Alma Mater Studiorum – Università di Bologna

DOTTORATO DI RICERCA IN
SCIENZE E TECNOLOGIE AGRARIE, AMBIENTALI E ALIMENTARI

Ciclo 34

Settore Concorsuale: 07/A1 - ECONOMIA AGRARIA ED ESTIMO

Settore Scientifico Disciplinare: AGR/01 - ECONOMIA ED ESTIMO RURALE

INNOVATION DIFFUSION AND BIOSTIMULANT KNOWLEDGE IN MOROCCAN AGRICULTURE

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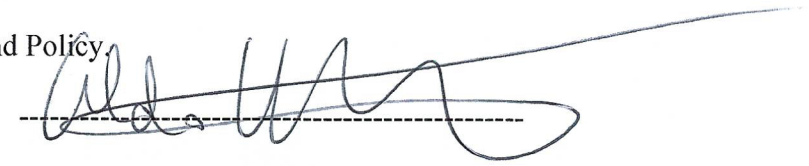

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بسم الله الرحمن الرحيم

اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (١) خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ (٢) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (٣) الَّذِي عَلَّمَ بِالْقَلَمِ (٤) عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ(٥)

صدق الله العظيم

In the name of God, the Merciful, the Compassionate,
Read: In the name of thy Lord who created (1), Created man from a clot (2) Read: and thy Lord is the Most Bounteous (3), Who taught by the pen (4), He taught man what he did not know (5).
God Almighty has spoken the truth.

In nome di Dio, il Compassionevole, il Misericordioso
Leggi: In nome del tuo Signore che ha creato (1), Ha creato l'uomo da un'aderenza (2), Leggi, che il Tuo Signore è Generosissimo (3), Colui che Ha insegnato mediante il calamo (4), Ha insegnato all'uomo quello che non sapeva (5).
Dio Onnipotente ha detto la verità.

This thesis is dedicated to Paolo Girelli for his endless support and encouragement.

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ABBREVIATIONS AND ACRONYMS

ADA: Agency for Agricultural Development

AFD: Agence Francaise et Developpement

CAGR: The Compound Annual Growth Rate is the mean annual growth rate of an investment over a specified period longer than one year

DARED: Green Climate Fund

DCQ: Quality Departments

DPV: Plant Protection Division

DRA: Regional Directorate of Agriculture

EBIC: European Biostimulants Industry Council

ENA: National School of Agriculture of Meknès (Morocco)

ENABEL: Belgium Fund

FAO: Food and Agriculture Organization of the United Nations

FDI: Foreign Direct Investment

FDI: Foreign Direct Investment

FEM: Fond pour L'Environement Mondial

FFEM: Fond Francais pour L'Environement Mondial

FHII: Fond Hassan II pour le Developpement Economique et Social

FiBL: Research Institute of Organic Agriculture

GCC: Gulf Cooperation Council

GMP: Green Morocco Plan in the French language "Projet Vert du Maroc"

IFAD: International Fund for Agriculture Development

IFOAM: International Foundation for Organic Agriculture Movement

IFPRI: International Food Policy Research Institute

IRRIG: Green Climate Fund

ISDB: Islamic Development Bank

KET: Key Enabling Technology

MAD: "Dirham", Moroccan' currency (1 €uro equal to 10.81 MAD)

OEC: Observatory of Economic Complexity

ONSSA: Office of Sanitary Safety of Food Products

PACCZO: Adaption Fund

PBs: Plant Biostimulants products

PPPs: Plant Protection products

RIM: Research in Motion

SPV: Plant Protection Services

UNIBO: Alma Mater Studiorum, University of Bologna (Italy)

SPSS: Statistical Product and Service Solutions

ACKNOWLEDGEMENTS

In the Name of God, the Merciful, the Compassionate,

I would like to dedicate this thesis to Dr Paolo Girelli and express my sincere gratitude for the opportunity he gave me to attend a doctorate at the Alma Mater University of Bologna, and for his faith in me, helping to make my dreams come true. Special thanks to his family - Paola Piona and Barbara Piona - for all their kind support in helping me achieve this magnificent result.

This doctorate would not have been possible without the support of Ilsa Group, providing me with the financial means and time to complete this study. It is something I will remember for years!

I would like to thank Dr Nicola Farina for his invaluable advice and suggestions since the start of this process, and I'm also indebted to my colleagues who sometimes replaced me at work. Thank you, guys!

Special thanks to my adviser, Prof. Aldo Bertazzoli, who guided me professionally on a path that was new and complex for me and who read my numerous revisions and helped make some sense of the confusion.

