medidas de centralidad.

El resultado será una tabla con las diferentes medidas de centralidad que ofrece UCINET (Figura 15). Al trabajar con datos de modo 2, no todas las medidas de centralidad son válidas para el análisis y su interceptación resulta más compleja, ya que estás medidas han sido desarrolladas inicialmente para datos de modo 1.

3.1.6. Visualización de la red

Para visualizar la red de adopción tecnológica, UCINET trae incorporado Netdraw como se muestra a continuación en la (Figura 16).



How to cite UCINET:

Borgatti, S.P., Everett, M.G. and Freeman, L.C. 2002. Ucinet 6 for Windows: Software for Social Network Analysis. Harvard, MA: Analytic Technologies.

A tutorial by Bob Hanneman & Mark Riddle is available here: http://faculty.ucr.edu/~hanneman/nettext/.

See also this great new book:

Borgatti, S.P., Everett, M.G. and Johnson, J.C. 2013. Analyzing Social Networks. Sage Publications UK.

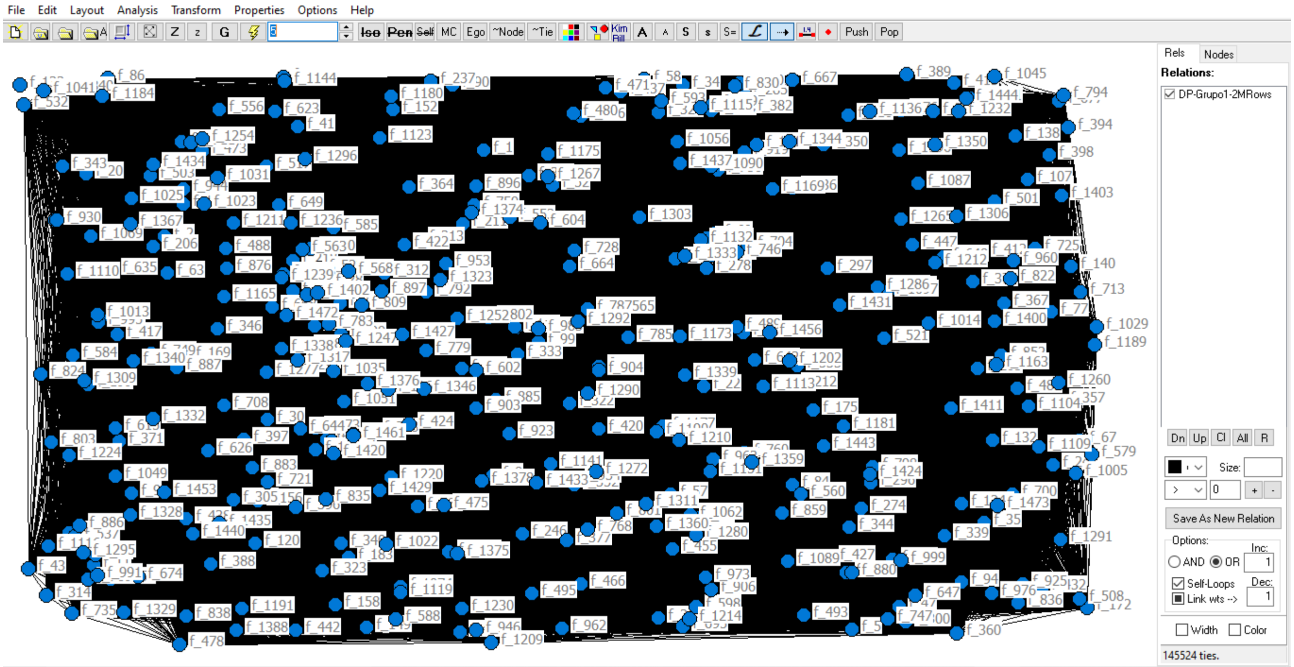
This copy of UCINET is registered to Trial User

Figura 16. Visualización de red con NetDraw.

En este tipo de visualización, tanto los actores (ganaderos) como los eventos (tecnologías) se tratan como nodos, y las líneas se utilizan para mostrar las conexiones de los actores con los eventos (Hanneman y Riddle, 2005). Se utilizó escalamiento multidimensional MDS no métrico dado que, este método proporciona una mejor "bondad de ajuste (estrés)".

El MDS no métrico al igual que el MDS métrico, utiliza matrices de adyacencia simétricas en las que las celdas reflejan las similitudes o diferencias entre los actores, pero con la diferencia de que los procedimientos MDS métricos, tratan los datos como ordinales, buscando una solución en la que el orden de rango de las distancias sea el mismo que el orden de clasificación de los valores originales. Por lo tanto, los nodos que están "socialmente" cerca uno del otro (porque hay un vínculo entre ellos o están vinculados a un amigo común) se ubican cerca uno del otro en el gráfico, mientras que los nodos que están socialmente distantes se ubican lejos el uno del otro en el gráfico (Everton, 2012). Sin embargo, cuando se trabaja con una cantidad de datos muy grande, la visualización se dificulta, como se observa en la (Figura 17), ya que dependiendo de las características de las relaciones que se estudian, y en especial cuando se estiman las conexiones a través de datos relacionales, los lazos posibles entre ganaderos pueden alcanzar un volumen considerable.

Los lazos iniciales son lazos débiles, como se observa en la parte inferior derecha de la Figura 17, los lazos en esta red de innovación ganadera ascienden a 145.524 lazos. Por lo que resulta necesario aplicar un procedimiento para hallar los lazos más fuertes entre los ganaderos.



Relations:
☑ DP-Grupo1-2MRows

Options:
○ AND ● OR
☑ Self-Loops
☒ Link wts -->

145524 ties.

Figura 17. Visualización inicial de la red.

En este sentido, a la hora de visualizar la red el mayor problema radica en encontrar un ***“threshold value”*** para facilitar la visualización e interpretación de la red. Este valor hace referencia al punto de corte que denota el número de relaciones que produce un cambio significativo en la red. Existe un vacío de conocimiento metodológico en el cálculo de este valor (Sankar et al., 2015; Opsahl et al., 2010), por lo que queda bajo criterios del investigador establecer el threshold value.

En este caso, NetDraw ofrece la posibilidad de incrementar el número de lazos o relaciones mínimas entre los actores para evaluar cambios en la estructura de la red. En la Figura 18, se observa el cambio en la red al establecer como mínimo un valor de 13. En el caso de la red de innovación ganadera, este número indica el número mínimo de tecnologías que dos ganaderos deben haber adoptado en conjunto para considerarse conectados. Es decir, de todas las tecnologías disponibles, estos dos ganaderos han adoptado las mismas 13 tecnologías, por tanto, han tomado decisiones de adopción parecidas.

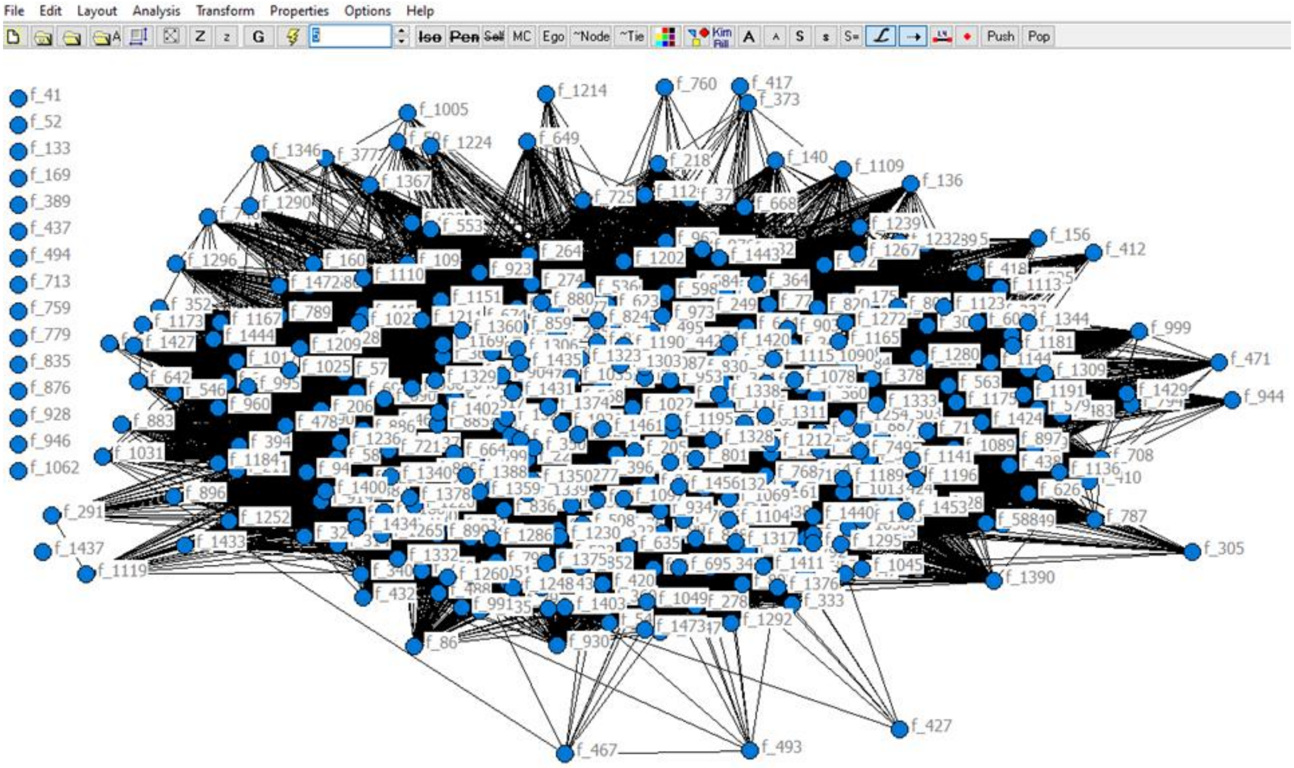
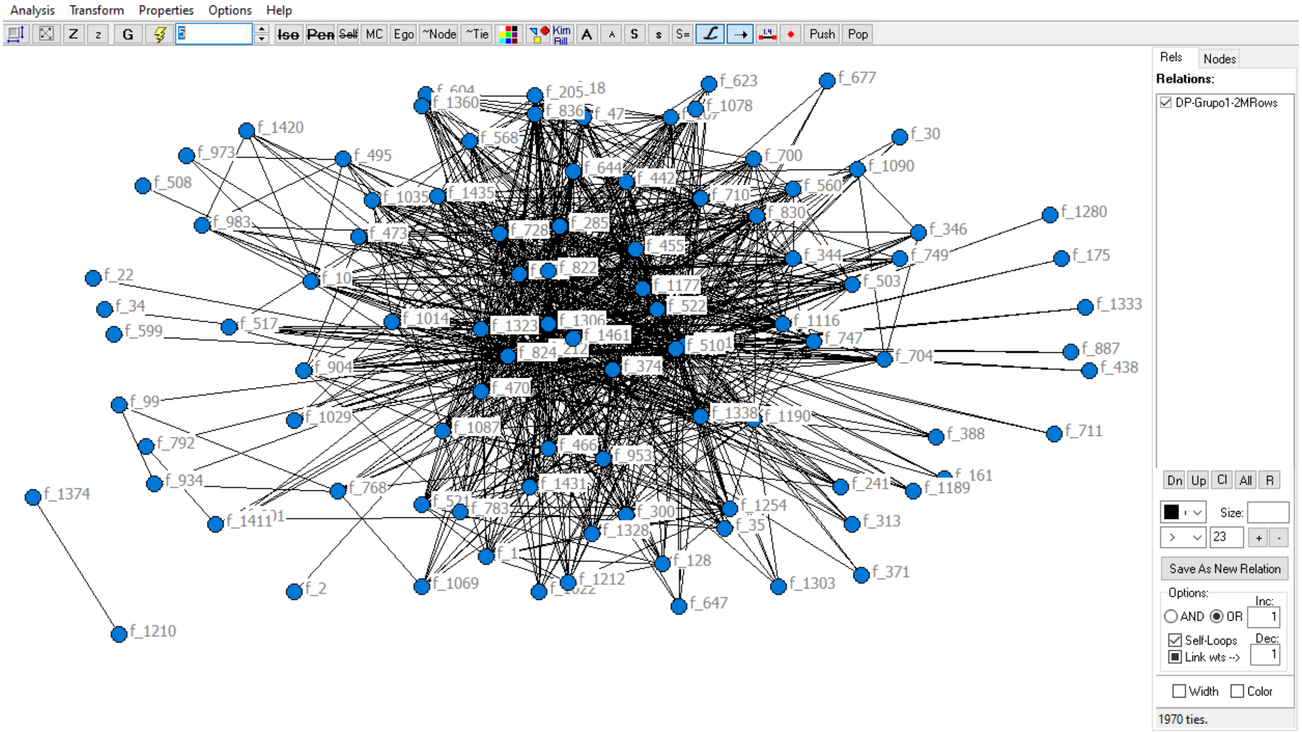


Figura 18. Búsqueda del threshold value: número de lazos = 13.

Sin embargo, la interpretación sigue siendo compleja y la estructura de la red no se visualiza con claridad. Por lo que es necesario establecer un nivel mínimo de relacionamiento más alto, de esta manera, al intentarlo con un valor de 23, como se observa en la Figura 19 la red cambia y se empieza a visualizar una estructura más comprensible.

En este caso, aparecen un par de ganaderos muy unidos entre sí, pero desconectados de la red (f_1374 y f_1210). Sí se desea encontrar a una red más clara aún, o encontrar ganaderos con lazos más fuerte se puede continuar con este tipo de procedimientos hasta llegar al grupo central de la red, ganaderos con el mayor nivel de centralidad. En la Figura 20, se observa cómo cambia la red al establecer un nivel mínimo de 29 tecnologías adoptadas en común.



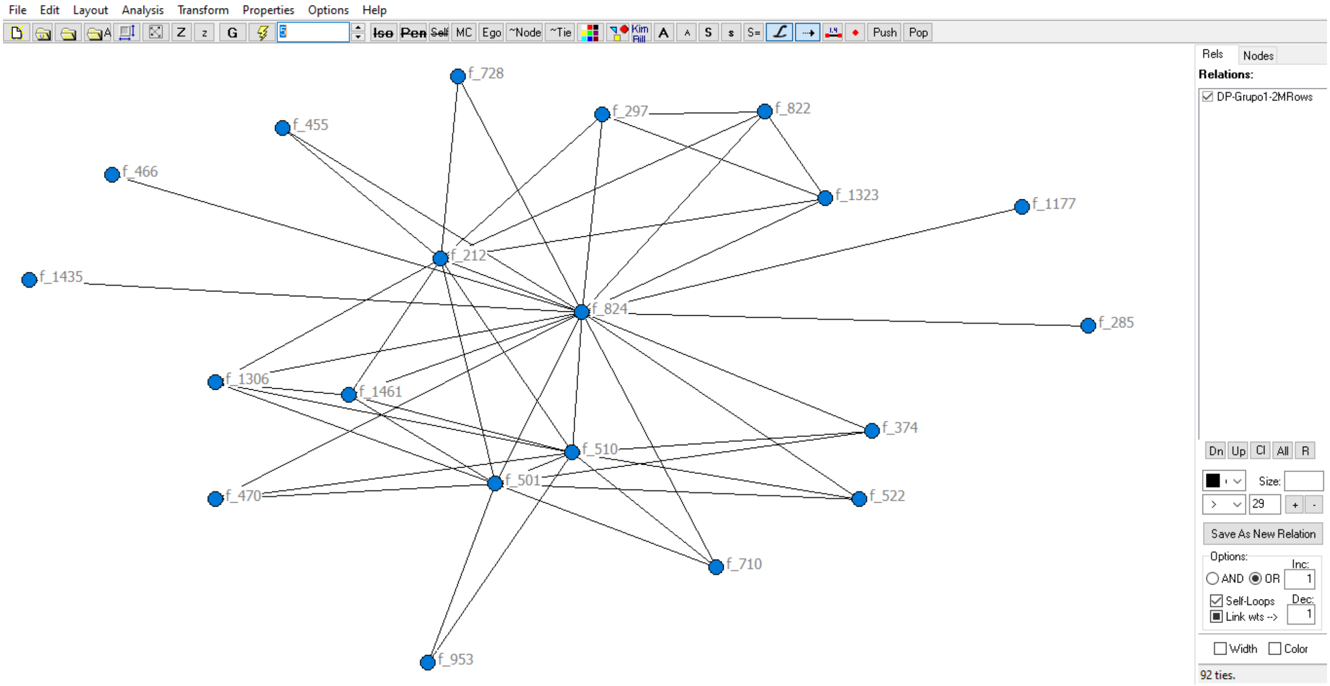
Relations:
☑ DP-Grupo1-2MRows

> 23

Options:
○ AND ● OR Inc: 1
☑ Self-Loops Dec: 1
Link wts -->
☐ Width ☐ Color

1970 ties.

Figura 19. Búsqueda del threshold value: número de lazos = 23.



Relations:
☑ DP-Grupo1-2MRows

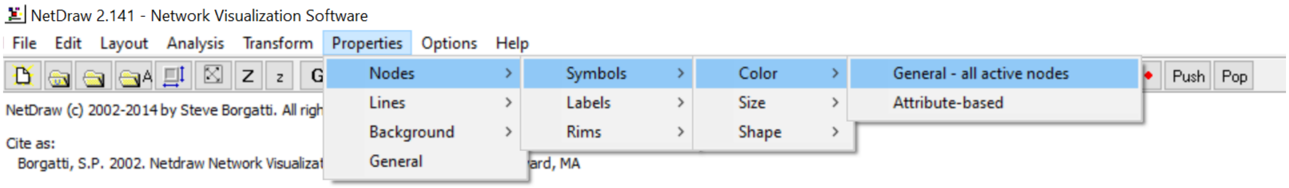
> 29

Options:
○ AND ● OR Inc: 1
☑ Self-Loops Dec: 1
Link wts -->
☐ Width ☐ Color

92 ties.

Figura 20. Búsqueda del threshold value: número de lazos = 29.

Una vez establecido el nivel de relación entre ganaderos, NetDraw permite cambiar colores y tamaño de los nodos, según atributos como el nivel de centralidad, el sexo, la organización a la que se esté afiliado, etc. Según los datos de atributos con los que se cuente. La ruta para este procedimiento como se observa en la Figura 21 es Properties>Nodes>Symbols>Color>General-all active nodes.



NetDraw (c) 2002-2014 by Steve Borgatti. All righ

Cite as:
Borgatti, S.P. 2002. Netdraw Network Visualizat ard, MA

Figura 21. Diseño y configuración de la red.

Al establecer el color y tamaño de los nodos, se puede visualizar más claramente los distintos subgrupos dentro de la red, como por ejemplo en la Figura 22, f_18 y f_644, son los ganaderos con la mayor centralidad, en este caso f_710 aunque tiene un nivel de centralidad más bajo, actúa como bróker o gatekeeper ya que es el enlace de conexión entre estos dos ganaderos y el resto de la red.

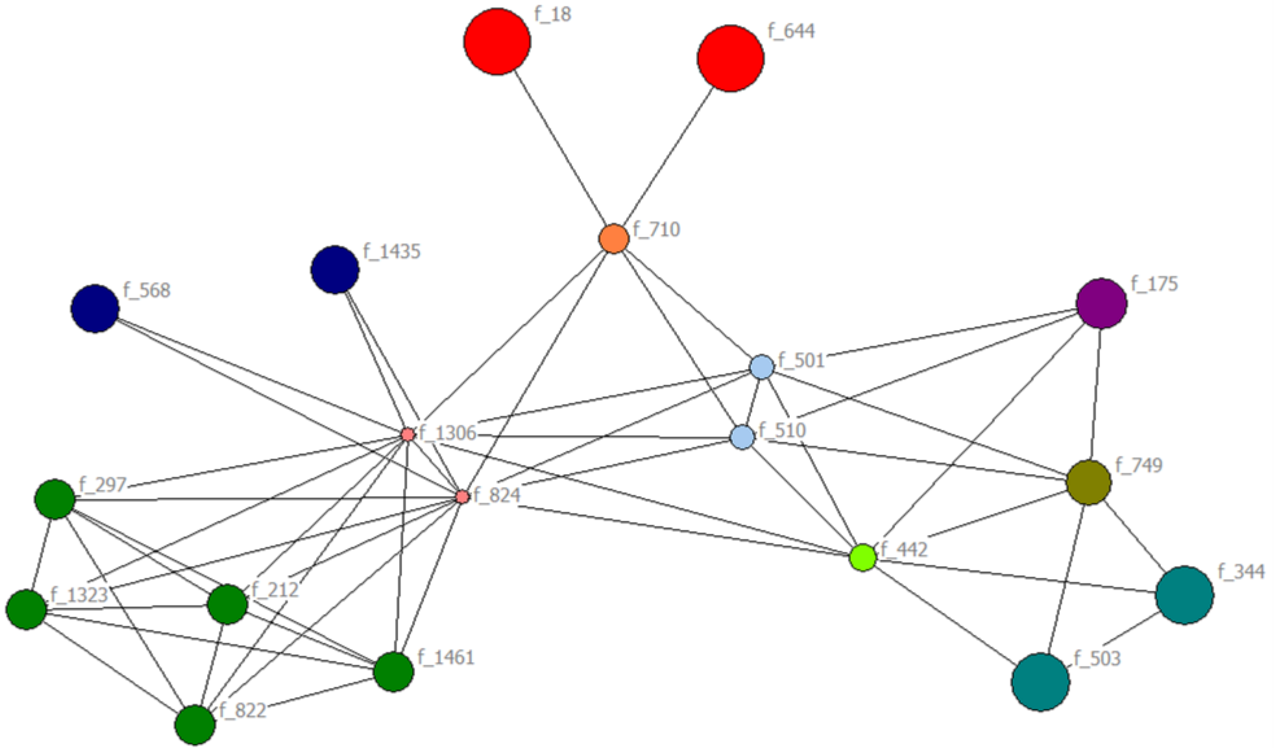


Figura 22. Red central.

Por otro lado, también puede observarse un grupo de 5 ganaderos de color verde oscuro muy fuertemente conectado entre ellos, conectados a la red a través de los ganaderos f_1306 y f_824, quienes también actúan como gatekeepers.

3.2. RECOGIDA DE DATOS Y ANÁLISIS REALIZADOS

3.2.1. Data Collection

This study was part of a larger research project in the Mexican tropics, where dual-purpose cattle farms were characterized according to their technological innovation level into five groups (Rangel et al., 2020; Villarroel-Molina et al., 2019). Data were collected from 2013 to 2016 by direct surveys done to smallholders of dual-purpose who have received technical advice from Mexico's Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA). Here, we focused on the more vulnerable and smaller group of farmers with 50 or fewer cows (n = 383), which represented 26% of the sample, distributed into dry and wet tropics. In average, the annual milk production was 11,229 L, 988 L/cow and 108 L/ha. The farm type had 19.25 Animal Unit (AU) of herd size, 27.17 ha, 1.09 UA/ha of stocking rate. The farmers' mean age was 51 years with three dependent relatives. The main characteristics of this group were previously described in (Rangel, et al., 2017; Rangel et al., 2020; Rojo-Rubio et al., 2009).

The selection of technological innovations was accomplished through qualitative and participatory analysis, according to the methodology described by Rangel et al. (2020), Rivas et al. (2019), Garcia-Martinez et al. (2016) and Torres et al. (2015), based on the farmer's technological preferences. Forty-five technologies were identified and grouped in five technological areas: management, feeding, reproduction, genetics and animal health, favouring a systemic and non-linear vision of innovation, within a transversal, collaborative and interactive process (Rangel et al., 2017).

3.2.2. Methodological Background

In the current study, we used the SNA methodological perspective from the social capital theory as a core element in the access to technological resources embedded in livestock innovation networks (Borgatti et al., 1998; Hauser et al., 2007; Lin, 1999; Parker, Halgin, & Borgatti, 2016; Rodríguez-Modroño, 2012; Saint-Ville et al, 2016; Zarazúa et al., 2012). Social capital consists of a series of resources that individuals can obtain from the structure of social networks. Two of the most important resources are information flowing through networks and obligations of reciprocity, which can come out of the confidence between agents in the same network (Burt, 2000; Lin, 1999; Medina, 2011; Rutten, Westlund, & Boekema, 2010). Therefore, SNA provides a useful theoretical framework to investigate social structures and has been recognised as a distinct research approach to study relations rather than attributes, mapping trust and knowledge networks (Villarroel-Molina et al., 2019; Zarazúa et al., 2012), and therefore can be applied to the study of social capital (Parker et al., 2016; Saint-Ville et al., 2016; Webb, 2008).

In this study, social capital is considered to be a resource through which farmers access valuable information that allows them to be more efficient in the production process. It is believed that those farmers well connected to key players (technological leaders) can imitate their strategies, which becomes a competitive advantage. Hence, it is not necessarily true that the farmers with a higher rate of technological adoption are the most productive, but rather a group of farmers appear on the network that, making use of this advantage in access to information, manage themselves to be more efficient with fewer technologies (Borgatti, 1992). These technologies are known as core technologies, with a high impact on productivity. Consequently, the position of a certain farmer and their proximity to the technological leaders in the technological innovation network is crucial when adopting or rejecting technology (Mashavave, 2013). Then, social networks as a form of social capital constitute a production input which can affect the farmer's productive capabilities and their level of technological adoption, influencing the economic performance and explaining the differences of the adoption rate among farmers with similar endowments (De-Pablos-Heredero et al., 2020).

In recent years, there has been an increasing amount of literature supporting the idea of social capital as a competitive advantage, explaining economic outcomes on the individual level (Burt, 2000, 2009; Granovetter, 2000; Norbutas & Corten, 2018; Rodríguez-Modroño, 2012). According to Webb (2008), the interactions within community members who interact directly, frequently, in multifaceted ways, generate opportunities by providing them with a competitive advantage in pursuing their ends. Burt (2000), described social capital as a function of brokerage opportunities, while Rodríguez-Modroño (2012) suggested it to be a source of information that enables the development of productive synergies. Similarly, Saint Ville et al. (2016) studied how different forms of social capital may affect innovation in smallholder farming systems and they found a strong presence of interpersonal agricultural knowledge networks operating to: (1) facilitate farmer-to-farmer knowledge exchange; (2) increase farmer access to information; and (3) connect farmers to sources of support, pointing out the role of peer farmers as the primary source of new agricultural knowledge.

Network Definition and Benchmark

Firstly, we constructed a two-mode network of 383 farmers and nine technologies based on the technological package of each respondent. Two-mode networks, also known as affiliation networks (Borgatti & Everett, 1997, 2013), consist of recording instances in which individuals participate in or attend the same events, or where there are archival data indicating which people belong to which organizations (Valente et al., 2020). This type of network allowed us to identify techno- logical adoption patterns, as well as those of the organization's membership. Secondly, after considering the different ways of analysing two-mode networks developed by Borgatti et al. (1997, 2018), Everett et al. (2013), and Hanneman & Riddle, (2005), the two-mode data were transformed into a bipartite graph. For the aim of this paper, the bipartite graph centrality measures were calculated, allowing the technological leaders to be identified.

In this case, we must note that the affiliation to an organization was considered as an essential and differentiating attribute. This is because it is believed that organizations are centres of social interaction and access to information, where communication flows, constituting a determining factor in the technology adoption processes. Therefore, through the surveys, it was possible to map six different types of organizations operating in the area, both public and private. The GGAVATT (Livestock Groups for Technological Validation and Transfer) was the most important organization at the public level, belonging to the Institute for Forestry, Agriculture and Livestock Research (INIFAP), an institution that operates nationally. The GGAVATT constituted the organization with the largest number of affiliated farmers (81.46% of the sample). According to Ponce-Méndez et al. (2016), the GGAVATT model is applicable at the regional and national level, to groups of livestock farmers with a common production goal and who were interested in adopting the technological model. The GGAVATT advisers (Figure 23) made a holistic approach to the farm, considering the different areas of improvement (reproduction, feeding, management, health, quality, management, and use of pastures).

Figure 23. GGAVATT women professional technical advisors.

In the private sector, there were several organizations. The second most important organization in the number of affiliates was the SPR (the Rural Production Society), with 9.4% of the sample. The Rural Production Society operates state-wide and was constituted by a group of producers who aim for agricultural activity improvement through the coordination of productive economic activities, mutual assistance, etc. This group of farmers also aims to obtain goods, services and public or private support to undertake, develop and consolidate productive and social investment projects. Other less widespread organizations in the area were the Cooperative Society (3.66%), the producers' organization (1.04%) and the non-productive organization (2.09%). The results showed that a small group of farmers has no affiliation with any organization (2.35%).

The farmers in the network were highlighted according to the organization type. The initial two-mode network was transformed into a one-mode network through UCINET software (Borgatti et al., 2002) for the network visualization and the identification of the influencer farmers (technological leaders) by considering their centrality network measures. Thus, only the farmers who have adopted six technologies or more are shown, that is, those with a technology adoption rate greater than 67%.

Finally, a comparative benchmarking analysis was carried out among the profiles of seven dual-purpose farmers chosen through the SNA measures (degree, closeness, eigenvector, betweenness and constraint). The mean, median, standard deviation, coefficient of variation, minimum and maximum were the descriptive statistic used in the technological analyses. The approach is novel as it seeks to introduce network measures into the analysis to study how farmers make production decisions and what factors influence their decisions. The analysis and visualization of the dual-purpose cattle network in the Mexican tropics were carried out using the UCINET software (Borgatti et al., 2002).

In **chapter 1** of results, we focused on the ***area of reproductive management***, as it is the one with the lowest technological level (Table 24). This area is composed of nine technologies: using male breeds (T23), using male crosses (T24), using female breeds (T25), using female crosses (T26), use of genetically tested bulls (T27), calf selection criteria (T28), female selection criteria (T29), sire selection criteria (T30), and crossbred system (T31).

In **chapter 2** of results, we focused on the ***area of genetics***. This area is composed of nine technologies: Breeding soundness evaluation in bulls (T32), Semen fertility evaluation (T33), Evaluation of female body condition (T34), Estrus detection (T35), Pregnancy diagnosis (T36), Type of mating (T37) and Breeding policy (T38).

In **chapter 3** of results ***all the 45 technologies,*** as it is shown in Table 27, were considered from a gender perspective. Therefore, after evaluating the technological adoption levels in five technological areas, we focus on reproduction, as it is the area where statistically significant differences were found between men and women.

RESULTADOS Y DISCUSIÓN

4. RESULTADOS Y DISCUSIÓN

4.1. Usefulness of network analysis to characterize technology leaders in small dual-purpose cattle farms in Mexico

Published as:

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Introduction

Smallholder livestock production constitutes a major component of developing countries' economies, a contribution that goes beyond direct food production to include multipurpose uses, such as food supply, source of income, assets saving, source of employment, soil fertility, livelihood, transport, agricultural traction and sustainable production (Bettencourt et al., 2015; Steinfeld & Mack, 1995). Nevertheless, the significance of smallholder agriculture is not only limited to a subgroup of low-income countries, contrary to widespread perception. Smallholder also plays an essential role in the EU and OECD countries, where they are an alternative to large and specialised farms; especially in the aftermath of the economic and financial crisis (Guiomar et al., 2018). However, this does not mean that the problems faced by smallholders are identical in all these countries. Neither does it mean that the role of smallholder agriculture in broader processes of development is the same everywhere (De-Pablos-Heredero et al., 2020; Bosc et al., 2013).

In Mexico, dual-purpose cattle encompasses between 51–67% of the highly marginalized area's producers (Morantes et al., 2020; Rojo-Rubio et al., 2009), contributing to the maintenance of traditional ways of life in the agricultural sector, and generating direct income (Granados-Rivera et al., 2018; Jaime Rangel et al., 2017; Garcia-Martinez et al., 2016). The dual-purpose productive system is an alternative to increasing profitability in livestock. From the biological point of view, this system favours the increase in cow dairy potential by crossing meat breeds adapted with specialized dairy breeds but conserving the rusticity of these animals (Rangel et al., 2020). Therefore, this is a traditional and extensive grazing system that uses low-cost resources, contributing to mitigate climate change by reducing greenhouse gas (GHG) emissions and increasing carbon accumulation (Morantes et al., 2019; Rangel et al., 2020; Rangel Jaime, 2016; Espinosa-García et al., 2015).

The low technology adoption rate is one of the major problems of very small dual-purpose farms in Mexico (Aguirre-López et al., 2020; Rangel et al., 2020 Garcia; Morantes et al., 2019; Martinez et al., 2016). According to Rangel et al. (2016), these farmers use only 46.96% of the technologies potentially available to them. In this sense, Espinosa-García et al. (2015) have pointed out that this is compounded by the lack of technology transfer programmes and technical assistance. Even when the adoption of new agricultural technologies is an important route out of poverty for many in the developing world, agricultural innovations are often adopted slowly, and some aspects of the adoption process re- main poorly understood (Aguirre-López et al., 2020; De-Pablos-Heredero et al., 2020; Abdulai & Huffman, 2005).

This indicates a need to investigate the reasons for the low technological adoption rate in dual-purpose livestock systems. With the purpose to understand the failures in the adoption process, previous studies have mainly focused on the farm's size and credit constraints on the adoption process (Bastanchury-López et al., 2020; Morantes et al., 2020). However, very few empirical researchers have explored the relationships between a farmer's contact networks and his decision to adopt or reject new technologies, and how these interactions may work to enhance or limit smallholder farmer innovation (Abdulai & Huffman, 2005; Mashavave et al., 2013).

Hence, a need to improve the understanding of technology adoption from a social network analysis (SNA) perspective (Borgatti & Halgin, 2011; Wasserman & Faust, 1994) has been identified, with a focus on the relationships among key farmers capable of spreading innovation and enhancing the adoption of new technologies. The social network analysis approach is used to identify farmers who are performing well and are successful at what they do, to evaluate with a benchmark analysis the strengths and weaknesses of their technological practices and the steps needed to improve their performance.

Regarding the usefulness of benchmarking analysis in the context of innovation dissemination, Kahan (2013) stated that farmers often do benchmarking informally from something as straightforward as observing and talking to successful farmers. A farmer sees another farmer with a larger harvest or one who gets a better price for the same product at the same market. Why is this so? A farmer hears of another farmer who reduces costs by introducing a new technology. Should she or he do the same? This study is aimed to answer the following research questions:

- What characterizes the key farmers in the technology adoption network?
- What are their technology strategies?
- Are the farmers playing a central position in the network the most innovative?

The objectives of this study were to identify influencer farmers in the innovation network and to perform a benchmarking analysis to evaluate what characteristics these leaders had, and thus deepen the knowledge of the rejection causes during technology adoption processes of dual-purpose cattle smallholders in Mexico.

Results and Discussion

Descriptive Statistics

The descriptive statistics of very small dual-purpose farms in Mexico are shown in Table 19. In this case, the highest variability was found in the cheese yield (299.17%), due to the fact that not all farms produce cheese and dairy products. On the other hand, calves sold also showed high variability, with an average of 4.90 calves sold and a coefficient of variation of 118.56%.

These results showed the essence of this livestock system, which is obtaining milk and meat from the same animal and makes it evident that some farmers are mainly engaged in milk production and others in meat and milk joint production. This productive orientation will determine its technological strategy. Moreover, the average farm had 19.25 UA of herd size in 27.17 ha and 1.09 UA/ha of stocking rate.

The farmer was 51 years old and three people were economically dependent on the farm (dependent relatives). The annual milk production was 11,229.4 L and the productivity per cow and ha was 988 L/cow and 108 L/ha, respectively.

Table 19. Structural characteristics of dual-purpose cattle farms (n = 383).

Variables	Mean	Median	SD [1]	CV [2]	Min [3]	Max [4]
Grazing surface, ha	27.17	19	38.67	142.33%	3	400
Total animal unit, UA	19.25	19.2	3.96	20.57%	10	47
Herd size, n° cattle	25.54	25	6.32	24.76%	10	65
Stocking rate, UA/ha	1.09	1	0.636	58.32%	0.05	3.82
Milk production, l/year	11,229	10	6825	60.78%	0	36,5
Milk per cow, l/cow/year	987.71	937.50	591.75	59.91%	0	2940
Calves sold, n° calves	4.90	4	5.81	118.56%	0	40
Unproductive animals, heads	2.53	0	4.52	178.92%	0	32
Cheese yield, kg/farm/year	245.25	0	733.71	299.17%	0	9000
Milk production, l/ha	107.80	52.63	186.79	173.27%	0	1429
Stakeholder's age, years	51	51	14.51	28.40%	20	85
Dependent's relatives, *n*	2.91	3	1.80	61.99%	0	9
Employments, workers	1.49	1	1.11	74.28%	0	6

[1] Standard deviation, [2] Coefficient of variation, [3] Minimum, [4] Maximum.

Technology descriptive statistics are shown in Table 20. The reproductive management technologies had an average adoption rate of 59.18%. However, the results showed that the crossbred system (95.82%), sire selection criteria (90.34%) and female selection criteria (89.56%) are the most adopted technologies within this area, while female selection criteria (89.56%), using female crosses (71.28%) and using male crosses (55.87%) have a medium level of adoption over the average. In contrast, calf selection criteria (49.87%), using male breeds (37.34%), using female breeds (22.45%) and use of genetically tested bulls (20.10%) are the least adopted technologies.

Table 20. Reproductive management technologies in dual-purpose cattle farms.

Code	Technological Level (%)	Mean	SD[1]	CV[2]
T31	Crossbred system	95.82	0.200	4.01
T30	Sire selection criteria	90.34	0.296	8.75
T29	Female selection criteria	89.56	0.306	9.38
T26	Using female crosses	71.28	0.453	20.53
T24	Using male crosses	55.87	0.497	24.72
T28	Calves' selection criteria	49.87	0.501	25.07
T23	Using male breeds	37.34	0.484	23.46
T25	Using female breeds	22.45	0.418	17.46
T27	Use of genetically tested bulls	20.10	0.401	16.10

[1] Standard deviation, [2] Coefficient of variation.

The descriptive statistics of the centrality network measures for the sample of 383 farmers (Table 21) showed that within the technological innovation network in reproductive management, dual-purpose farmers had an average degree of 5.38 with a minimum value of two and a maximum value of nine; the degree is related to the number of technologies that these farmers have adopted.

The average betweenness was 3.92, being one of the measures with the highest coefficient of variation (8.93). These results were similar to that of Aguirre-López et al. (2020), who found a betweenness of 0.394 in the adoption patterns of conservation agriculture practices among 222 maize smallholder farmers in the Mexican state of Chiapas. However, eigenvector and constraint showed the least variability, being 1.47 and 0.003, respectively.

Table 21. Centrality network measures in dual-purpose cattle farms.

	Mean	Standard Error	Median	SD[1]	CV[2]	Min[3]	Max[4]
Degree	5.38	0.06	5	1.21	1.47	2	9
Closeness	793	0.283	793	5.52	30.45	785	839
Eigenvector	0.105	0.001	0.11	0.02	0.000	0.04	0.15
Betweenness	3.94	0.154	2.87	2.99	8.93	0.03	16.71
Constraint	0.198	0.003	0.20	0.06	0.003	0.11	0.50

[1] Standard deviation, [2] Coefficient of variation, [3] Minimum, [4] Maximum.

Social Network Analysis Results

The farmers grouped according to the type of organization are shown in

Figure *24* (two-mode network). The GGAVATT farmers showed more homogeneous groups with well-defined structures, reluctant to technological exchange with other farmers external to their group. On the contrary, the SPR farmers were a smaller group, more heterogeneous and closer to the other associations. The GGAVATT and SPR farmers showed a higher level of technology adoption and a higher degree than the rest of the organizations (Table 22).

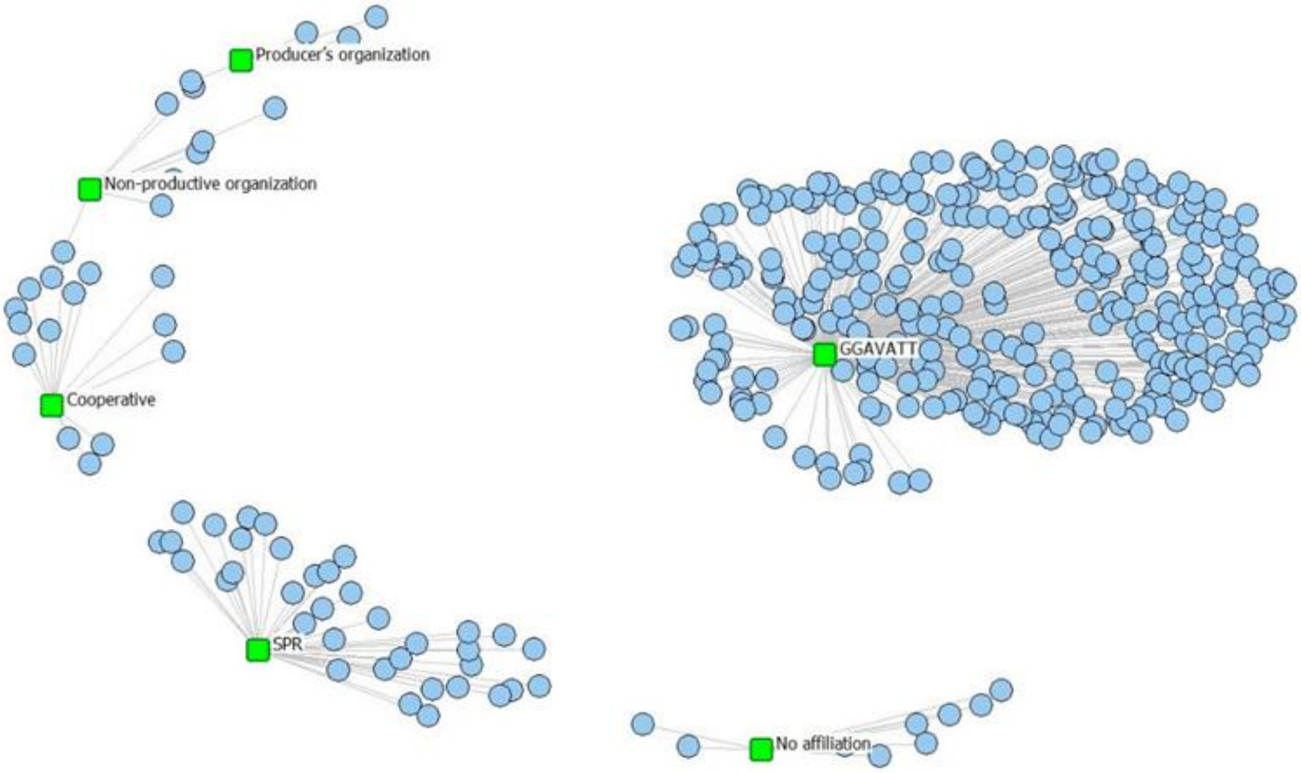

Figure 24. Two-mode network visualization of farmers and type of organization 🟩. Organizations: GGAVATT (Livestock Groups for Technological Validation and Transfer), SPR (the Rural Production Society), cooperative, producer's organization, non-productive organization, no affiliation. ● Farmers.

Table 22. Farmer's benchmarking by organization type.