Furthermore, I would like to thank Prof. Claudio Ciavatta, who first showed me the right way to start the doctorate and encouraged me to undertake this experience.

I would also like to thank Prof. Mohamed El Amrani and Julia Titin for offering me advice and encouragement, with a perfect blend of insight and humour, as well as for their support in contacting several stakeholders and carrying out the scheduled interviews with local farmers. I'm proud of, and grateful for, my time working with them.

Finally, immense gratitude, as always, to my family and friends who, with patience and unconditional love, have supported me throughout the entire thesis process and hard times.

Finally, the knowledge acquired from the research doctorate has enriched me significantly from a cultural and professional point of view and will also be invaluable for the development of Ilsa activities.

Thank you, God, for always being there for me.

ABSTRACT

In the context of agricultural development, climate change, market and political instability posing significant challenges to farmers living in the MENA region, the introduction and adoption of innovation appears to be an essential requirement.

Innovation is central to achieving agricultural development and represents a foundation for the socio-economic development and stability of any country.

Our study focused on Morocco, as an Arab and North African country because it has recently become a gateway to western Africa, benefiting from social and political stability. Furthermore, thanks to the efforts of local government, relationships with Arab and African countries have been strengthened in various sectors, including agriculture.

In connection with innovation in the agricultural sector, our research aimed to investigate the dissemination of knowledge of existing innovation amongst farmers belonging to the first pillar of the Green Morocco Plan (GMP), located in the Fès-Meknès region. The second goal is to assess how innovation adoption is influenced by the network of relationships that various farmers are involved in. Our research on the diffusion of biostimulant (PBs) products acts as a case study.

From a methodological point of view, we used Social Network Analysis (SNA) to identify the primary stakeholders responsible for the innovation diffusion of (PBs). Based on extensive scientific literature, we noted that SNA is used in several disciplines such as agriculture, communication, marketing, medicine, and economics. Besides, we found that no one had analysed the diffusion of innovation concerning PBs in the Moroccan context by applying the SNA approach.

We followed the objectives of our research by adopting an "ego network" approach, also known as a personal network, according to which the subjects under investigation or "egos" are called on to directly describe the network of relationships they have, without the subjects identified in that phase (alters) becoming, in turn, the object of investigation.

We collected data through "face-to-face" interviews with 80 farmers in the Fès-Meknès region in April and May 2021. Farmers were chosen from a list provided by the local ADA. The list indicates the name of agricultural cooperatives, which farmers are members of, and other growers were identified using snowball methods.

The data obtained from the 80 questionnaires were processed with the aim of: 1) analysing the total number of main and specific topics discussed between egos and egos' alters regarding the variation of some egos attributes; 2) analysing egos' network characteristics using E-Net software appropriated for the ego network, and 3) identifying the significant variables that influence farmers to access knowledge about PBs, use PBs and reuse of PBs a Binary Logistic Regression was applied.

The first result of our study disclosed that the main PBs specific topics discussed between farmers and alters were technical positioning, the need to use PBs, knowledge of PBs, and organic PBs. Based on the frequency of topics discussed between growers and their alters, we noted that farmers dealing with topics related to PBs have specific features: they have a high school diploma and a bachelor's degree; they are specialised in fruits and cereals farming, and they are managers and members of a professional organisation.

The second result of our survey showed interesting results related to the SNA: 1) PBs topics seem to become generally a common argument for farmers who have already exchanged fertiliser information with their alters; 2) we disclosed a moderate heterogeneity in farmers' networks, as farmers have access to information mainly from acquaintances and professionals, and 3) we revealed that farmers' networks have a relatively low density and alters are not tightly connected to each other. On the other hand, farmers have a brokerage position in the networks controlling the flow of information about the PBs.

The third result obtained from the logistic regression revealed that both the farmers' attributes and the networks' characteristics influence growers to know PBs, use PBs and reuse PBs.

INTRODUCTION

This research synthesises the activities developed within an industrial doctorate supported by an Italian industrial company that manufactures organic PBs.

Based on our research goal, the main focus was on:

- analysing PBs' knowledge diffusion amongst professional farmers, particularly growers belonging to the first pillar of the GMP, located in the Fès-Meknès region (Morocco).
- investigating the type and amount of information exchanged between farmers and other stakeholders involved in the network.
- assessing how innovation adoption is influenced by the farmers' attributes and their networks of relationships.

At the beginning of our study, we examined the changes in the policy framework and the GMP. We also considered the national fertiliser consumption and food exports, as many observers argue that the GMP has made it possible to increase national agricultural production, fertiliser consumption and exports through the expansion into new markets.