		High level			Medium level		Low level
Organization type	Leader farmer	GGAVATT[1]	SPR[2]	Cooperative	Producers Organization	No Affiliation	Non-productive organization
Farmer, code	f_623	f_374	f_1165	f_325	f_522	f_183	f_76
SNA and technology							
Technological adoption rate, %	100	89	89	78	78	78	56
Degree	9	8	8	7	7	7	5
Closeness	785	787	787	789	789	789	793
Eigenvector	0.15	0.13	0.13	0.12	0.12	0.13	0.11
Betweenness	16.71	13.59	13.59	10.5	8.64	7.54	1.57
Constraint	0.11	0.13	0.13	0.14	0.14	0.14	0.20
Structural characterization							
Productive animals, cows	11	13	14	11	17	10	11
Animal units, heads	23.7	17.9	22.6	24.2	22.4	18.6	21.1
Stocking rate, UA/ha	40	22	31	37	25	25	26
Grazing surface, ha	1.00	1.12	2.26	0.56	1.32	0.81	0.41
Productive orientation	Milk, meat, and cheese	Milk	Milk-meat	Milk-meat	Milk	Milk-meat	Milk-cheese
Milk production, l/ha	76.79	141.54	171.43	464.55	63.15	54.78	12.83
Milk yield, l/year	20,020	11,040	24,000	15,330	18,250	12,600	7,200
Milk per cow, l/cow/year	1,820	849	1,714	1,394	1,074	1,260	654
Calves sold, nº calves	13	0	10	5	0	3	0
Cheese yield, kg/farm/year	730	10	0	0	0	0	100
Stakeholder's age, years	50	28	40	64	45	48	52
Economics dependents, nº	1	1	3	8	5	1	3
Employees, workers	4	1	1	3	4	3	3

[1] Livestock Groups for Technological Validation and Transfer; [2] The Rural Production Society

The dual-purpose farmer’s network in reproductive management, coloured by organizations, are presented in Figure 25. In this innovation one-mode network, only one central farmer was found with the higher betweenness value and, therefore, with a very high social capital compared to their technological peers. This is the farmer f_623, affiliated to the SPR, the only farmer with an adoption rate of 100%. The network structure highlighted those farmers affiliated to the GGAVATT tend to form homogenous groups. These results corroborate the findings of Rangel et al. (2020), who found in the dual-purpose livestock system that while the structural characteristics of the farms were quite heterogeneous, the technological levels were quite homogeneous.

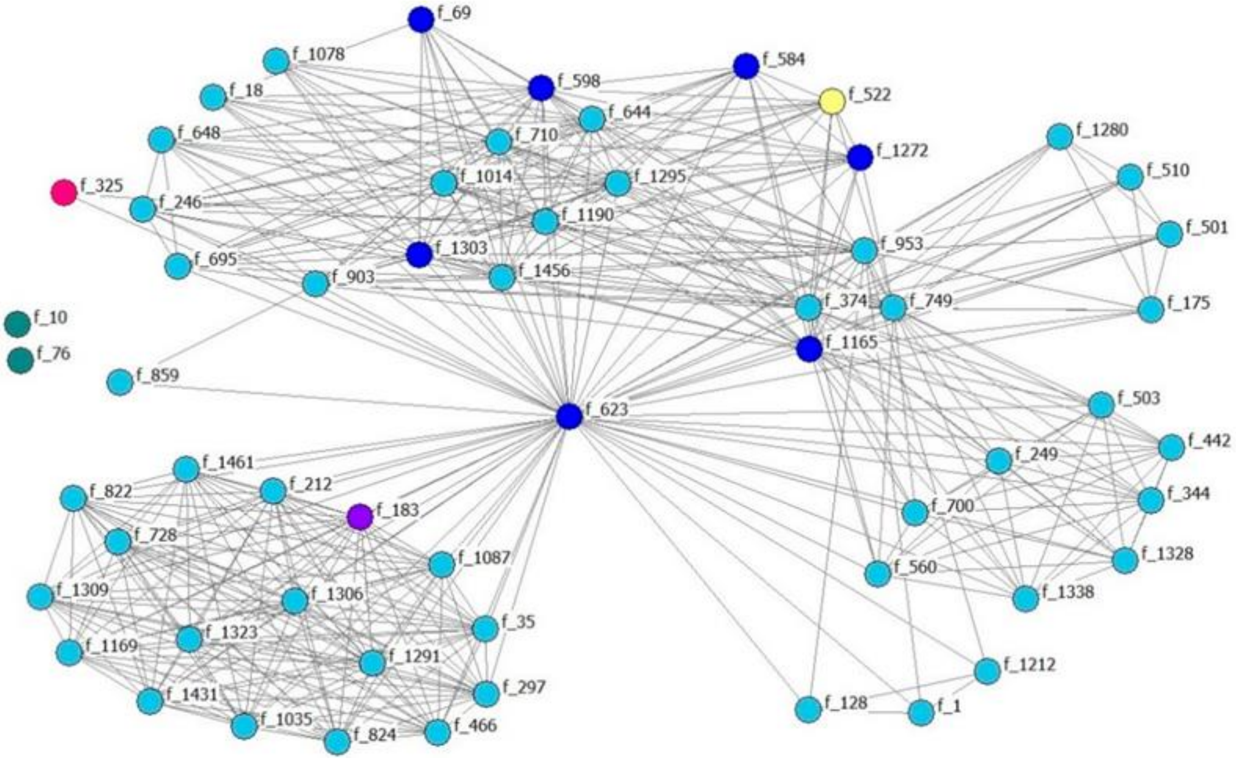

Figure 25. One-mode network visualization of farmers. Nodes’ colour: organization type. Farmer code (f_ni), organization type: ● GAVVAT (Livestock Groups for Technological Validation and Transfer), SPR (the Rural Production Society) cooperative, ○ producers’ organization, ● no organization, non-productive organization.

Figure 26 shows the two-mode network relating farmers and technologies. The network structure indicated that some of the reproductive management technologies were jointly adopted: calf selection criteria (T28), female selection criteria (T29) and sire selection criteria (T30). So, they were considered complementary technologies (Rangel et al., 2020).

On the contrary, the technologies "male crosses" (T24) and "female crosses" (T26) followed another adoption pattern. These results also showed that the crossbred system (T31), with an adoption rate of 96%, was the most widely adopted technology. It can be considered an elementary technology in reproductive management. However, the least adopted technologies in this group of farmers were using male breeds (T23), female breeds (T25) and genetically tested bulls (T27), with an adoption rate of 37.34%, 22.45% and 20.10%, respectively.

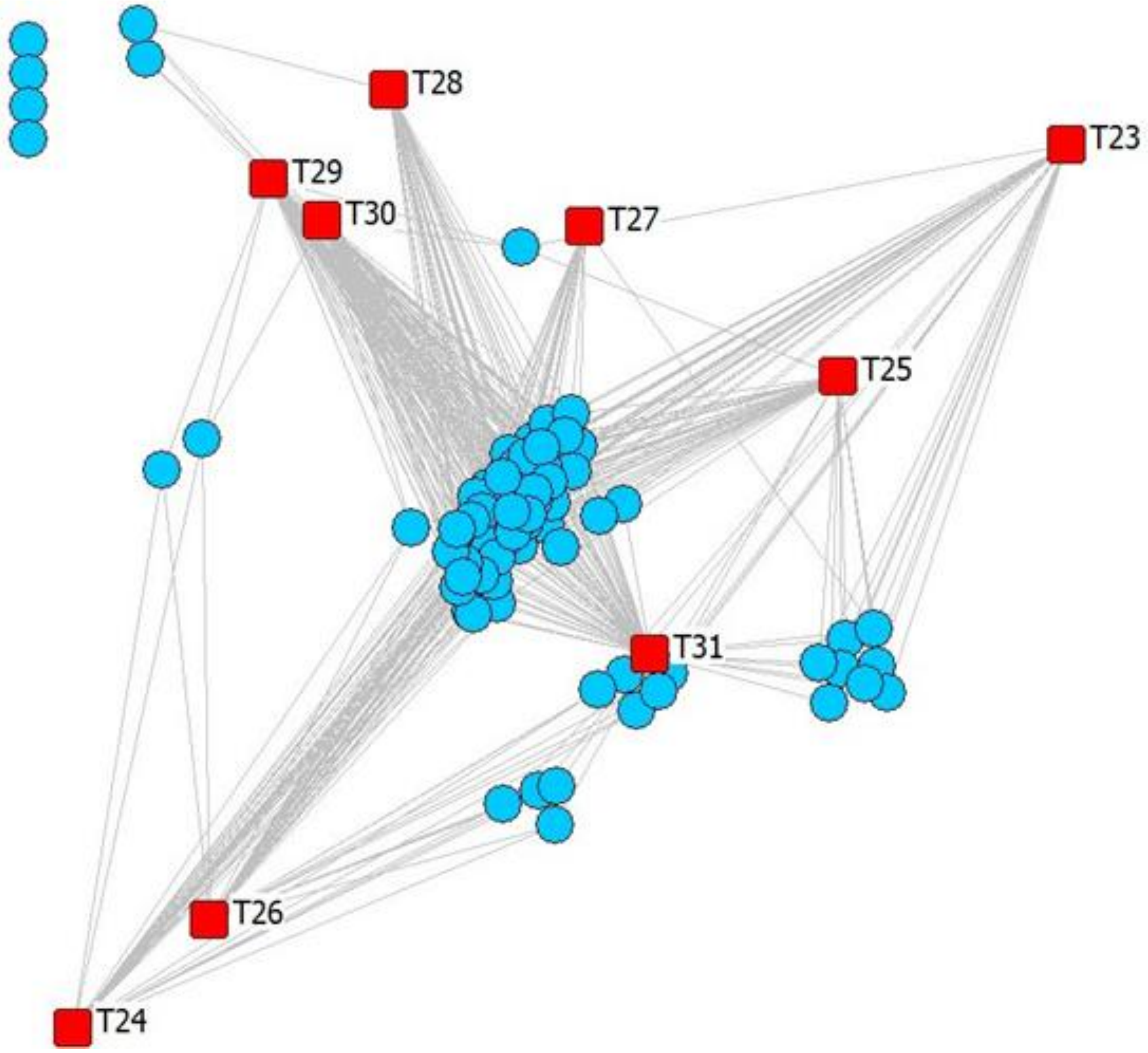

Figure 26. Two-mode network visualization of farmers and technologies. 🟥 Technologies: T23. Using male breeds, T24. Using male crosses, T25. Using female breeds, T26. Using female crosses, T27. Use of genetically tested bulls, T28. Calves' selection criteria, T29. Female selection criteria, T30. Sire selection criteria, T31. Crossbred system; ● Farmers.

Benchmarking Analysis

The benchmarking of influencer farmers by organization type is shown in Table 22, both in its centrality network measures, technological level, and structural characteristics. The Farmer influencer (f_623), was affiliated to the SPR, with an adoption rate of 100% and the highest betweenness value in the network (16.71).

Besides, high values of degree, eigenvector, betweenness and low levels of constraint favoured high levels of social capital. This farmer presented a similar productive structure (size, productive animals, surface, etc.) to the rest of the GGAVATT and SPR leaders, although was different in its productive orientation and in the use of resources. Its strategy was diversified, allocating part of the production to the sale of milk, meat, and cheese. According to De-Pablos-Heredero et al. (2020); Guiomar et al. (2018); Rangel et al. (2020) high technological adoption rates are associated with a diversified productive strategy.

Likewise, they obtained high productivity by lactation (1820 l/cow), high stocking rate (40 UA/ha), and generated four direct employments. Despite previous studies have reported that farm size is the main factor in determining the technology adoption level (Díaz et al., 2010; Espejel-García et al., 2014; Ponce-Méndez et al., 2016) and that relation exists amongst the farm's size, productivity, and efficiency (Rada & Fuglie, 2019), within the group of small-scale farmers, the producers can also be efficient (De-Pablos-Heredero et al., 2020; Gautam & Ahmed, 2019; Rangel, Espinosa, de Pablos-Heredero, Rivas, et al., 2017). These results highlighted that the differences in technology adoption were given by the network measures and the productive strategies developed. Furthermore, through benchmarking analysis, three farmers’ profiles were identified.

High technology level. The GGAVATT and SPR farmers were technologically similar (f_374, F_1165), showed close positions in the network (Figure 23) and very similar centrality network measures (Table 22).

The GGAVATT farmer received public technical assistance (Figure 27). On the contrary, the advice in SPR was private. Their productive orientation was strongly different. The GGAVAAT farmer was specialized in milk, while SPR farmer in milk–meat. In addition, the SPR farmer showed high productivity (1714 l/cow and 10 calves sold).

Figure 27. Dual-purpose smallholders training under the GGAVATT methodology.

In the GGAVATT there has been a generational renewal with younger producers and only one employee (Figure 28), while in SPR, the farmer was older, with three people economically dependent on the activity. Similar results were reported by Granados-Rivera et al., (2018) and Díaz et al. (2010).

Figure 28. New generations of women farmers combining traditional knowledge with modern technologies.

Medium technology level. The leaders of other producer private organizations had much more limited advice (Rangel, Espinosa, de Pablos-Heredero, Barba, et al., 2017; Garcia-Martinez et al., 2016; Bettencourt et al., 2015). Cooperative, producers' organization and non-affiliation farmers showed a medium technological level (78%) and similar network centrality values among them. The leading producers of each organization of this group showed low technological adoption and centrality values, a low diversification degree, dairy specialization, low calf production and no cheese production (Rangel, et al., 2017; Rivas, Perea, et al., 2019; Steinfeld & Mack, 1995).

However, the number of people economically dependent on the activity and the number of workers were high. Non-affiliation farmers (f_183) were close to other organizations (Figure 23) and showed similar technological and centrality network values.

Low technological level. The farmer affiliated to non-productive organizations (f_76), showed low network centrality and technology values (56%). This is due to the fact that this farmer was disconnected to the network. His strategy was based on milk and cheese production, with three workers (Díaz et al., 2010; Garcia-Martinez et al., 2016; Rangel, Espinosa, de Pablos-Heredero, Rivas et al., 2017; Rojo-Rubio et al., 2009).

The benchmarking analysis showed that belonging to a certain organization favours the technology adoption rate, although the degree of connectivity with other producers is more important. Being connected to technological leaders and farmers affiliated to different organizations with different social capital positively affects the technology adoption rate since this diversity is a source of information, knowledge, and resources.

This research makes a significant contribution to advancing the understanding of the low technology adoption rate in the area of reproductive management in livestock systems, as technology is a strategic tool for developing and increasing the competitiveness and viability of the farms (Bastanchury-López et al., 2020; De-Pablos-Heredero et al., 2020; Rivas et al., 2019), and contributions to the field will foster development that allows one to identify viable technologies, the sequence of adoption, the mode of dissemination and the technological leaders.

These findings agree with Zacharakis et al. (2005), who suggested that networks are most effective when they are diverse, inclusive, flexible, horizontal (linking those of similar status) and vertical, linking those who have resources not available within the community. These results also match those found by Dhehibi et al. (2020), who studied the agricultural technology transfer preferences of small-holder farmers in Tunisia and found that farmer-to-farmer interactions were perceived as the most effective agricultural extension methods. The author also points out that the know-how influenced the adoption level. In the context of innovation dissemination, this is related to the social learning theory which states that people learn with and from others by example or through observation (Akers & Jennings, 2015). Similarly, Zarazúa et al. (2012) applied the SNA approach to assess social capital indicators in two groups of corn producers in Michoacán and found a strong relationship between the enhancement of technological innovation and the links established by farmers with actors involved in livestock activities. In this case, the farmers belonging to the most open network presented better productive outcomes.

These results were in line with those of Espejel-García et al. (2014) where, in their study of the interaction patterns in Mexico rural innovation system, they found that there were agents who act as intermediaries of innovation with the ability to articulate the innovation system, link the actors and bring innovation to the end user. The author concluded that intermediaries with greater links defined the sources and types of innovation and activate interaction patterns between the several actors of the system.

On the other hand, Gholifar et al. (2019) used the SNA approach to study sustainable aquaculture systems through an institutional collaboration network at Alborz Watershed in Iran and found that organizations can play a key role in the distribution of information, knowledge, and intersectoral cooperation among social agents, and pointed out that government agencies have more power and centrality in comparison to nongovernmental organizations, indicating a lack of co-management in the field.

However, these results differ from Kleinnijenhuis et al. (2011) who measured social influence in networks of practice and found that the members in the network who communicate about informal practice, and know who knows what, exert more social influence than others, suggesting that members' social influence is rooted in their utilitarian value for others, and not in their organizational embeddedness.

In summary, the present findings seem to be consistent with previous research on agricultural technology adoption (Vishnu, Gupta, & Subash, 2019; Hernández Guevara, 2015; Rendón-Medel et al., 2013; Weiss, Hamann, Kinney, & Marsh, 2012; Hauser et al., 2007; Deroian, 2002), which found that farmers' decisions to innovate are not based only on economic performance, but also in the context of social interactions among themselves and with agents that promote change.

The main limitation of this methodology lies in the sample definition. Future studies on the current topic are therefore recommended, using other analyses proposed in the literature to further investigate the nature of network data in the theoretical framework under study.

4.2. The importance of network position in the diffusion of agricultural innovations in smallholders of dual-purpose cattle in Mexico

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Introduction

The 2030 Agenda for Sustainable Development is a universal framework for action to end extreme poverty (Goal 1), fight inequality, and address the urgency of climate change and its impacts (Barg, 2018). In this context, small-scale farms play a crucial role in ensuring food security by widely contributing to the supply and access to food in rural areas (Mikecz & Vos, 2016; Rangel et al., 2017; Villarroel-Molina, De-Pablos-Heredero, Rangel, Vitale, & García, 2021). Besides, small-scale farms are family-based systems spread worldwide that apply diversified activities (crop and livestock), contributing to improving land use (Biermann, Kanie, & Kim, 2017).

According to García et al. (2016), 85% of small-scale farms are subsistence productions geared primarily to on-farm consumption, while only 15% are market-oriented with commercial objectives.

Therefore, smallholders mainly seek family welfare (including education) and vulnerability reduction by applying low-cost strategies. However, these systems are characterized by low technology adoption levels, low competitiveness, and extreme vulnerability to environmental risks and market changes (De-Pablos-Heredero, Montes-Botella, & Garcia-Martinez, 2018; Hooft, Wollen, & Bhandari, 2012).

In developed countries, these issues are compounded by the loss of profitability, lack of generational change, low status in terms of occupational prestige, and the excessive bureaucracy and regulations in rural areas, threatening smallholders' interests and livelihoods (O'Brien & Creţan, 2019; Rivas, Manuel Perea, et al., 2019). Furthermore, in developing countries, thefts and family safety, children's future (employment and education), and the continuous habitat degradation by pesticides and unfriendly agricultural practices are major concerns (Rangel et al., 2017; Rivas, Manuel Perea, et al., 2019; Valdovinos-Terán, Espinoza-García, & Velez Izquierdo, 2015).

The sustainable development paradigm lies in how to improve productivity in a sustainable way. Understanding how technologies spread among farmers and organizations is required to enable the technological adoption to smallholders. In this scenario, the application of social networks in the diffusion of innovation is a key tool (Valdovinos Terán et al., 2015; Villarroel-Molina et al., 2021). According to Rangel et al. (2017) and Mikecz et al. (2016), technology adoption was related to size, intensification level, and economic results, pointing out that size is the main factor to determine the technology adoption level.

In this regard, dual-purpose (DP) cattle represent an alternative to intensive livestock farming (Garcia-Martinez et al., 2016; Villarroel-Molina, Rangel, Barba, & García, 2019). The strengthening of social networks will positively influence the low-cost reproductive technology adoption and its direct application, increasing the system productivity without compromising its sustainability. Faced with a sustainable intensification, with "*intensive margin*" (marginal cost > mean variable cost), the improvement of productivity with own resources of the system will be possible by friendly practice at minimum cost. In small-scale DP farms, it will be possible to develop a low-cost strategy characterized by the low or null opportunity cost of family labour, poor dimension, and "extensive margin" (marginal cost < mean variable cost) (De-Pablos-Heredero et al., 2018; Garcia-Martinez et al., 2016).

The dual-purpose bovine production system (DP) is the most widespread small-scale model in Latin American tropics, in which meat and milk are simultaneously produced. The DP is a genetic cross among native cows (highly adapted to the extreme tropic climate conditions), and European dairy breeds (good milk producers) (Rangel et al., 2017; Rangel, 2016; Torres et al., 2015).

The importance of dual-purpose cattle for sustainable development and land-use efficiency lies in its flexibility in the use of resources, combining agricultural and livestock activities. The DP system uses extensive grazing, with low inputs, low-cost resources such as by-products and crop residues, in a circular economy system process, with land-sharing orientation (Rangel et al., 2020; Torres et al., 2020)

The land-sharing or wildlife-friendly farming model allows identifying the best technologies and management practices recommended to smallholders (Bastanchury-López, et al., 2020; Boval, Angeon, & Rudel, 2017). In doing so, DP cattle farms contribute to mitigating climate change by reducing greenhouse gas emissions and increasing carbon accumulation (Villarroel-Molina et al., 2021). In addition, DP in developing countries has been widely recognized as a pathway out of poverty, a major income-generating activity, and a means of income diversification (Garcia-Martinez et al., 2016; Torres et al., 2015; Villarroel-Molina et al., 2019).

In this context, many solutions to challenges facing global food production and consumption lie in how livestock sectors are managed (Hatab, Cavinato, & Lagerkvist, 2019; Herrero et al., 2016). However, even though the technology is an important tool to increase a sustainable productivity, and despite the efforts made to introduce new technologies into the production system, DP farmers continue to reject technologies that could potentially benefit their livelihood (Rangel et al., 2017; Rangel et al., 2016; Torres et al., 2015).

The low technology adoption rate has been associated with multiple factors, such as small-dimension, weak financial capacities, lack of technical support, risk aversion, and the misalignment between technological improvements and the farm’s objectives, hence the need to understand the reasons for farmer’s behaviour towards technology and its low adoption rate.

This research group has previously studied dual-purpose livestock systems in the Mexican tropics. Rangel et al. (2020), characterized technologically 1,475 farmers, and identified five dual-purpose farmer groups, with high homogeneity within the group and heterogeneity amongst groups. García-Martínez et al. (2016) highlighted the need to study the low adoption rate of the most vulnerable group. Furthermore, Villarroel-Molina et al. (2021) showed the usefulness of network analysis to identify key innovations in adoption success and failure factors in livestock systems. Villarroel-Molina et al. (2019) used SNA to characterize technological leaders in the genetic area.

This study contributes to ***deepening the knowledge of the low technology adoption rate in DP livestock systems*** *from a novel perspective, as most of the studies in the field have estimated the network's structure based on adoption intentions* (Cano-Reyes et al., 2015; *Zarazúa et al., 2012). As an original approach, this research estimated networks from the technologies already adopted by farmers, identifying DP best practices and technologies.*

Theoretical Background of Social Network Analysis (SNA)

One of the most central concepts in social network analysis and structural hole theory is the notion of position. On one hand, network position studies refer to the advantages acquired by an actor by occupying a brokering position within a network, so structure is used as an indicator of how information is distributed in a group of people. According to Borgatti and Everett (1992), position has played a critical role in the study of the adoption and diffusion of innovation. On the other hand, Reagans et al. (2003) and Crandall et al. (2008) have pointed out that brokers are potential amplifiers for innovation since they are well positioned to synthesize ideas that arise from different groups of knowledge or technological specialization. Likewise, Burt (2015, 2009, 2000) claimed that individuals hold certain positional advantages or disadvantages from how they are embedded in social structures.

The SNA methodology has developed a series of measures that can be included in the processes of agricultural extension to foster innovation. According to Borgatti et al. (1997), Bonacich (1987, 2001), Opsahl et al. (2010), and Freeman (1978), the most popular centrality measures are degree, betweenness, eigenvector, and closeness, but we have also included the measure of constraint. Each of these measures quantifies how close each actor is to the central position in the network, but the concept of being central is defined differently in each case (Sankar, & Kumar, 2015). Degree centrality identifies the most popular farmer who shares the maximum number of technologies with other farmers. Closeness centrality identifies the farmers who have the fastest access to information in the network. The top farmers identified by the betweenness centrality are the mediators, brokers, and gatekeepers of communication who can control and influence the diffusion of technologies and innovation in the network. Eigenvector centrality identifies the most influential and authoritative farmers. Constraint is an index that measures the extent to which an actor’s contacts are redundant, decreasing the probability of obtaining new information.

Therefore, this research is aimed to address the following research question: How does network position affect the technology adoption of dual-purpose farmers in Mexico? We believe that obtaining an advantageous position in the network has a positive impact on farmers’ technology performance, as it increases the sources of information, allows knowledge-sharing, and facilitates the bringing together of complementary skills from different groups of farmers. This statement is based on social capital theory, which has suggested that people who do better (best practices or higher performances) are somehow better connected (Villarroel-Molina et al., 2021). According to the dynamic capabilities approach, technology adoption processes can follow different pathways. Bastanchury-López et al. (2019, 2020), linked this theory with mixed systems performance to understand how best results can be achieved, and found that improvements of dynamic absorption and integration capabilities had a positive impact on performance in dairy sheep farms in Spain. The authors grouped dynamic capabilities into four types: (i) detection capability: the ability to diagnose the environment and understand the needs of the customers better than competitors; (ii) absorption capability: the ability to acknowledge the value of the new, assimilate the information, and apply it to commercial ends; (iii) integration capability: the result of sharing and combining information; and (iv) innovation capability: developing new products and markets through coordination towards a strategic orientation by applying innovative behaviours and processes.

In this context, it is not only the access of agents to information through their network linkages that matters, but their ability to absorb and integrate new technologies. So, the proposals that will be tested are:

- ***Decentralized approach*** (peer-to-peer and bottom-up diffusion): A farmer who acts as a broker between two or more closely connected groups of farmers could gain important comparative advantages, performing better than other farmers do. Brokering position allows obtaining new information from other groups, becoming an early adopter in the community. This is the behaviour found by Villarroel-

Molina et al. (2021) and Zaheer et al. (2005).

- ***Centralized approach*** (top-down diffusion): In the diffusion of a high cost or complex adoption technology, the organizations act as diffusion agents or facilitators, frequently applying them in pilot farms. In this case, the adoption is homogeneous, and the network structure will be different from the previous one. This is the traditional diffusion approach described in dual-purpose by Espejel-García et al. (2014), Espinosa-García et al. (2015), and Zarazúa et al. (2009).

Both strategies occur simultaneously over time, but it must be considered that the brokering position becomes a comparative advantage only when it happens amongst groups of farmers who provide new or diverse information (2021).

Therefore, due to the very low technology adoption rate in DP (Villarroel-Molina et al., 2021; Rangel et al., 2020), it would be of great interest to go in deep in the knowledge of technology adoption and the diffusion process. Thus, the main purpose of this study was to explore how the reproductive technology adoption process happens and how the smallholder's network position affects the level of technological adoption in very small dual-purpose cattle farms in Mexico. To address this issue, we applied social network analysis (SNA) and examined networks amongst farmers and their implications in reproductive technology dissemination. This study provided insights for practitioners, policymakers, and researchers on actionable strategies and the critical success factors of livestock technology transfer programs in Mexico.

Results

Network measures descriptive statistics for the sample of 383 farmers are shown in Table 23. The degree obtained was 1.93 related to the low number of technologies that these farmers have adopted, where 50% of smallholders adopted less than one reproductive technology of the seven technologies evaluated.

The eigenvector was also very low (0.057), indicating a homogeneous behaviour among farmers and little new information from their closest network. The average betweenness was 8.25, being one of the measures with the highest coefficient of variation (179.42%), related to high heterogeneity in the control of information and degree of influence among farmers. Surprisingly, 50% of the farmers showed a betweenness around 0, while the 25% of farmers presented more than 10.72, the maximum value being 86.76. Network redundant information measured by the level of constraint was very low (0.0117), associated with the network structure itself and the low existing technological level.

Table 23. Centrality network measures in dual-purpose farms.

Centrality measures	Mean	Standard Error	Median	SD[1]	CV[2]	Q1	Q3	Min[3]	Max[4]
Degree	1.89	0.070	1	1.369	72.36	1	2	0	7
Closeness	841.19	8.68	817	169.81	20.19	806	817	795	1945
Eigenvector	0.057	0.00097	0.0462	0.019	33.43	0.046	0.065	0.014	0.108
Betweenness	8.08	0.741	0	14.49	179.42	0	10.72	0	86.76
Constraint	0.012	0.0001	0.0109	0.0028	24.20	0.010	0.011	0	0.0497

[1] Standard deviation; [2] Coefficient of variation (%); [3] Minimum; [4] Maximum.

Table 24. Reproductive technologies in dual-purpose cattle farms.

Code	Technologies	Mean	SD 1	CV 2
T32	Breeding soundness evaluation in bulls	96.61	18.13	3.29
T37	Type of mating	29.50	45.67	20.85
T35	Estrus detection	21.41	41.07	16.87
T36	Pregnancy diagnosis	15.40	36.15	13.07
T38	Breeding policy	12.27	32.85	10.79
T33	Semen fertility evaluation	11.49	31.93	10.20
T34	Evaluation of female body condition	2.61	15.97	2.55

[1] Standard deviation, [2] Coefficient of variation.

Social Network Analysis Results

Figure 29 shows the dual-purpose farmer's technological innovation network in the reproductive area. To facilitate network visualization and interpretation, only farmers with an adoption rate higher than 40% are shown. The network structure showed that GGAVATT farmers occupy the central positions that are distributed in defined subgroups with other farmers of the same organization (social homogeneity), so there is no evidence of clear leadership. Besides, the structure of the network also showed that farmers from other organizations are distributed peripherally, associated to different groups of farmers (social heterogeneity). Regarding the Producer's associations and Non-productive organization, the farmers f_522 and f_10 stood out, with a betweenness of 19.16 and 16.64, respectively. Furthermore, farmer f_585, who was not affiliated with any organization, was connected to the network with a betweenness of 17.97, his technological strategy was very similar to that of the farmer f_325, belonging to Cooperative, with a betweenness of 17.97.

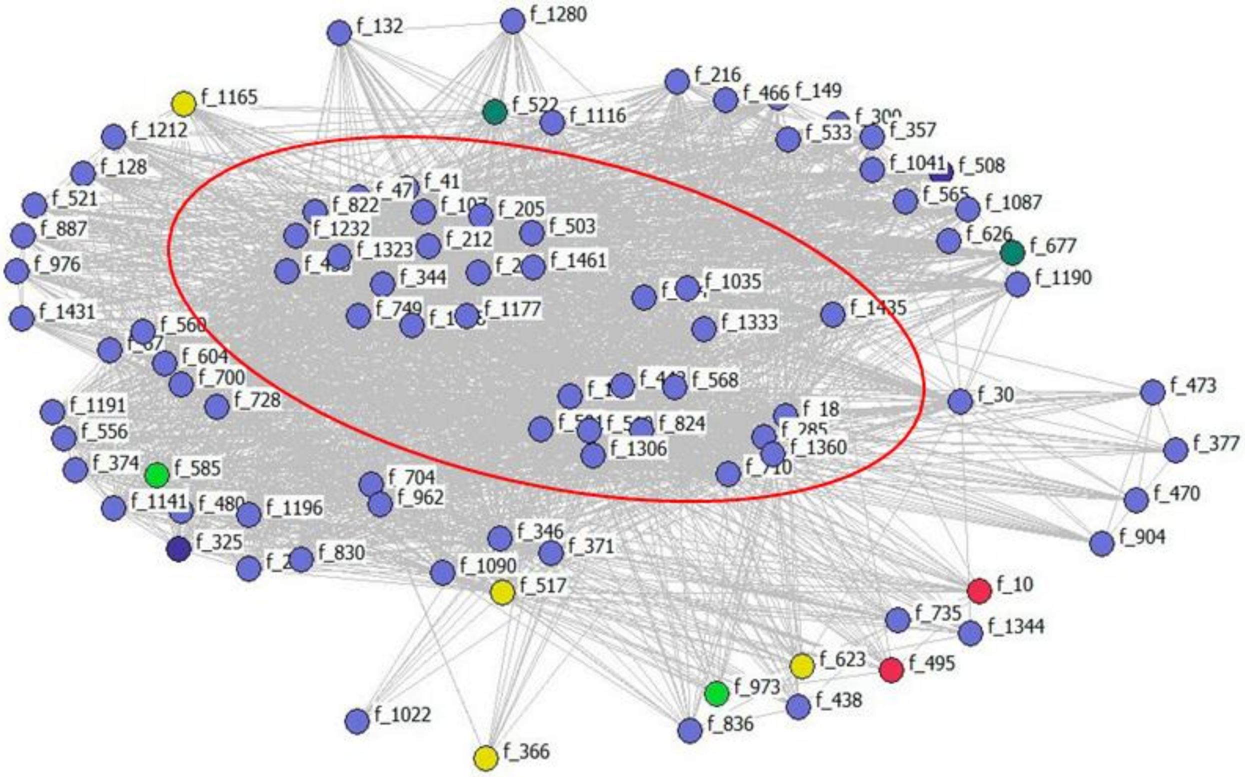

Figure 29. One-mode network visualization of farmers with a technological adoption level greater than 40%. Nodes' colour: organization type. Farmer code (f_ni), organization type: ● GGAVATT, ● SPR, ● Cooperative, ● Producers associations, ● No affiliation,● Non-productive organization.

To facilitate central farmers and technology leader's identification, only farmers with an adoption rate higher than 70% are shown in Figure *30*. In doing so, four leaders with an adoption rate of 100% were identified in the reproductive technological innovation network, all affiliated with the GGAVATT: f_1306, f_824, f_501, and f_510, with the highest betweenness (86.76) and levels of constraints above average (0.0134). The farmers' behavior was analysed based on the established technological capacity-building, compared to other studies that have evaluated farmers' technological preferences based on adoption intentions (Cano-Reyes et al., 2015; Cardenas-Bejarano et al., 2016; Monárrez-Espino & Hoyos, 2010). Besides, f_517 was the only farmer from an organization other than GGAVATT that appears on the network. This farmer was affiliated with SPR, being the leader of this group with an adoption rate of 71.43%, and high betweenness centrality (66.69) much higher than the betweenness of other GGAVATT farmers with lower adoption rates.

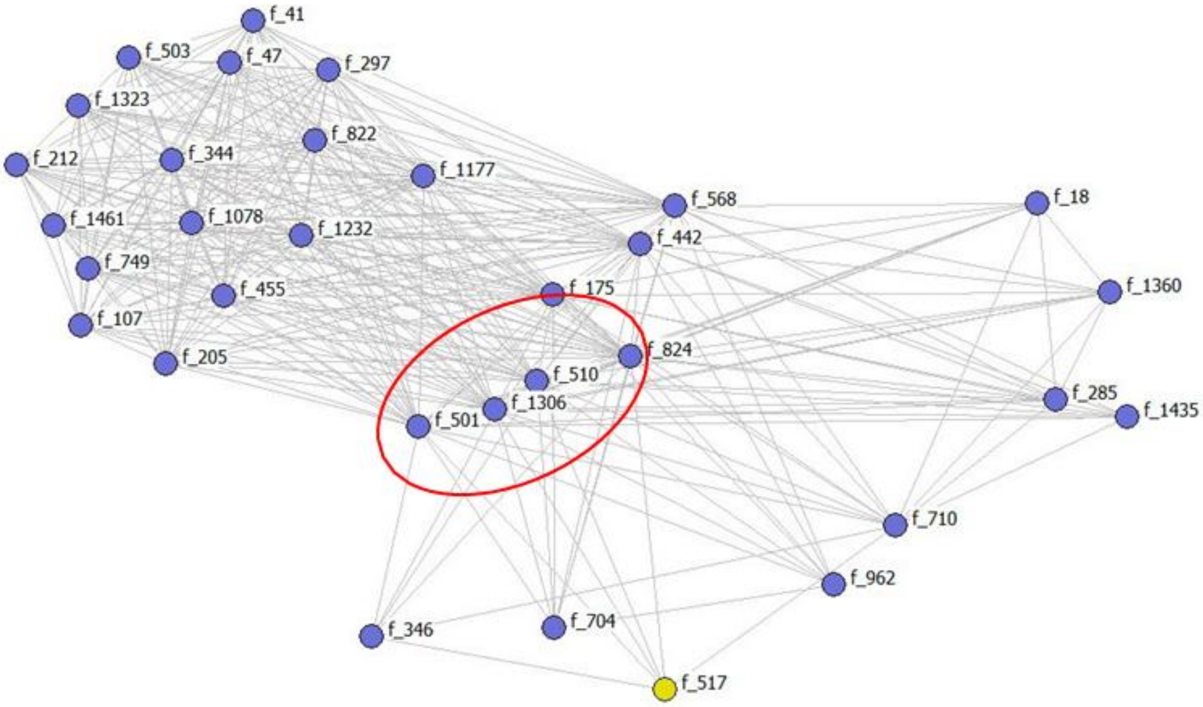

Figure 30. One-mode network visualization of farmers with a technological adoption level greater than 70%. Nodes' colour: organization type. Farmer code (f_ni), organization type: ● GGAVATT, ● SPR, ●Cooperative, ● Producers associations, ● No affiliation,● Non-productive organization.

Figure 31 showed the two-mode network visualization of farmers and technologies. The network structure indicated that breeding soundness evaluation in bulls (T32) is a basic technology within the reproductive technology package, adopted by most dual-purpose farmers. Another visible adoption pattern is the joint adoption of semen fertility evaluation (T33), estrus detection (T35), and pregnancy diagnosis (T36), for which they are considered complementary technologies.

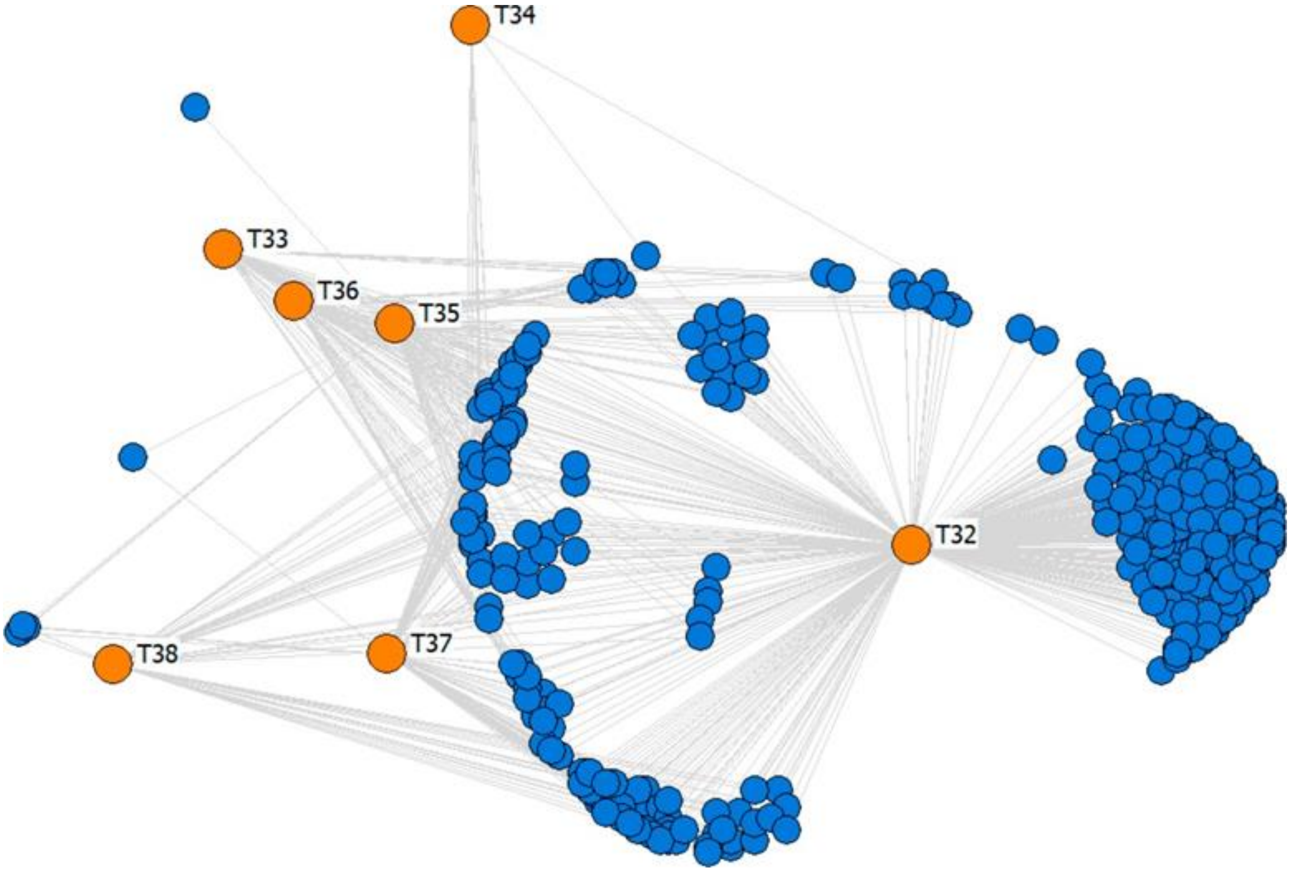

Figure 31. Two-mode network visualization of farmers and technologies. ● Technologies. T32, breeding soundness evaluation in bulls. T33, semen fertility evaluation. T34, evaluation of female body condition. T35, oestrus detection. T36, pregnancy diagnosis. T37, type of mating. T38, breeding policy. ●Farmers.

Benchmarking Analysis

The benchmarking of influencer farmers by organization type is shown in Table 25. The leaders were selected according to technological adoption and centrality measures (degree, betweenness, eigenvector, closeness, and constraint). The analysis showed that farmers f_1306 and f_510 were subsistence farmers with more than 70 years and low productive indices, being the first of them meat production-oriented, and the second one milk production-oriented. Farmers f_824 and f_501 are middle-aged producers located in the wet tropic, over 45 years old, who generate two jobs. The first of them was milk production-oriented (1428.57 L/cow/year), and the second showed a mixed productive strategy towards milk and meat. These farmers were affiliated with GGAVATT and showed a high preference for reproductive technologies with an adoption rate of 100% in this technological area. Finally, farmer f_517 affiliated with the SPR was younger (31 years old), showed an adoption rate of 71.43% and a different strategy, combining the sale of cheese and meat.

Table 25. Farmer's benchmarking by organization type and technological level.

Farmer, Code	f_1306	f_824	f_501	f_510	f_517
Organization type	GGAVATT[1]	GGAVATT[1]	GGAVATT[1]	GGAVATT[1]	SPR[2]
Technological level, %	100	100	100	100	71.43
Structural characterization					
Ecological zone, tropic	Dry	Wet	Wet	Wet	Dry
Productive animals, cows	12	14	14	10	15
Animal unit, heads	22.8	30.8	20.5	19.20	21.9
Stocking rate, UA/ha	1.333	0.993	0.891	0.96	2.701
Grazing surface, ha	17	21	20	20	8
Productive orientation	Meat/ subsistence	Milk	Milk/ meat	Milk subsistence	Meat/ milk
Milk production, L/ha	317.64	952.38	650	605	960
Milk yield, L/year	5400	10	6500	6050	7680
Milk per cow, L/cow/year	450	1428.57	1181.82	1210	512
Calves sold, n◦ calves	5	3	6	4	10
Cheese yield, kg/farm/year	0	0	0	0	1000
Stakeholder's age, years	74	57	46	76	31
Dependent relatives, n◦	1	2	5	3	3
Employees, workers	0	2	2	2	1

[1] Livestock Groups for Technological Validation and Transfer; [2] The Rural Production Society.

Discussion

Dual-purpose cattle farms were very small, limited to subsistence farming where an important part of the production was oriented to self-consumption, with a highly variable productive strategy (cheese yield, milk, and calves) depending on the immediate environment and the opportunity costs. Given the context in this group of farms, the productive orientation will influence the technology adoption process (Bastanchury-López et al., 2020; De-Pablos-Heredero et al., 2018; Rangel et al., 2020). Likewise, affiliation with an organization was considered an important factor in the technology adoption process (Villarroel-Molina et al., 2021), since organizations are places of access to technological innovations and interaction among farmers where communication flows, constituting a determining factor in the technology capabilities of absorption, integration, and adoption.

The centrality measurements obtained were similar to that of Walther et al. (2019), who used SNA to measure the effects of income and gender on informal social networks in the rice value chain, among 490 farmers in Benin, Niger, and Nigeria, and found a degree of 2.5 for women and 3 for men. Our results also agree with the author in eigenvector, both for women (0.03) and for men (0.05). However, regarding betweenness, our results just match the betweenness of 92 found for women, but differ from the 170 found for men. Walter et al. (2019) concluded that the monthly profit of farmers was determined by their structural position within the network and the capacity of building connections with other communities outside their ethnic groups and countries. Apart from this, Aguilar-Gallegos et al. (2016) used the SNA approach to study the effects of direct and indirect interactions among 180 rubber producers and key players in the Mexican state of Oaxaca, and found a very low level of betweenness amongst farmers (0.74). This result coincides with 25% of the farmers evaluated in this research, who showed betweenness close to zero. The author relates this behaviour to the fact that some farmers establish links with extension agents rather than with their peers.

These results were consistent with structural hole theory and network positioning studies, as high levels of constraints are associated with redundancy in contacts who provide little new information. This circumstance leads farmers to maintain their adoption practices, specializing too much in a specific technological area (Valdovinos et al., 2015).

The two-mode network makes a significant contribution to advancing the understanding of the reproductive technology low adoption rate as a strategic tool for development and increasing farms competitiveness and viability (Rivas, et al., 2019; Garcia-Martinez et al., 2016). Based on the adoption patterns identified through SNA, T33, T35, and T36 are complementary technologies. It should be noted that the adoption of one of these technologies will have an impact on the adoption of the other two (Villarroel-Molina et al., 2021).

The network structure obtained provides a real diagnosis of the most vulnerable farmers' technological situation, and points out the wide technological gap amongst reproduction technologies. In this process, farmers need to know about these technologies to start implementing them on farms (knowledge and absorption capabilities) (Bastanchury-López et al., 2020; De-Pablos-Heredero et al., 2020). In this regard, the GGAVATT technicians have made a great effort to enhance the adoption of evaluation in bulls (T32) through technology transfer programs (Ponce-Méndez et al., 2016).

The potential role of SNA to adopt sustainable innovations is high. Applying this pattern of diffusion could improve the adoption of reproductive technologies. The technologies evaluated were compatible with land-sharing practices, i.e., these are low-cost technologies that do not imply greater intensification or contribution of external inputs and do not present negative impacts on the sustainability of the system (De-Pablos-Heredero et al., 2020; Rangel Jaime, 2016). In this research SNA and technology were not focused on system intensification but rather towards the improvement of productivity with own farm resources (Cardenas-Bejarano et al., 2016; Espejel-García et al., 2014; Rivas et al., 2019).

In a second stage the implementation of T34, T37, and T38 should be favoured, which requires a productive structure for their adoption (Rivas, et al., 2019). These findings are aligned with those of Aguirre et al. (2020), who applied SNA to study the adoption patterns of conservation agriculture practices among 222 maize smallholder farmers in the Mexican state of Chiapas, and found that farmers apply practices that solve emerging problems in the short term, but set aside those practices, which in the medium and long term, would lead to higher and stable yields. However, the network structure differs from that found by Villarroel et al. (2021), who evaluated the usefulness of SNA to characterize technology leaders in small dual-purpose cattle farms in Mexico, in the area of genetics, and found a more diverse technological strategy.

The benchmarking analysis showed that farmers affiliated with GGAVATT had competitive advantages in reproduction, such as the access to knowledge (knowledge and absorption capabilities), favouring the technology adoption rate, and a high degree of connectivity with other farmers who belong to the same group (Bastanchury-López et al., 2019).

The results showed a centralized pattern of technology adoption (top-down diffusion), where technological adoption, although very low, was concentrated in GGAVATT farmers, with a diffuse network structure and a differentiated leaders’ network position. However, these findings differ from Villarroel et al. (2021), who found a network structure with well-defined leaders who acted as knowledge disseminators in the organizations and between organizations, identifying decentralized patterns in the diffusion of technology (peer to peer). According to Dhehibi et al. (2020) and Zarazúa et al. (2012), being connected to technological leaders and farmers affiliated with different organizations (diverse social capital) positively affects the technology adoption rate. Besides, Zarazúa et al. (2012) applied SNA to measure social capital amongst corn producers in Mexico and found a strong relationship between the enhancement of technological innovation and the links established by farmers with actors involved in livestock activities. Farmers belonging to the most open network presented better productive outcomes and that intermediaries with greater links defined the sources and types of innovation and activated interaction patterns between several actors of the system. Regarding the theory of dynamic capabilities, Bastanchury et al. (2020) and De-Pablos-Heredero et al. (2020) studied the stages of the technology adoption process in dairy sheep family farms in Spain, and described the first as a phase of technology knowledge and absorption, the second as an integration stage, and the phase of innovation capability as the final stage.

The GGAVATT of a public nature and with the aim of social benefit acts as a knowledge diffuser in the first stage (knowledge and absorption capabilities), with a technology diffusion centralized model (top-down diffusion) and oriented to give technical assistance to the farmers who are affiliated with this organization (Cardenas-Bejarano et al., 2016; Zarazúa et al., 2009). Due to the farmer's lack of these reproductive technologies, their knowledge and absorption are carried out directly and homogeneously from the GGAVATT technicians to the affiliated farmers through participatory workshops and in situ demonstrations (Ponce-Méndez et al., 2016). In the context of innovation dissemination, this is related to the social learning theory, which states that people learn with and from others by example or through observation (Akers & Jennings, 2015). Dhehibi et al. (2020), pointed out that the know-how influenced the adoption level.

In a second stage of growth and specialization, as described by Villarroel et al. (2021) and Aguilar Gallegos et al. (2016), early adopters present a well-defined network structure and are well positioned within the network, standing out as leaders amongst farmers (integration capability). Probably, in a later stage of technological maturity, farmers will start a decentralized diffusion (bottom-down), resulting in innovation processes amongst farmers (***peer to peer***).

According to the literature and the results, the technology adoption process was sequential and cumulative. In the earlier phase, producer organizations were priorities to technology capabilities of knowledge and absorption. In the technology phase of maturity, capabilities of integration and innovation were provided by the producers, in a decentralized process with highly influential leaders. Thus, the presented findings seem to be consistent with previous research on agricultural technology adoption (Rangel et al., 2020; Villarroel-Molina et al., 2021; Villarroel-Molina et al., 2019), which found that farmers' decisions to innovate were based in the context of social interactions among themselves and with agents that promote change.

In summary, SNA can help to understand the actor’s behaviour involved in the networks of innovation diffusion, the way these actors engage in the diffusion, and role they play in the adoption of sustainable practices (Valdovinos et al., 2015; Zarazúa et al., 2012). Technological adoption analysis was carried out regardless of farm size, with a minimum cost strategy (Rangel et al., 2017; Rivas, et al., 2019; Torres et al., 2015).

Due to the low level of technology adoption, the system could be improved by favouring the knowledge and absorption capabilities in the less adopted reproductive technologies (Bastanchury-López et al., 2020; Garcia-Martinez et al., 2016), therefore making it possible to increase productivity while maintaining diversified strategies (milk, meat, and cheese) and land-sharing practices in DP farms.

4.3. How does gender impact technology adoption in dual-purpose cattle in Mexico?

Under review:

Villarroel-Molina, O., De-Pablos-Heredero, C., Barba, C., Rangel, J., & García, A. (2021). How does gender affect technology adoption in dual-purpose cattle in Mexico?. Land

Introduction

The United Nations formulated the Millennium Development Goals (MDGs) for eradication of poverty in 2000. The progress achieved with the MDGs was substantial. By 2015, the world had already met the first goal of cutting global rates of extreme poverty and hunger by half. However, the scope of achievement was uneven. After, The Sustainable Development Goals (SDGs) expanded its scope to 17 goals from the eight (8) goals in the MDGs.

SDG 5 is dedicated specifically to gender issues. Although access to education, elimination of the gender gap and representation in decision-making are women's rights, challenges faced by women are more pronounced in the case of rural women, especially in developing and underdeveloped countries (Chatterjee et al., 2020; Hay & Pearce, 2014). However, gender equality and women's empowerment represent the goals and solutions of many other Sustainable Development Goals, such as Goal two, which seeks to end hunger and achieve food security in developing countries.

Women are central to family food security and nutrition, being responsible for the food preparation and children care (Kassie et al., 2020; Kennedy et al., 2017; Ayoade et al., 2009). Furthermore, the gender perspective recognizes that some issues and constraints related to project success are gender specific, and stem from the fact that men and women play different roles, have different needs, and face different constraints on several different levels.

Mexico is the second most populous country in Latin America, being women 51.5% of the population. This proportion does not mean better personal and professional opportunities for the female gender in the country but quite the opposite, as Mexico faces social and economic inequalities and disadvantages, in addition to high discrimination against women. This is evidenced by 77% of men doing primary, secondary, and tertiary economic activities against 45% of women (Contreras-Medina et al., 2021). Apart from this, the agriculture activity of Mexico supports 58% of the total production value and represents 42% of total income, where the activities developed by women are fundamental not only because they carry out diversified and traditional agricultural practices that maintain and improve crops, but also because they retain ancestral knowledge and traditional uses of the different crops and local varieties (Figure 32).

However, women still do not participate as equal partners in sustainable development practices, often have limited access to resources and are excluded from decision-making processes (Witkowski & Blanco Lobo, 2017).

Figure 32. Ancestral knowledge in the region (craftswoman).

Additional efforts are needed to support the empowerment of women and the search for ways to address existing inequalities. According to Contreras-Medina et al. (2021), historically, the female gender in rural world is invisible and discriminated against daily in all areas with unequal treatment. Due to this, it is essential to promote the inclusion of women and detect their needs, based on their experiences and perspectives for a sustainable technological and systemic change (Contreras-Medina et al., 2021; Witkowski & Blanco Lobo, 2017).

The dual-purpose livestock systems in the Mexican tropics respond to small-scale production, and are key to the food security of the inhabitants of the tropics; both in terms of provision and access to food, stability, and prices (REDGATRO, 2018). Globally, dual-purpose systems generate between 19 and 12% of meat and milk world's production (Barg, 2018; De-Pablos-Heredero et al., 2020) and live on the poverty line, in fragile extensive systems with a high degree of marginalization. In addition, these subsistence farms showed a low level of technological innovation, which makes it difficult to access external inputs and are highly vulnerable to environmental disasters and economic turmoil (Hooft et al., 2012).

Therefore, a new approach is required to help improve this problem, as the full participation of women, but this will not happen until women are perceived as the subjects of development (Walther et al., 2019). In view of the above, there is a need to analyse the involvement of women in dual-purpose livestock production in Mexico.

Historically, the low technology adoption rate has been one of the main problems of small-scale livestock systems in Latin America, which negatively influences their productivity and threatens the food security of many families whose livelihood depends on livestock farming (De-Pablos-Heredero et al., 2020; Rangel et al., 2020).

The lack of technological innovation is due to multiple factors, such as low dimension, poor financial capability, lack of support to technological adoption, poor structures, risk aversion, misalignment between technological improvements and farm's objectives, amongst others (Ryschawy et al., 2012; Zarazúa et al., 2012; Dubeuf, 2011).

Figure 33. Woman withdrawing the remaining whey from the curd and curdling of milk

Several methodologies have been used to assess the technological level; Garcia-Martinez et al. (2016) and De-Pablos-Heredero et al. (2020) assessed the impact of technological innovation on performance in dairy sheep farms in Spain; Rangel et al. (2020) developed a technological characterization in dual purpose livestock in Mexico; Cortes-Arriola et al. (2015) and Cuevas-Reyes et al (2013) quantified the relation among size and technology adoption level, and Rada et al. (2019) and Foster and Rosenzweigh (2022) found an inverse relationship between farm's size and land productivity.

Besides, a growing literature applying social network analysis (SNA) to several fields of agricultural science and technological dissemination in agrolivestock systems has emerged (Aguilar-Gallegos et al., 2016; Avendaño-Ruiz et al., 2017; Cardenas-Bejarano et al., 2016; Diez, 2008; Espejel-García et al., 2014; Gómez-Carreto et al., 2015; Hartwich & Scheidegger, 2010; Nuñez-Espinoza et al., 2014; Rodríguez-Modroño, 2012; Roldán-Suárez et al., 2018; Stojcheska et al., 2016; Vishnu et al., 2019), which has added a new dimension in understanding the role of social networks.

Today, most studies using SNA have sought to understand naturally occurring network processes, and less attention has been paid on how social network characteristics and use of SNA can be used to inform different adoption patterns according to gender, ethnic group, and objectives, etc.

Currently, technological adoption is analysed by a holistic point of view, linking closely social factors as producers' characterization, their setting, and the type of relation between themselves (Díaz-José et al., 2013; Espejel-García et al., 2014). In addition, within social networks, factors such as technological learning, learning by doing and learning by imitation are of great importance, as well as adoption by observation among producer's neighbour to reach an accumulated experience in a delayed manner (Borgatti & Molina, 2003). However, low adoption rates are associated with the intrinsic uncertainty of innovation (Deroian, 2002).

In this sense technical advisors and local leaders play an important role in technological adoption and innovation diffusion since SNA identify diffusion patterns and units of analysis are frequently connected into an intensive network (Borgatti & Li, 2009; Dawson et al., 2011; Espejel-García et al., 2014; Kempe et al., 2017; Medel et al., 2007; Opsahl et al., 2010; Warner et al., 2012; Wasserman & Faust, 2013).

The improvement of technology adoption requires the deepest knowledge of how innovation spreads and what the relationships and links amongst stakeholders to transfer innovation are (Wasserman & Faust, 2013). Besides, SNA use in smallholders facilitates the understanding of the rural processes of innovation (Hartwich & Scheidegger, 2010).

In this context, understanding gender roles is important to identify effective support for local development since men and women have different approaches to technological adoption in small scale farms in developing countries, due to work division and cultural and social factors (Contreras-Medina et al., 2021; Walther et al., 2019). Furthermore, given the key role of women in agriculture, their inclusion and empowerment are a fundamental requirement to achieve the well-being of rural communities (Figure 34).

Gender analysis is a methodology that seeks to understand the distinct culturally and socially defined roles and tasks that women and men assume both within the family, household system and in the community.

Figure 34. DP farmer woman (calf rearing passed down through generations).

Therefore, an effective response requires knowing the skills and knowledge of women in livestock systems to identify solutions and improve the problem of low technology adoption in dual-purpose cattle system. On the one hand, the gender perspective adoption as a key element in agricultural development processes has been slow, so concrete actions are still necessary to achieve tangible results. In addition, the role of women in rural areas of developing countries is not very visible, although it is key in the administration of generally complex households.

The recognition of women's work is the first step to face exclusion, although there is no clear perception of the role they play in rural areas. On the other hand, the predominant production system in rural Mexico is mainly the family subsistence system, where the separation between agricultural activity and the family sphere is practically non-existent (Figure 35). Consequently, women's work in the different fields is less visible than in other environments where the tasks are clearly delimited (Torres et al., 2016).

Figure 35. Woman packing cheese and draining whey off the curds.

Since women are generally underrepresented in livestock studies, integrating the gender perspective into our technology adoption analysis contributes to understanding the main differences between men and women and how these influence in technology adoption decisions.

Our gendered analysis considers the diversity of social relationships that link farmers and measures the degree to which the structure of these relationships facilitates or limits technology adoption and productivity.

This paper aims to deepen the knowledge of the technological adoption process within the context of rural women, in developing countries and dual-purpose cattle farms in Mexico to understand how gender impacts innovation processes.

Figure 36. New generations of DP women farmers.

The paper draws on in depth empirical research about women using technology in rural settings to explore how gender affects technology adoption.

The sequences of this research were: 1. Identify differences in technology adoption patterns between men and women. 2. To build a characterization of the technological and socio-economic indicators in the farms of Dual-purpose cattle in Mexico by gender.

Results

Differences in centrality measures between men and women

The five technological areas showed similar values between men and women, in addition no significant differences were found due to the gender factor ($p>0.05$) (Table 26). Mean values and coefficients of variation were closer between both groups. Just reproductive area showed different variation coefficient values, 29.41% in men compared to 19.75% in women, although no significant differences were obtained.

Table 26. Descriptive statistics for technological packages (Mean ± SE (CV, %)).

Technological packages	Men	Women	p-Value[1]
Management	59.19 ± 6.61 (15.63)	60.66 ± 6.21 (15.74)	1.000 ns
Feeding	28.15 ± 6.32 (15.29)	25.84 ± 6.25 (14.51)	0.854 ns
Genetics	57.84 ± 6.52 (15.36)	57.84 ± 6.33 (14.86)	0.965 ns
Reproduction	29.41 ± 4.94 (11.82)	19.75 ± 4.32 (6.71)	0.109 ns
Animal Health	74.79 ± 5.18 (10.39)	70.17 ± 5.00 (9.31)	0.654 ns

ns = not significantly different between men and women.

In Table 27 the centrality measurement was shown (Degree, Betweenness, Close-ness, Eigenvector and Bonacich Power). Centrality measures were calculated for five technological areas in the dual-purpose system in Mexico: feeding, reproduction, health, genetics, and management. A comparison of samples was performed using one-way anova to identify whether there were statistically significant differences between men and women in these areas, and centrality measures descriptive statistics were calculated.

The results showed that there were significant differences in the reproduction area for the values of degree, closeness, eigenvector, betweenness and Bonacich power ($p < 0.05$). Therefore, the rest of the SNA analysis was addressed in the reproduction area.

The centrality measures descriptive statistics for the group of men showed that, within the reproduction technological innovation network, the dual-purpose farmers had an average degree of 1.94, related to the number of technologies that these farmers have adopted. In the case of women, the average degree was 1.38. Regarding the average betweenness, related to the ability to interfere with communication or information flowing through the network, it was 8.42 for men, with a variation coefficient of 176.18%, while it was 4.59 for women, with a variation coefficient of 223.14%.

Closeness was the measure with the lowest coefficient of variation in reproduction (20.21), with an average of 837.34 in the men's network, and 880.71, in the women's network. This measure refers to how close or far a farmer is from all the other farmers in the network. Eigenvector quantifies the farmer's level of influence in the network through the power and influence of their closest contacts. Therefore, farmers who present a high value on this measure are connected to many actors who are also relevant. On the contrary, farmers connected to other less relevant actors will have a low eigenvector centrality. The results for this measure were low for both men and women, at 0.03 in both cases.

Table 27. Centrality measures descriptive statistics for technological packages (Mean ± SE (CV, %)).

Technological package		All	Men	Women	p-Value[1]
Feeding	Degree	3.83 ± 2.26 (58.85)	3.85 ± 2.27 (58.91)	3.62 ± 2.11 (58.55)	0.545 ns
	Betweenness	36.02 ± 43.68 (121.25)	36.28 ± 44.46 (122.53)	33.36 ± 35.14 (121.25)	0.779 ns
	Closeness	1,016 ± 247.25 (24.34)	1,017.79 ± 251.29 (24.69)	997.56 ± 203.37 (20.39)	0.977 ns
	Eigenvector	0.032 ± 0.02 (51.10)	0.032 ± 0.02 (51.11)	0.032 ± 0.02 (51.75)	0.783 ns
	Bonacich Power	2,632.59 ± 1,345.39 (51.11)	2,638.52 ± 1,348.53 (51.11)	2,571.78 ± 1,330.99 (51.75)	0.781 ns
Reproduction	Degree	1.89 ± 1.37 (72.46)	1.94 ± 1.39 (71.79)	1.38 ± 0.99 (71.27)	0.010 *
	Betweenness	8.08 ± 14.51 (179.65)	8.42 ± 14.83 (176.18)	4.59 ± 10.25 (223.14)	0.029 *
	Closeness	841.19 ± 170.03 (20,21)	837.34 ± 156.99 (18.75)	**880.71 ± 270.13 (30.67)**	0.015 *
	Eigenvector	0.029 ± 0.01 (33.47)	0.03 ± 0.01 (33.02)	0.02 ± 0.07 (35.42)	0.012*
	Bonacich Power	2,150.03 ± 718.91 (33.44)	2,179.66 ± 718.98 (32.99)	1,845.91 ± 653.24 (35.39)	0.004**
Health	Degree	5.08 ± 1.12 (22.07)	5.09 ± 1.127 (22.12)	4.91 ± 1.06 (21.48)	0.368 ns
	Eigenvector	0.036 ± 0.01 (16.98)	0.036 ± 0.01 (16.93)	0.035 ± 0.01 (17.77)	0.475 ns
	Closeness	793.65 ± 102.79 (12.95)	794.11 ± 107.35 (13.52)	789 ± 27.47 (3.48)	0.405 ns
	Betweenness	2.12 ± 2.15 (101.52)	2.17 ± 2.18 (100.57)	1.59 ± 1.745 (109.24)	0.248 ns
	Bonacich Power	4,520.40 ± 767.63 (16.98)	4,524.66 ± 765.91 (16.93)	4,476.74 ± 795.49 (17.77)	0.459 ns
Genetics	Degree	5.33 ± 1.32 (24.87)	5.34 ± 1.34 (25.01)	5.21 ± 1.23 (23.54)	0.437 ns
	Betweenness	3.89 ± 3.00 (76.98)	3.93 ± 3.02 (76.88)	3.58 ± 2.81 (78.45)	0.297 ns
	Closeness	805.28 ± 954.13 (14.70)	806.46 ± 123.98 (15.37)	793.12 ± 4.09 (0.52)	0.485 ns
	Eigenvector	0.03 ± 0.01 (22.38)	0.04 ± 0.01 (22.85)	0.04 ± 0.01 (17.14)	0.481 ns
	Bonacich Power	4,264.14 ± 954.12 (22.38)	4,263.86 ± 973.94 (22.84)	4,267.01 ± 731.42 (17.14)	0.475 ns
Management	Degree	4.85 ± 1.37 (28.20)	4.85 ± 1.37 (28.19)	4.85 ± 1.40 (28.76)	0.834 ns
	Betweenness	4.51 ± 6.68 (148.55)	4.61 ± 6.97 (151.26)	3.49 ± 1.95 (55.91)	0.799 ns
	Closeness	801.73 ± 103.72 (12.94)	802.45 ± 108.41 (13.51)	794.41 ± 23.39 (2.95)	0.851 ns
	Eigenvector	0.04 ± 0.01 (25.36)	0.04 ± 0.01 (25.39)	0.04 ± 0.01 (25.47)	0.697 ns
	Bonacich Power	4,067.59 ± 1031.55 (25.36)	4,065.43 ± 1,032.04 (25.39)	4,089.74 ± 1,041.72 (25.47)	0.673 ns

[1] * $p < 0.05$; ** $p < 0.01$; ns = not significantly different between men and women.

Finally, the Bonacich Power was calculated. This measure refers to the power that an actor gives to be the one who connects his unpopular contacts since they depend on him. The results showed that the Bonacich Power for men was 2,179.66, while for women, it was lower (1,845.91).

According to the significant differences found in centrality measures for the reproductive area, we deepened the SNA in this area. Reproductive technologies were identified by Rangel et al. (2020) and García et al. (2016) in very small dual-purpose bovine farms from the Mexican tropics (Table 1).

This area was composed of the following seven technologies oriented to improve reproductive efficiency parameters: Breeding soundness evaluation in bulls (T32), semen fertility evaluation (T33), evaluation of female body condition (T34), oestrus detection (T35), pregnancy diagnosis (T36), type of mating (seasonal o continuous) (T37), and breeding policy (T38).

Technology adoption network pattern of dual-purpose farmers in the reproduction area.

Figure *37* shows the dual-purpose farmer's technological network in the reproduction area. The network consisted of 383 farmers, of which 91.12% were men and only 8.89% were women. To facilitate network visualization and interpretation, only farmers with an adoption rate higher than 57% in reproductive area were selected (Villarroel-Molina et al., 2021).

In the network, male farmers have been coloured green, while women have been coloured yellow. The network structure makes it possible to visualize how male and female farmers are interrelated. The network structure makes it evident the existence of a core group, composed of farmers f_1306, f_1501, f_824, f_510, f_442, f_175 and f_568.

The men-farmers located in the central part of the image reach the highest values of centrality, e.g., betweenness, acting as brokers, intermediating the communication that flows through the network (blue ellipse). This group was called leaders or pioneers in technological innovation.

In opposite, the men-farmers located on the left side of the network present lower centrality values although they show great cohesion and homogeneity among them in reproductive technology area (red ellipse). This group is called technological followers.

Regarding the role of women, the results showed that no women occupy central positions in the network and that only the farmer f_503 is highly integrated, close to other central farmers. The woman that appears in the image occupies an intermediate position between the technological leaders and followers, with higher centrality values (eigenvector) than the farmer on the left of the network. This woman reaches a strategic position, with closer connections to the technological leaders and differentiated from the rest of the technological follower (violet ellipse).

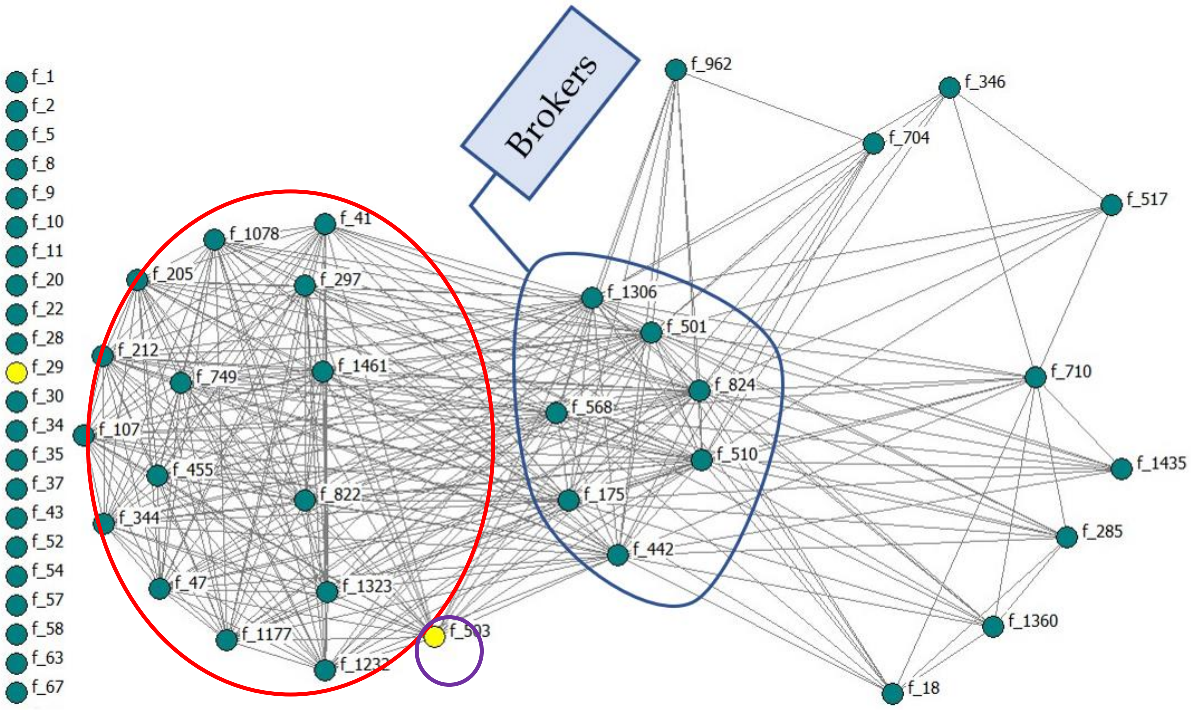

Figure 37. One-mode network visualization of farmers. (Farmers with an adoption higher than 57%). Farmer code (f_ni). Nodes' colour by gender: ○ Women, ● Men.

The technology structure of the men's adoption network is shown in Figure 38. In this case, the position of each technology is determined by its adoption frequency and by the farmer's centrality who has adopted it.

The results showed that farmers have a strong preference for breeding soundness evaluation in bulls (T32), with an adoption rate of 96.85% (Table 28). This technology was considered basic. In addition, they tend to jointly adopt semen fertility evaluation (T33), evaluation of female (T34) and pregnancy diagnosis (T36). Therefore, these technologies were complementary in adoption pattern of the men. On the contrary, T35, T37 T38 technologies were far removed from the core technologies and located in different places of the network. These three technologies were considered substitutes and competitive with each other. With a higher degree of complexity and consequently a lower adoption rate.

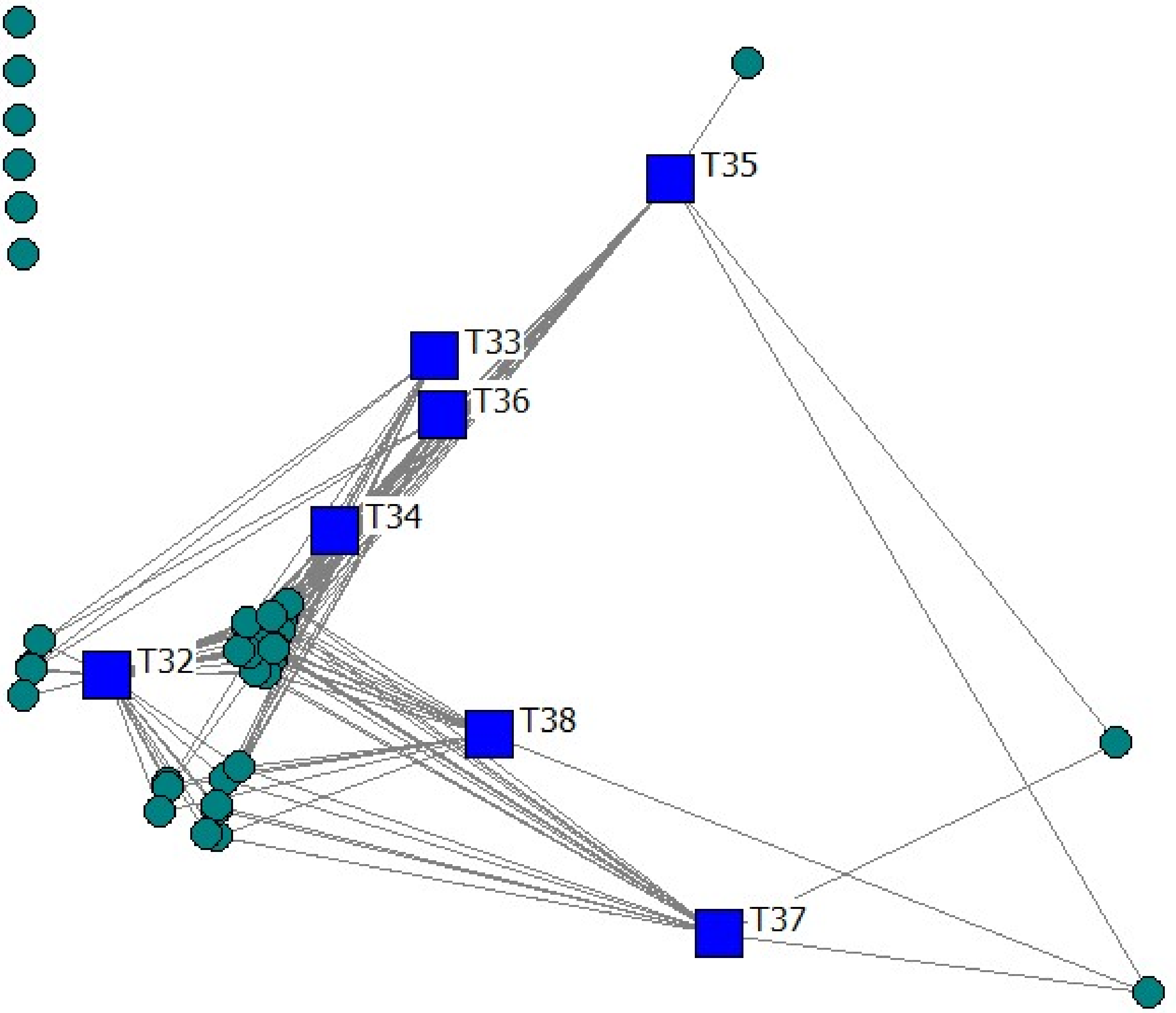

Figure 38. Two-mode network visualization of farmers and technologies. ■Technologies, Farmer: ● Men.

Figure 39 shows the technology structure of women adoption network. In this case, the structure is diffuse. Women showed a strong preference for breeding soundness evaluation in bulls (T32), with an adoption rate of 94.12%. In addition, they often jointly adopt the semen fertility evaluation (T33), pregnancy diagnosis (T36) and type of mating (T37) (Complementary technologies).

However, women showed less preference for the evaluation of female body condition (T34), oestrus detection (T35) and breeding policy (T38) with a lower rate of adoption, and substitutes for each other.

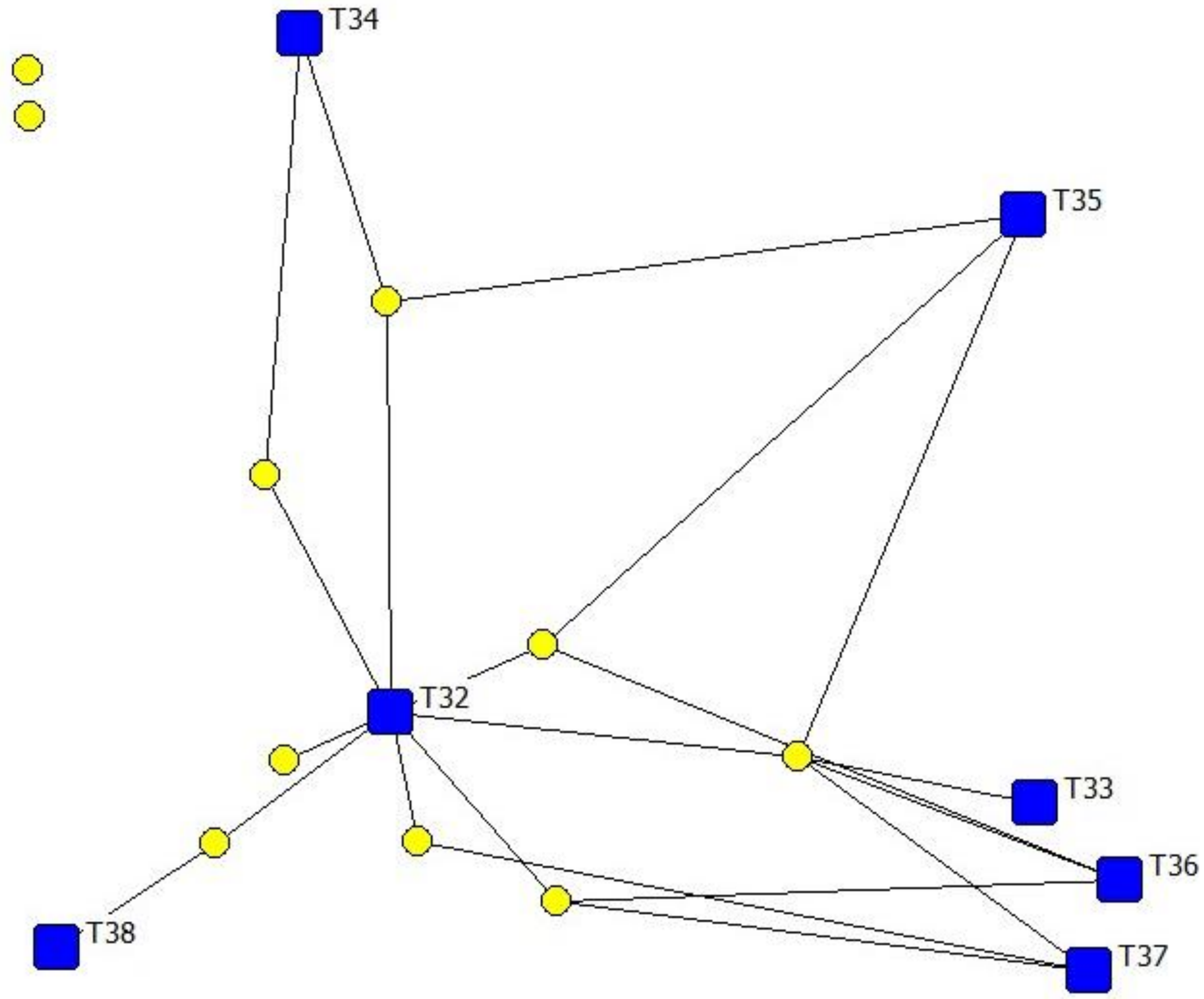

Figure 39. Two-mode network visualization of farmers and technologies. (Men). ■Technologies, Farmer: ○Women.

Figure 39 shows the technology structure of women adoption network. In this case, the structure was fuzzy. Women showed a strong preference for breeding soundness evaluation in bulls (T32), with an adoption rate of 94.12% (basic technology). In addition, they often jointly adopt the semen fertility evaluation (T33), pregnancy diagnosis (T36) and type of mating (T37) (complementary technologies). However, women showed less preference for the evaluation of female body condition (T34), oestrus detection (T35) and breeding policy (T38) with a lower rate of adoption and far from each other in the network.

The comparison of reproductive technologies ratio between men and women is shown in table 29. Significant differences in oestrus detection (T35) and the type of mating (T37) have been found ($p<0.05$).

Table 28. Technological adoption rate of men and women in reproductive area.

Code	Technology	Men	Women	p-Value[1]
T32	Breeding soundness evaluation in bulls	96,85%	94,12%	0.403 ns
T33	Semen fertility evaluation	12,32%	2,94%	0.102 ns
T34	Evaluation of female body condition	2,29%	5,88%	0.211 ns
T35	Estrus detection	22,64%	8,82%	0.051 *
T36	Pregnancy diagnosis	15,76%	11,76%	0.539 ns
T37	Type of mating	31,23%	11,76%	0.017 *
T38	Breeding policy	13,18%	2,94%	0.083 ns
	Tasa de adopción en el área de reproducción	27,75%	**19,75%**	

[1]* $p < 0.05$; ns = not significantly different between men and women. [2]UW: Unit of work.

Characterization of small farms according to gender

The descriptive statistics for social, technical, and productive items of small dual-purpose farms in Mexico are shown in Table 30. The average age of the men was 51 years old, who generated one job on average, with a technical assistance rate of over two years. The women turned out to be a little younger, with an average of 47 years, almost two jobs created and less technical assistance than the men (1.62 years). Statistically significant differences were found in the number of economic dependents ($p < 0.05$).

Regarding the educational level, only 2% of farmers had a medium level of education, most had basic education (76.2%), and 21.8% had no studies. In the case of women, the majority had only basic education (61.8%), while 38.2% had no studies.

Regarding to productive performance variables of dual-purpose cattle farmers in Mexico, the results showed statistically significant differences in the values of milk production per ha, milk production per cow, and grazing surface per ha ($p < 0.05$).

By conducting a comparative analysis of men and women productive performance, the results showed that although women represent 8.89% of the population studied and had a lower average adoption rate than men, they were more productive in these variables. Women's milk production was 121.37 l/ha, while men showed an average milk production of 106.48 l/ha, which means that men produce almost 15L/ha less than women on average. Furthermore, considering milk production, women showed better outcomes, reaching 11,781 l/year, while the annual production of men was 11,217 l/year.

Table 29. Technical and structural indicators by gender (Mean ± SE (CV, %)).

	Men	**Women**	p-Value[1]
Age (years)	51.48 ± 14.26 (27.70)	47.47 ± 16.61 (35)	0.186 ns
Economic Dependents (n)	**1.80 ± 1.79 (59.05)**	**1.74 ± 1.58 (91.18)**	0.000 ***
Employments (UW)[2]	1.46 ± 1.11 (75.49)	1.79 ± 1.12 (62.55)	0.143 ns
Technical assistance (years)	2.25 ± 2.04 (90.69)	1.62 ± 1.33 (81.98)	0.129 ns
Milk production l/ha	**106.48 ± 192.27 (180.57)**	**121.37 ± 117.43 (96.76)**	0.007 **
Milk yield, l/year	11,217.13 ± 6,815.17 (60.76)	11,781.65 ± 6,804.18 (57.75)	0.529 ns
Milk per cow, l/cow/year	**971.26 ± 580.04 (59.72)**	**1,172.30 ± 676.64 (57.72)**	0.049 *
Calves sold, nº calves	4.88 ± 5.79 (118.67)	5.12 ± 6.05 (118.24)	0.756 ns
Unproductive animals, heads	2.6 ± 4.63 (178.04)	1.82 ± 3.19 (175.55)	0.238 ns
Cheese yield, kg/farm/year	245.72 ± 735.55 (299.35)	240.32 ± 725.26 (301.79)	0.436 ns
Total production cows	11.92 ± 2.81 (23.58)	10.97 ± 3.39 (30.89)	0.940 ns
Animal units, heads	19.41 ± 4.18 (21.53)	18.33 ± 3.71 (20.27)	0.275 ns
Herd size, nº cattle	25.8 ± 6.61 (25.64)	24 ± 5.67 (23.62)	0.231 ns
Stocking rate, UA/ ha	1.08 ± 0.62 (57.57)	1.19 ± 0.64 (64.11)	0.609 ns
Grazing Surface, ha	**28.09 ± 40.29 (143.43)**	**19.29 ± 19.30 (100.02)**	0.037 *

[1] * p < 0.05; ** p < 0.01; *** p < 0.001; ns = not significantly different between men and women. [2] UW: Unit of work.

Discussion

Women also showed better milk production outcomes per cow, with annual milk production of 1,172 l/cow, while men had an annual production of 971 l/cow, which means 201 l/cow less than women. These results may be influenced by the fact that men had almost three unproductive animals on average while women had two. The men's average grazing surface was 28.09 ha, with a high coefficient of variation (143.43%), while women showed a lower average grazing surface than men (19.29 ha).

Interest in conceptualizing, measuring, and applying social network analysis (SNA) in gender differences in the rural world has grown tremendously in recent years (Chatterjee et al., 2020; Walther et al., 2019; Torres et al., 2016; Hay & Pearce, 2014; Ayoade et al., 2009; Cecelski, 2000). While these studies have broadened our understanding of the role that social networks play in technology adoption in small scale farms, there has been less studies that have investigated the application of SNA to deepen how does gender affect technology adoption in smallholders.

The development of gender studies in dual-purpose livestock in Mexico is novel and offers a different perspective to understand technology adoption. This study was adjusted to objective 5 of the Sustainable Development goals of the United Nations. Likewise, the application of social networks methodology is innovative and appropriate in this field of knowledge. The dual-purpose cattle system is the majority in Mexico and other Latin American countries, widespread in poor populations, with indigenous people, low levels of education and where the role of women is invisible and not sufficiently valued (Villarroel-Molina et al., 2021; Rangel et al., 2020; Torres et al., 2016).

According to Bullock et al. (2019) and Contreras-Medina et al. (2021) the gender perspective recognizes that some issues and constraints related to technological adoption success are gender specific, and stem from the fact that both are different, have different needs, and face different constraints on several different levels. In this research, social networks analysis allowed to identify the technology adoption network structure by gender of Mexican dual-purpose farmers, contributing to understand the distinct roles and tasks that women and men assume both within the family and household system and in link with the community.

Regarding men and women position into the reproductive technology adoption network and their centrality measures, we have found that most technological brokers (leaders) are men. Likewise, male followers respond to a homogeneous and compact model with similar values of centrality among themselves. The women showed an intermediate position, closer to the brokers and far away from the group of male followers.

The results of this work were in line with those of Walther et al. (2019), who studied to what extent gender is a strong predictor of social ties in the chain value of rice from farmers in Benin, Niger, and Nigeria, and found that women occupy structurally unfavourable positions relative to men. The author argued that these gender disparities are particularly evident when actors are represented in terms of their capacity to play intermediary (broker) roles. Most of the brokers situated at the core of the network are men, and women rarely occupy structurally equivalent roles. However, the results of this work differ from those of Walther et al. (2019) in the productive outcomes since dual-purpose women, although do not occupy central positions in the network, they were well connected.

Therefore, this allows them to access valuable information and be capable of better integrating it into the production process, achieving greater productivity. On the contrary, Walther et al. (2019) found that farmers' results were determined by their structural position within the rice value chain and, that the most prosperous actors were deeply embedded in their community through numerous links, being able to establish connections with other communities outside their ethnic groups and countries.

SNA also made it possible to identify men's and women's preferences, adoption patterns and technological strategies. In the scope of the seven reproductive technologies evaluated, results showed that both men and women had a strong preference for breeding soundness evaluation in bulls (T32), with an adoption rate of 96.85%, although they differ in their adoption pattern both in complementary and substitutive technologies. As a result, we found that men tend to jointly adopt semen fertility evaluation (T33) and pregnancy diagnosis (T36).

Therefore, these technologies are considered complementary technologies. On the one hand, evaluation of female body condition (T34) was the technology for which men showed the least preference, with an adoption rate of 2.29%. On the other hand, women tend to jointly adopt semen fertility evaluation (T33), pregnancy diagnosis (T36) and type of mating (T37). However, women showed less preference for evaluation of female body condition (T34), and breeding policy (T38), with an adoption rate of 2.94% each. According to results found by Bullock et al. (2019), women showed different patterns to exercise agency in economic and agricultural decision-making in Kenya.

We have described patterns in gender relations and how innovation-specific decision-making may create spaces for women. Our key findings highlight how innovation processes often replicate gender patterns through decision-making in productive assets, however access to agricultural knowledge, offers avenues for women to expand their opportunity spaces by expanding social networks and their ability to negotiate for resources in the household.

Besides, when conducting a comparative analysis of men and women productive performance, the results showed that although women were 8.89% of the population studied, they showed higher levels in terms of milk productivity, 20% of the differences in production per cow were explained by gender (971.26 l/cow in man, face to 1,172.30 l/cow in women). Moreover, family structures were smaller in farms with women compared to men (1.74 vs 1.80 economic dependents per farm), finally women's farms showed smaller size of farm. Women's farms, being smaller, showed greater dairy specialization, with milk production being the core of the activity.

In the discussion, only differences by gender have been considered, however within the group of men the results were different among brokers and follower men, i.e., f_175 is a broker with 2,461 l/cow/year and 13 ha of grazing surface, in opposite f_710 is follower with a production of 520 l/cow/year and 52 ha of grazing surface. In summary, although women were not the technological leaders, they quickly adopted technologies and surpassed the average results obtained by men.

Despite the importance of gender differences in the process of innovation found, little is known about how men and women differ in technology adoption or farm management (risk aversion). Women tend to have greater tolerance for risk-taking than men in terms of willingness to try new or unusual products and enjoyment from the stimulation of newness.

Women are more willing than men to adopt a new innovation earlier than other farmers (Cho & Workman, 2014; Chen, 2001). Several researchers found that women (compared with men) are more opened to uncertain and unstructured contexts. In opposite Maio & Esses (2001), Washburn et al. (2005), Maxfield et al. (2010), found that men and women did not differ in tendency for risk taking.

These results are in line with those of the project “Climate-smart livestock pro-duction and soil restoration in Uruguayan grasslands”, carried out by the Ministry of Livestock, Agriculture and Fisheries and Environment of Uruguay, where it was found that a livestock system with female participation in decision-making has a greater tendency to innovate and incorporate changes in the production system. The results also showed that there is a tendency for businesses run by women to have slightly higher productivity than the rest, with the higher educational level of women being one of the most differentiating characteristics between men and women (Ayoade et al., 2009).

The results of this work also differ from those found by Torres et al. (2016), who studied the dual-purpose cattle system in Ecuador and found that women barely assume responsibilities in the production unit, being their work perceived as relevant only in the domestic sphere.

This work favours a higher visibility of women's activity and allows gender to be considered as a relevant factor in the results of the dual-purpose livestock system. Women and socio-economic perspectives such as indigenous knowledge and people's participation, in general have been largely ignored in energy planning and policy until recently (Cecelski, 2000).

According to Hay et al. (2014), Rubio-Bañón et al. (2016) and Contreras-Medina et al. (2021), more research needs to be undertaken on how to incorporate differences in cultural organizations, traditional knowledge, and practices into the perspective of community empowerment.

DISCUSION GLOBAL

5. DISCUSIÓN GLOBAL

El sistema ganadero de doble propósito (DP) ha sido ampliamente descrito en América Latina tropical por Argel (2006), García-Martínez et al. (2015). Rangel et al. (2017), Rangel-Quintos et al. (2016), Torres et al. (2016) y Valdovinos Terán et al. (2015) consideran el doble propósito como una variante del sistema minifundista mixto entre agricultura y ganadería con una parte de pastoreo de pastos nativos en tierras comunales, dentro de una ganadería multifuncional (leche y carne). Las granjas de PD son ***fincas de subsistencia orientadas al autoconsumo***, con muy baja tasa de adopción de tecnología y, es el modelo de pequeña escala más difundido en los trópicos latinoamericanos, donde constituye una herramienta clave en términos de seguridad alimentaria (García-Martínez et al., 2015).

Además, los ***sistemas de producción de pequeña escala*** mejoran la sostenibilidad ambiental y contribuyen a mitigar el efecto invernadero debido al desarrollo tecnológico y la facilidad de adaptación de los sistemas (Herrero et al., 2016). Sin embargo, los agricultores de DP carecen de conocimientos especializados, donde se desconoce el efecto de las redes sociales como factor clave en la difusión de la innovación tecnológica y la difusión del conocimiento. Por lo tanto, el principal desafío es cómo mejorar el nivel tecnológico sin comprometer la sostenibilidad del sistema mediante la aplicación de prácticas de uso compartido de la tierra y el uso de redes sociales para mejorar esta brecha de conocimiento.

Por tanto, el objetivo general de esta investigación fue evaluar el ***efecto de las redes sociales en el comportamiento de los agricultores de Doble Propósito*** hacia la adopción de tecnología en el trópico mexicano, considerando características técnicas, productivas y sociales. Para alcanzar este objetivo general, se han planteado y abordado objetivos específicos a lo largo de los tres capítulos de esta tesis doctoral, tal y como se muestra a continuación:

El **Capítulo I** tuvo como objetivo identificar a los ganaderos centrales en la red de innovación y realizar un análisis de benchmarking para evaluar qué características tenían estos líderes, y así ***profundizar en el conocimiento de las causas de rechazo durante los procesos de adopción de tecnología*** del ganado de doble propósito en México.

El análisis de benchmarking mostró que ***pertenecer a una determinada organización favorece la tasa de adopción de tecnología***, aunque es más importante el grado de conectividad con otros productores. Estar conectado con líderes tecnológicos y agricultores afiliados a diferentes organizaciones con gran capital social incide positivamente en la tasa de adopción de tecnología ya que esta diversidad es fuente de información, conocimiento y recursos.

Estos hallazgos concuerdan con los de Zacharakis y Flora (2005), quienes sugirieron que las redes son más efectivas cuando son diversas, inclusivas, flexibles, horizontales (vinculando a quienes tienen un estatus similar) y verticales, vinculando a quienes tienen recursos que no están disponibles dentro de la comunidad. Estos resultados también coinciden con los encontrados por Dhehibi et al. (2020), quien estudió el proceso de transferencia de tecnología agrícola de los pequeños agricultores en Túnez y descubrió que las ***interacciones de agricultor a agricultor*** se percibían como los métodos de extensión agrícola más efectivos.

De igual forma, Zarazúa et al. (2012) aplicó el ARS para evaluar indicadores de capital social en dos grupos de productores de maíz en Michoacán y encontró una fuerte relación entre la potenciación de la innovación tecnológica y los vínculos que establecen los agricultores con actores involucrados en la actividad ganadera. Estos resultados estuvieron en línea con los de Espejel-García et al. (2014) donde, en su estudio de los patrones de interacción en el sistema de innovación rural de México, encontró que existían ***agentes que actúan como intermediarios de la innovación*** con capacidad de articular el sistema de innovación, vincular a los actores y llevar la innovación al usuario final.

Por otro lado, Gholifar et al. (2019) utilizó el ARS para estudiar los sistemas de acuicultura sostenible a través de una red de colaboración institucional en la cuenca hidrográfica de Alborz en Irán y descubrió que ***las organizaciones pueden desempeñar un papel clave*** en la distribución de información, conocimiento y la cooperación intersectorial entre los agentes sociales, y señaló que las agencias gubernamentales tienen más poder y centralidad en comparación con las organizaciones no gubernamentales. Sin embargo, estos resultados difieren de los encontrados por Kleinnijenhuis et al. (2011), quien midió la influencia social en las redes de práctica y encontró que los miembros de la red que comunican sobre la práctica informal y saben quién sabe qué, ejercen más influencia social que otros, lo que sugiere que la influencia social de los miembros está enraizada en su valor utilitario. para otros, y no en su arraigo organizacional.

Esta investigación contribuye significativamente a avanzar en la comprensión de la baja tasa de adopción tecnológica en el ***área de manejo reproductivo*** en los sistemas ganaderos, ya que la tecnología es una herramienta estratégica para el desarrollo y aumento de la competitividad y viabilidad de las fincas (Bastanchury-López et al., 2020; De-Pablos-Heredero et al., 2020; Rivas et al., 2019).

En resumen, los hallazgos del Capítulo I parecen ser consistentes con investigaciones previas sobre adopción de tecnología agrícola (Vishnu, Gupta, & Subash, 2019; Hernández Guevara, 2015; Weiss, Díaz-José, Rendón-Medel, Aguilar-Ávila, & Muñoz-Rodríguez, 2013; Hamann, Kinney, & Marsh, 2012; Hauser et al., 2007; Deroian, 2002), que han encontrado que ***las decisiones de innovar de los agricultores no se relacionan sólo con el nivel de ingreso***, sino también con el contexto de las interacciones sociales entre ellos y con agentes que promuevan el cambio.

Los objetivos del **Capítulo II** fueron abordar la siguiente pregunta de investigación:

How does network position affect the technology adoption of dual-purpose farmers in Mexico?

Para abordar esta pregunta aplicamos el análisis de redes sociales (ARS) y examinamos las redes entre los agricultores y sus implicaciones en la difusión de tecnología reproductiva. Los resultados mostraron que ***la orientación productiva influye en el proceso de adopción de tecnología*** (Rangel et al., 2020; Bastanchury-López; De-Pablos-Heredero et al., 2018).

Por otro lado, las medidas de centralidad obtenidas fueron similares a las de Walther et al. (2019), quienes utilizaron el ARS para medir los efectos del ingreso y el género en las redes sociales informales en la cadena de valor del arroz, entre 490 agricultores en Benin, Níger y Nigeria, y encontraron que la ganancia mensual de los agricultores estaba determinada por su posición estructural dentro de la red y la capacidad de construir conexiones con otras comunidades fuera de sus grupos étnicos y países. Aparte de esto, Aguilar-Gallegos et al. (2016) utilizaron el ARS para estudiar los efectos de las interacciones directas e indirectas entre 180 productores de caucho y actores clave en el estado mexicano de Oaxaca y encontraron un nivel muy bajo de intermediación entre los agricultores (0,74).

La estructura de red obtenida proporciona un diagnóstico real de la situación tecnológica de los agricultores más vulnerables, y señala la amplia brecha tecnológica entre las tecnologías de reproducción. En este proceso, los agricultores necesitan conocer estas tecnologías para comenzar a implementarlas en las fincas (conocimiento y capacidades de absorción) (Bastanchury-López et al., 2020; De-Pablos-Heredero et al., 2020).

Asimismo, la ***afiliación a una organización*** se consideró un factor importante en el proceso de adopción de tecnología (Villarroel-Molina et al., 2021), ya que las organizaciones son lugares de acceso a las innovaciones tecnológicas y de interacción entre los agricultores donde fluye la comunicación, constituyendo un factor determinante en las capacidades tecnológicas de absorción, integración y adopción.

En este sentido, los técnicos de GGAVATT han realizado un gran esfuerzo para potenciar la adopción de la evaluación en toros (T32) a través de programas de transferencia de tecnología (Ponce-Méndez et al., 2016). El papel potencial del SCN para adoptar innovaciones sostenibles es alto. La aplicación de este patrón de difusión podría mejorar la adopción de tecnologías reproductivas.

En una segunda etapa se debe favorecer la implementación de T34, T37 y T38, lo que requiere de una estructura productiva para su adopción (Rivas, et al., 2019). Estos hallazgos están alineados con los de Aguirre et al. (2020), quienes aplicaron el ARS para estudiar los patrones de adopción de prácticas de agricultura de conservación entre 222 pequeños agricultores de maíz en el estado mexicano de Chiapas, y encontraron que los agricultores aplican prácticas que resuelven problemas emergentes en el corto plazo, pero dejan de lado esas prácticas, que, en el mediano y largo plazo, conduciría a rendimientos más altos y estables. Sin embargo, la estructura de la red difiere de la encontrada por Villarroel et al. (2021), quienes evaluaron la utilidad del ARS para caracterizar líderes tecnológicos en pequeñas fincas ganaderas de doble propósito en México, en el área de genética, y encontraron una estrategia tecnológica más diversa.

El análisis de benchmarking mostró que los agricultores afiliados al GGAVATT tenían ***ventajas competitivas en la reproducción***, como el acceso al conocimiento (capacidades de conocimiento y absorción), favoreciendo la tasa de adopción de tecnología, y un alto grado de conectividad con otros agricultores que pertenecen al mismo grupo (Bastanchury-López et al., 2019). Los resultados mostraron un patrón centralizado de adopción de tecnología (difusión de arriba hacia abajo), donde la adopción de tecnología, aunque muy baja, se concentró en los agricultores de GGAVATT, con una estructura de red difusa y una posición de red de líderes diferenciada. Sin embargo, estos hallazgos difieren de los de Villarroel et al. (2021), que encontró una estructura de red con líderes bien definidos que actuaban como difusores de conocimiento en las organizaciones y entre organizaciones, identificando patrones descentralizados en la difusión de tecnología (*peer to peer*).

Según Dhehibi et al. (2020) y Zarazúa et al. (2012), estar conectado con líderes tecnológicos y agricultores afiliados a diferentes organizaciones (diverso capital social) afecta positivamente la tasa de adopción de tecnología. Además, Zarazúa et al. (2012) aplicó el ARS para medir el capital social entre los productores de maíz en México y encontró una fuerte relación entre la potenciación de la innovación tecnológica y los vínculos que establecen los agricultores con los actores involucrados en las actividades ganaderas. Los agricultores pertenecientes a la red más abierta presentaron mejores resultados productivos y los intermediarios con mayores vínculos definieron las fuentes y tipos de innovación y activaron patrones de interacción entre varios actores del sistema.

En cuanto a la teoría de las capacidades dinámicas, Bastanchury et al. (2020) y De-Pablos-Heredero et al. (2020) estudiaron las etapas del proceso de adopción de tecnología en explotaciones familiares de ovejas lecheras en España, y describieron la primera como una fase de conocimiento y absorción de tecnología, la segunda como una etapa de integración y la fase de capacidad de innovación como la etapa final. El GGAVATT de carácter público y con fines de beneficio social actúa como ***difusor de conocimiento*** en una primera etapa (conocimiento y capacidades de absorción), con un modelo centralizado de difusión de tecnología (*top-down diffusion*) y orientado a dar asistencia técnica a los agricultores afiliados a esta organización (Cardenas-Bejarano et al., 2016; Zarazúa et al., 2009). Debido a la falta de estas tecnologías reproductivas por parte del productor, su conocimiento y absorción se realiza de manera directa y homogénea desde los técnicos de GGAVATT hacia los productores afiliados a través de talleres participativos y demostraciones in situ (Figura 40) (Ponce-Méndez et al., 2016).

Figura 40. Técnica del GGAVATT hacienda demostración in situ.

En una ***segunda etapa de crecimiento y especialización***, como describen Villarroel et al. (2021) y Aguilar Gallegos et al. (2016), los primeros adoptantes (*early adopters*) presentan una estructura de red bien definida y están bien posicionados dentro de la red, destacándose como líderes entre los agricultores (capacidad de integración). Probablemente, en una etapa posterior de madurez tecnológica, los agricultores iniciarán una difusión descentralizada (de abajo hacia abajo), lo que resultará en procesos de innovación entre agricultores (*peer to peer*).

According to the literature and the results, the technology adoption process was sequential and cumulative. In the earlier phase, producer organizations were priorities to technology capabilities of knowledge and absorption. In the technology phase of maturity, capabilities of integration and innovation were provided by the producers, in a decentralized process with highly influential leaders.

In summary, SNA can help to understand the actor's behaviour involved in the innovation networks, the way these actors engage in the diffusion, and role they play in the adoption of sustainable practices (Valdovinos Terán et al., 2015; Zarazúa et al., 2012). Technological adoption analysis was carried out regardless of farm size, with a minimum cost strategy (Rivas et al., 2019; Rangel et al., 2017; Torres et al., 2015). Due to the low level of technology adoption, the system could be improved by favouring the knowledge and absorption capabilities in the less adopted reproductive technologies (Bastanchury-López et al., 2020; Garcia-Martinez et al., 2016), therefore making it possible to increase productivity while maintaining diversified strategies (milk, meat, and cheese) and land-sharing practices in DP farms.

Los objetivos del **Capítulo III** fueron evaluar si existen diferencias significativas entre la red de adopción de tecnología de hombres y mujeres y si estas diferencias impactan en su productividad e influyen en sus preferencias de adopción en el ***área de reproducción.***

El ARS permitió identificar las preferencias, patrones de adopción y estrategias tecnológicas de hombres y mujeres. Los resultados mostraron que ***tanto hombres como mujeres tenían una fuerte preferencia por la evaluación de la salud reproductiva en toros*** (T32), con una tasa de adopción del 96,85 %.

Además, los hombres tienden a adoptar conjuntamente la evaluación de la fertilidad del semen (T33) y el diagnóstico de embarazo (T36). Por lo tanto, estas tecnologías se consideran tecnologías complementarias. Sin embargo, la evaluación de la condición corporal femenina (T34) fue la tecnología por la que los hombres mostraron menor preferencia, con una tasa de adopción del 2,29%. Por otro lado, las mujeres tienden a adoptar conjuntamente la evaluación de la fertilidad del semen (T33), el diagnóstico de preñez (T36) y el tipo de apareamiento (T37). Sin embargo, las mujeres mostraron menor preferencia por la evaluación de la condición corporal femenina (T34) y la política de reproducción (T38), con una tasa de adopción de 2,94% cada una.

Al realizar un análisis comparativo del desempeño productivo de hombres y mujeres, los resultados arrojaron que, aunque las mujeres eran el 8,89% de la población estudiada, eran más productivas que los hombres. La producción de leche de las mujeres fue de 121,37 L/ha, mientras que los hombres tuvieron una producción promedio de 106,48 L/ha, lo que significa que los hombres producen casi 15 L/ha menos que las mujeres. Además, se encontró que las mujeres tenían mejores resultados de producción de leche por vaca, con una producción de leche de 1.172 l/vaca al año, mientras que los hombres tenían una producción de 971 l/vaca al año, lo que significa 201 l/vaca menos que las mujeres.

En cuanto a las medidas de centralidad y posición de las mujeres en la red de adopción tecnológica, los resultados de este trabajo están en línea con los de Walther et al. (2019), que estudió en qué medida el género es un fuerte predictor de vínculos sociales en la cadena de valor de arroz de 490 agricultores en Benin, Níger y Nigeria, y encontró que las mujeres ocupan posiciones estructuralmente desfavorables en relación con los hombres. El autor argumentó que estas disparidades de género son particularmente evidentes cuando los actores están representados en términos de su capacidad para desempeñar roles de intermediarios.

La gran mayoría de los intermediarios situados en el corazón de la red son hombres, y las mujeres rara vez ocupan roles estructuralmente equivalentes. Sin embargo, los resultados de este trabajo difieren de los de Walther et al. (2019) en los resultados productivos ya que las ganaderas de doble propósito, aunque no ocupan posiciones centrales en la red, estaban bien conectadas. Por el contrario, Walther et al. (2019) encontraron que la ganancia mensual de los agricultores estaba determinada por su posición estructural dentro de la cadena de valor del arroz y que los actores más prósperos estaban profundamente arraigados en su comunidad a través de numerosos vínculos, pudiendo establecer conexiones con otras comunidades fuera de sus grupos étnicos. Los resultados de este trabajo también difieren de los encontrados por Torres et al. (2016), quienes estudiaron el sistema ganadero de doble propósito en Ecuador y encontraron que las mujeres apenas asumen responsabilidades en la unidad de producción, siendo su trabajo percibido como relevante solo en el ámbito doméstico.

CONCLUSIONES

6. CONCLUSIONES

The utility of social networks methodology in the characterization of the technological innovation adoption patterns and diffusion in the in the agri-food sector, in natural resources, in cattle raising and in the dual-purpose cattle is showed. It is noted that UCINET is the software chosen by most researchers. In the case of working with producer groups, the use of this software is recommended. The most frequently used indicators in livestock are: degree, betweenness, closeness and eigenvector, so they could be proposed as structural variables in subsequent quantitative analyses.

Risk aversion, low training and low financial capacity of DP farmers contributes to technological adoption through interaction with nearby networks over peer influence. Likewise, the review results favour the construction of models closes to reality, which incorporate the technological adoption patterns of each farmer (whether or not they have implemented each technology) compared to their individual preferences (two-mode matrix). SNA may be of great interest to deepen the identification of appropriate technologies for small-scale DP producers, identify leaders and promote the diffusion of innovation process in tropical areas.

Chapter I

This research delved into the factors to explain the low technology adoption rate in the very small dual-purpose cattle farms in the Mexican tropics, employing the descriptive measure of social network analysis approach to examine its structure. The sample consisted of 383 farmers and nine reproductive management technologies are measured. The results showed that the farmer’s position in the network has a significant impact on their access to information as a productive resource. On the contrary, the farmers farthest from the central network position showed the lowest levels of betweenness and high rates of constraint.

Using various centrality network measures, we identified three important factors within the agricultural innovation processes: the central farmers, the core technologies, and their adoption patterns. We found that there are elementary technologies widely adopted by most farmers and complementary technologies that tend to be jointly adopted; the adoption of one affects the adoption of the other.

The social network analysis approach seemed to be a valuable tool in improving decision-making processes within agricultural extension and training programmes, since it allowed one to analyse patterns of relationships between farmers and had a graph visualization of the network, showing the key agents with high potential to spread innovations. SNA was a useful methodological perspective of analysis to map knowledge networks within smallholder farmer communities that should be undertaken at the planning stage of programme development to build community social capital.

Chapter II

This research was carried out on the most vulnerable and smallest dual-purpose cattle farmers in the Mexican tropics, who showed a very low technological adoption level in reproduction. The technology adoption process in the network was related to factors such as network position, the organization with which farmers were affiliated, and the production strategy. In this research, being affiliated with GGAVATT and connected to technological leaders and farmers was found to positively affect the technology adoption rate. Breeding soundness evaluation in bulls was found to be a widely adopted technology by most farmers (96.61%), while the evaluation of female body condition was the least adopted technology (2.91%).

In the two-mode network, another adoption pattern found was the joint adoption of semen fertility evaluation, oestrus detection, and pregnancy diagnosis, for which they were considered complementary technologies, where the adoption of one affects the adoption of the other.

Social network methodology helped to identify key farmers with great potential to spread innovations within their group and amongst other farmers from different groups. SNA also allowed going deep into technology adoption patterns. The social network analysis approach and the dynamic capabilities theory helped to understand the phases of technological adoption. Reproductive technology adoption was in the first technological stage (absorption capabilities), led by GGAVATT in a centralized model (bottom-down). SNA was a useful methodological perspective of analysis to map knowledge networks within smallholder farmer communities that should be undertaken at the planning stage of program development to build community social capital.

It would be of great interest to know the pattern of technological adoption in other areas of dual-purpose cattle farms, such as feeding, pasture management, and milk quality. The main limitation of this methodology lies in knowing the adoption impact of each reproductive technology on the technical performance and the productive and economic outcome.

Future studies on the current topic are therefore recommended, using other analyses proposed in the literature to further investigate the network effect on operating results

Chapter III

The SNA methodology was shown to be a useful tool to differentiate technology adoption patterns between men and women of dual-purpose cattle farms in tropical Mexican. In the reproductive technical area centrality measures, significant differences between men and women were found. Men mostly occupied the central leadership positions of the network (brokers).

In opposite, women occupied positions close to the leaders in the network, quickly adopting those reproductive technologies they selected. The adoption pattern in basic technologies was similar between men and women. Differences were found in the adoption of complementary and substitute technologies between men and women. The women focused on those technologies linked to the cow reproductive efficiency.

Farms run by women were smaller (both in cows and grazing surface) although with greater specialization and milk productivity; both per cow and per ha, increasing productivity by 20%. Differences in adoption preferences between men and women and differences in technological combinations seem to generate differences in productivity. Women achieved better outcomes with fewer technological resources.

In future studies, it would be necessary to delve into the reasons that cause women leaders not to appear on the network and their motivations for technological preferences

RESUMEN

7. RESUMEN

Durante la última década ha aumentado considerablemente el interés por la aplicación del análisis de redes sociales (ARS), aunque su utilización es muy limitada en el estudio de la adopción de la innovación por parte de los pequeños productores. El objetivo de este trabajo fue realizar una revisión de los trabajos de ARS y construir un marco conceptual para su aplicación en sistemas ganaderos bovinos de doble propósito en áreas tropicales. Los resultados de esta revisión mostraron que los indicadores más frecuentemente utilizados en ganadería son: centralidad, intermediación y cercanía. Asimismo, sugieren que la metodología de redes sociales es una herramienta importante para conocer los patrones de adopción y difusión de la innovación tecnológica en ganaderos de pequeña escala de doble propósito (DP). Se destaca la importancia de conocer los patrones de adopción tecnológica de los productores a través de la matriz de modo 2.

Capítulo I)

La baja tasa de adopción tecnológica es uno de los principales problemas en las fincas ganaderas de doble propósito muy pequeñas en México. Utilizando el enfoque de análisis de redes sociales, caracterizamos a los agricultores líderes en la red de innovación y profundizamos en el conocimiento sobre las causas de la baja adopción tecnológica. La muestra estuvo compuesta por 383 fincas muy pequeñas de ganado de doble propósito caracterizadas por utilizar nueve tecnologías de manejo reproductivo. Nuestros hallazgos sugieren que la posición de red de los agricultores tuvo un impacto significativo en el nivel tecnológico. Por lo tanto, los agricultores más alejados de los líderes tecnológicos mostraron los niveles más bajos de intermediación y altas tasas de restricción. Además, el asesoramiento, la orientación productiva y la intensificación también fueron elementos diferenciadores a nivel tecnológico. Los hallazgos brindaron información relevante y herramientas útiles a los formuladores de políticas para apoyar, coordinar y mejorar mejor la adopción de la innovación entre los agricultores.

Capítulo II)

El sistema de producción bovina (DP) de doble propósito es el modelo de pequeña escala más difundido en el trópico latinoamericano, donde constituye una herramienta clave en términos de seguridad alimentaria. La mayoría de los PD son fincas de subsistencia orientadas al autoconsumo, con una tasa de adopción de tecnología muy baja.

Por lo tanto, el principal desafío es cómo mejorar el nivel tecnológico sin comprometer la sostenibilidad del sistema mediante la aplicación de prácticas de uso compartido de la tierra. Así, a través de la metodología de redes sociales, este trabajo analizó cómo los agricultores adoptan tecnologías reproductivas. La muestra estuvo compuesta por 383 fincas muy pequeñas de ganado de doble propósito. Se evaluaron siete tecnologías de reproducción orientadas a mejorar la eficiencia reproductiva: evaluación de la salud reproductiva en toros, evaluación de la fertilidad del semen, evaluación de la condición corporal de la hembra, detección de celo, diagnóstico de preñez, apareamiento estacional o continuo y política de crianza. El Análisis de Redes Sociales (ARS) permitió identificar patrones de adopción, como la adopción conjunta de evaluación de fertilidad de semen, detección de celo y diagnóstico de preñez, que se consideraron tecnologías complementarias. De manera similar, se encontró que la evaluación de la solidez reproductiva en toros es la tecnología más ampliamente adoptada. Los resultados mostraron que estos productores presentaron un nivel muy bajo de adopción de tecnologías de reproducción y sugirieron que la afiliación de los productores a organizaciones como los Grupos Ganaderos de Validación y Transferencia Tecnológica (GGAVATT) y su posición en la red tuvo un impacto significativo en el nivel de adopción tecnológica. En la primera etapa de adopción, este trabajo destacó la importancia de los modelos centralizados del GGAVATT para los agricultores, relacionados con el conocimiento y las capacidades dinámicas de absorción. En una etapa posterior, son prioritarios los modelos descentralizados a través de líderes tecnológicos, relacionados con las capacidades dinámicas de integración e innovación.

Capítulo III)

Este trabajo examina el papel de la mujer en el sistema ganadero de doble propósito (DP) en el Litoral Centro y Suroriental de México, a través de patrones de adopción tecnológica. El objetivo fue evaluar si existen diferencias significativas entre la red de adopción de tecnología de hombres y mujeres y su impacto en la productividad. La muestra estuvo compuesta por 383 fincas pequeñas de DP con 20 o menos vacas y un alto nivel de vulnerabilidad. Se aplicó la metodología SCN y se calcularon las medidas de centralidad para cinco áreas tecnológicas (manejo, alimentación, genética, reproducción y salud animal). Se encontraron diferencias significativas en la reproducción. Por lo tanto, el SNA se desarrolló en esta área tecnológica, donde los hombres ocupaban mayoritariamente los puestos centrales (brokers) mientras que las mujeres apenas estaban cerca de los líderes de la red. Los resultados han mostrado que las mujeres priorizaron aquellas tecnologías vinculadas a la eficiencia reproductiva de la hembra, y las fincas dirigidas por mujeres eran más pequeñas y presentaban mayores niveles de especialización y productividad lechera (20% superior). Las mujeres estaban profundamente arraigadas en las redes de los hombres a través de numerosos lazos y eran capaces de construir conexiones con grupos de agricultores fuera de su propio grupo.

SUMMARY

8. SUMMARY

During the last decade, the interest in social network analysis (SNA) has grown considerably. Although the utilization of social network analysis to study smallholder innovation systems is still very limited, the aim of this paper is to review research themes concerning the application of SNA in livestock systems and related areas, from the focus of the dissemination of innovation and knowledge, to build a conceptual framework and benchmark to study livestock systems in tropical areas. The findings of this review suggesting that the methodology of social networks is an important tool to know the patterns of adoption and dissemination of technological innovation in the smallholders of dual-purpose cattle (DP). The importance of developing technological adoption patterns of each farmer through two-mode matrix is highlighted.

Chapter I)

The low technology adoption rate is one of the major problems in very small dual-purpose cattle farms in Mexico. Using the social network analysis approach, we characterized the farmer leaders in the innovation network and deepened the knowledge on the low technological adoption causes. The sample consisted of 383 very small farms of dual-purpose cattle characterized by using nine reproductive management technologies. Our findings suggested that the network position of farmers had a significant impact on the technological level. Hence, the farmers farthest from the technology leaders showed the lowest levels of betweenness centrality index and high rates of constraint. Apart from this, advice, productive orientation, and intensification were also differentiating elements at the technological level. The findings provided relevant insights and useful tools to policy makers to better support, coordinate and enhance the adoption of innovation among smallholders.

Chapter II)

The dual-purpose bovine production system (DP) is the most widespread small-scale model in Latin American tropics, where it constitutes a key tool in terms of food security. Most DPs are subsistence farms oriented to self-consumption, with a very low technology adoption rate. Hence, the main challenge is how to improve the technological level without compromising the system sustainability by applying land-sharing practices. Thus, through networks methodology, this paper analysed how farmers adopt reproductive

technologies. The sample consisted of 383 very small farms of dual-purpose cattle. Seven reproduction technologies oriented to improve reproductive efficiency were evaluated: Breeding soundness evaluation in bulls, semen fertility evaluation, evaluation of female body condition, oestrus detection, pregnancy diagnosis, seasonal or continuous mating, and breeding policy. Social Network Analysis (SNA) allowed identifying adoption patterns, as the joint adoption of semen fertility evaluation, estrus detection, and pregnancy diagnosis, which were consider complementary technologies. Similarly, breeding soundness evaluation in bulls was found to be the most widely adopted technology. The results showed that these farmers presented a very low level of reproduction technology adoption rate and suggested that farmer's affiliation with organizations such as the Livestock Groups for Technological Validation and Transfer (GGAVATT), and its network position had a significant impact on the level of technological adoption. In the first stage of adoption, this work highlighted the importance of centralized models from the GGAVATT to the farmers, related to the knowledge and absorption dynamic capabilities. In a later stage, decentralized models through technological leaders are a priority, related to integration and innovation dynamic capabilities.

Chapter III)

This paper examines the role of women in the dual-purpose livestock system (DP) in the Central and South-eastern Coastal of Mexico, through technology adoption patterns. The aim was to evaluate whether there are significant differences between the technology adoption network of men and women and their impact on productivity. The sample was composed of 383 small farms of DP with 20 or fewer cows and a high level of vulnerability. SNA methodology was applied, and the centrality measures were calculated for five technological areas (management, feeding, ge-netics, reproduction, and animal health). Significant differences were found in reproduction. Therefore, the SNA was developed in this technological area, where men mainly occupied central positions (brokers) while women were just close to the leaders in the network. The results have shown that women prioritized those technologies linked to the reproductive efficiency of the female, and farms run by women were smaller and presented higher levels of specialization and milk productivity (20% higher). Women were deeply embedded in men's networks through numerous ties and capable of building connections with groups of farmers outside their own group.

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ANEXOS

ANEXOS

Ganadería de doble propósito en México:

Figura 41. Modo de vida de las ganaderas de doble propósito.

Figura 42. Tareas que desempeñan las ganaderas de doble propósito.

Figura 43. Niñez en los sistemas ganaderos de DP. (Dependientes económicos de los ganaderos y ganaderas).

Figura 44. Difusión del conocimiento, como preparar queso fresco artesanal.

Figura 45. Reunión de ganaderos y ganaderas de doble propósito (difusión del conocimiento).

Figure 46. Cultivos tropicales.

Figura 47. Manejo de ganado por una mujer en Ocozocoautla Chiapas, México. Normalmente, las mujeres tienen que hacer frente a este tipo de actividades debido a la ausencia de hogares encabezados por hombres.

Figura 48. Toma de muestras de garrapatas para su posterior análisis en laboratorio (identificación de resistencia a acaricidas comerciales).

Figura 49. Amarre previo al ordeño.

Figura 50.Exploración reproductiva.

APLICACIÓN DE LA METODOLOGÍA DE REDES SOCIALES (ARS) PARA ANALIZAR LA INNOVACION TECNOLÓGICA EN LA CONSERVACIÓN DE RAZAS GANADERAS

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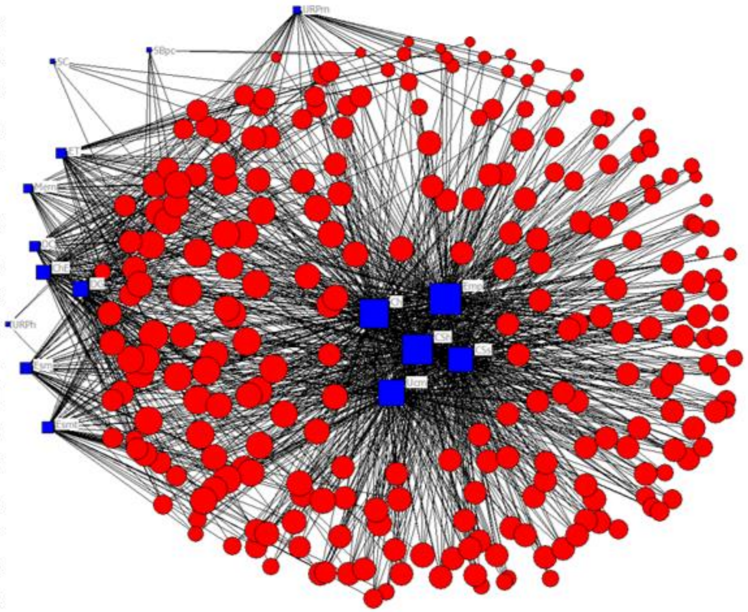
ARS contempla el conjunto de nodos (actores clave) y vínculos que representan alguna relación, o falta de relación, entre los nodos de la innovación tecnológica en la conservación de razas ganaderas.

Objetivo: realizar un análisis exploratorio de la aplicación de la ARS como herramienta de gestión de la conservación de las razas autóctonas en peligro de extinción.

Hipótesis: El incremento del nivel tecnológico está asociado al aumento del conocimiento en conservación y mejora. Los ganaderos con posición central en la red tienen mayor capacidad de absorber mayor flujo de información y mayor probabilidad de éxito en la adopción tecnológica.



XI CONGRESO IBÉRICO SOBRE RECURSOS GENÉTICOS ANIMALES
Beniaján (Murcia), 27 y 28 de septiembre de 2018

Metodología: Construcción de la red y visualización gráfica mediante UCINET.

Resultados: La relación entre productores y tecnologías en las áreas reproductiva y de gestión genética, muestran como las posiciones centrales se corresponden con la monitorización de las cubriciones, así como los criterios de selección en machos y hembras.

Conclusiones: Se evidencia la posibilidad de implementación de mecanismos para el desarrollo de un proceso de innovación tecnológica por parte de los ganaderos que permitiría abrir un proceso de innovación a otros productores más allá de su red más cercana y fomentar la co-creación de valor a través de prácticas de innovación abierta.

IDENTIFICACIÓN DE LIDERAZGO EN GANADEROS DE RAZAS EN PELIGRO DE EXTINCIÓN MEDIANTE ANÁLISIS DE REDES SOCIALES (ARS). PROPUESTA METODOLÓGICA

Villarroel-Molina, O.[1], de Pablos, C.[2], Barba, C.[1], Angón, E.[1], Perea, J.M.[1], Checa, C.[1] y García, A.[1]

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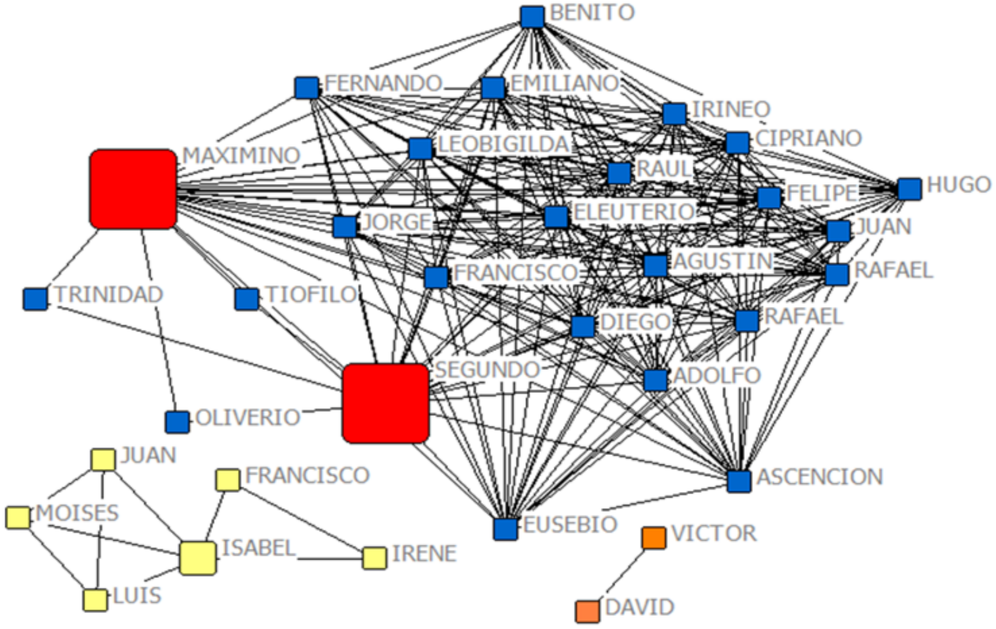
A partir de la aplicación de las técnicas ARS se plantea la identificación de ganaderos líderes en el programa de conservación de razas en peligro de extinción mediante la obtención de las medidas de centralidad más representativas (Softwares UNICET). Se propone una clasificación cruzada utilizando dos criterios de modo simultáneo; la intermediación o *betweenness* y las interacciones de escala cruzada o *cutpoints*, de acuerdo a los que se establecen tres tipos de relación:

- Actores clave

  Líderes en interconexiones (azul)
- Actores puente

  Líderes en interconexiones a escala cruzada y árbitros de escala (amarillo)
- Líderes tecnológicos

  Actores claves y puente de forma simultánea (rojo)



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ACTAS DEL PRIMER CONGRESO ANUAL DE ESTUDIANTES DE DOCTORADO DE LA UNIVERSIDAD MIGUEL HERNÁNDEZ DE ELCHE

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I CONGRESO ANUAL DE ESTUDIANTES DE DOCTORADO

UNIVERSITAS *Miguel Hernández*

2 de febrero de 2021

An exploratory analysis of Smallholders Social Capital through SocialNetwork Analysis.

Oriana Villarroel-Molina[1], Carmen De-Pablos-Heredero[2], Jaime Rangel[3], María Prosperina Vitale[4], Antón García[1]

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The low technology adoption rate is one of the main problems in the small-scale dual- purpose farms in Mexican tropics. The objectives of this study were to identify influencer farmers in the innovation network and to perform a benchmarking analysis to evaluate what characteristics these technology leaders have, and thus deepen the knowledge of the rejection causes during adoption processes. Social Network Analysis (SNA) was used from the Social Capital Theory approach, considered as a resource through which farmersaccess information that allows them to be more efficient in the production process. It is believed that those farmers well connected to key players can imitate their technologicalstrategies, which becomes a competitive advantage. A sample of 383 of these smallholders was selected. The following centrality measures has been calculated trough UCINET: degree, betweenness, closeness, eigenvector and constrain. We focused on the area of genetics, as it is the one with the lowest technological level (59.18%). The results showed that crossbred system (95.82%), sire selection criteria (90.34%) and female selection criteria (89.56%) are the most adopted technologies within this area. While, female selection criteria (89.56%), using female crosses (71.28%) and using male crosses(55.87%) have a medium level of adoption over the average. In contrast, calves selectioncriteria (49.87%), using male breeds (37.34%), using female breeds (22.45%) and use of genetically tested bulls (20.10%) are the less adopted technologies. The results showed that the differences in technology adoption were given by the social network measures, the productive strategies developed and, that to be connected to technological leaders positively affects the adoption rate.

Keywords: social network analysis, innovations, dual-purpose cattle, technology adoption, social capita.

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Por su participación en el ***"Seminario Internacional de Sistemas de Producción Ganadera"*** *(videoconferencia), con su ponencia oral titulada* ***"Uso de la metodología de redes sociales para mejorar la adopción de tecnologías en sistemas ganaderos"****, con una duración de dos horas, la cual forma parte de las intervenciones internacionales.*

Dr. Jorge E. Vieyra Duran
Jefe de Área de Sistemas Agropecuarios,UAM-I

Dra. Edith Arenas Ríos
Jefa de Departamento de Biología de Reproducción, UAM-I

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Ciudad de México a 12 de marzo del 2022