To achieve the research goals, we applied the theories of innovation diffusion processes to identify the variables influencing PBs adoption and diffusion in the Fès-Meknès region.

The analysis of the existing innovation diffusion supported by the SNA is the new basic idea of our research. In this connection, it was crucial to examine:

- the ingoing and outgoing information exchanged between actors involved in the network concerning the knowledge, use and reuse of PBs.
- the information derived from external stakeholders who receive or provide information to farmers.

Farmers and stakeholders who communicate with each other constitute a network on which information is exchanged and disseminated. For the analysis of this phenomenon, the most suitable selected method is the SNA. Hypothesising that the social network surrounding any farmer could influence the innovation path, we adopted an Ego Network approach composed of Ego with its Alters to investigate the farmers' network characteristics.

Successively, we applied a Binary Logistic Regression to identify the variables (farmers' attributes and networks' characteristics) that influence PBs' knowledge diffusion and adoption.

Our research goal is to get practical and helpful information to develop marketing strategies aimed at further increasing the dissemination and adoption of PBs. Considering that these marketing strategies can be much more effective and incisive than those developed with less detailed information.

The first result obtained allows us to examine the most relevant topics discussed between Ego and his Alters regarding PBs and identify the Ego class most sensitive to these topics and the class number. From these results, companies manufacturing PBs can produce technical-informative material (brochures, technical notes, podcasts, etc.) based on the topics discussed between the farmer and his alters. This material can be distributed mainly to that category of farmers and alters analysed (acquaintances and professionals). Furthermore, the number of classes represents an economic value and indicates the most profitable priorities companies should focus on in marketing strategies.

The second result taken using the SNA allows us to analyse the diffusion of PBs, identify the main source of information for the Ego, and analyse the characteristics of the Ego's network.

The third result was attained using the binary logistic regression that consents us to identify the most significant variables (Ego's attributes and characteristics of his network) that influence the diffusion, use and reuse of PBs.

These results are helpful to the main players to define suitable actions aimed to favour a further spread of PBs:

- supplying technical support to all stakeholders analysed.
- creating collaboration with research organisations and other stakeholders involved in the network.
- realising technical-informative material based on farmers' attributes (specialisation, education level, age).
- establishing relationships with farmer's alters (acquaintances and professionals), providing them with technical information about the PBs.

Finally, we would like to stress that SNA has been adopted in various sectors (medicine, economics, communication, and agriculture). In the Moroccan agricultural context, we found no one had analysed the innovation diffusion in terms of PBs using the SNA approach.

For this reason, we believe that the results obtained from this study may also be helpful to other PBs producers to make a further contribution to the spread of PBs in the Fès-Meknès region. This is essential for Morocco, as it favours a further development of national agriculture to face the climatic (drought) and geopolitical (pandemic, Russia-Ukraine war) challenges and to allow the country to reduce imports of food (in particular cereals, oils and sugar) from other countries (mainly from, France, Canada, Ukraine, Russia, Germany, Brazil and Malaysia).

Moreover, the method used in this research could be replicated in different regions of Morocco and other geo-climatically similar areas to Morocco (countries of the Arab world).

In addition, other companies with different portfolios could further extend the method to their products to achieve more comprehensive results and develop more effective marketing campaigns.

The thesis is structured in 6 chapters: Chapter 1 provides an overview of agriculture in Morocco and the Fès-Meknès region and projects allocated to innovating the sector. It reports the results obtained from the GMP and import-export volumes of food products and fertilisers before and during the fulfilment of the GMP. Chapter 2 reports the theoretical background and presents the theories and approaches used to assess innovation diffusion and adoption. It reviews some researches where SNA was applied to study innovation diffusion in the agricultural sector. Chapter 3 overviews the challenges in agriculture that led Morocco to introduce innovation in the sector, also considering some empirical researches about the diffusion of innovation in Morocco and describes. Chapter 3 also focuses on PBs and their spread worldwide. Chapter 4 describes the method and logic behind sample-taking and data collection, preparation and analysis. Furthermore, it illustrates all the methods and measures used to obtain the results helpful in achieving the research goals. Chapter 5 presents three result blocks related to research goals, and Chapter 6 presents conclusions drawn from the results.

1. OVERVIEW OF THE MOROCCAN AGRICULTURAL CONTEXT

1.1 Strategies for Moroccan agriculture

In Morocco, from 1990 to 2007, national agriculture was orphaned due to an absence of a real strategy for its development. The accumulation of serious problems, such as sector liberalisation, limited and degraded natural resources, complex and archaic land structures and an underdeveloped cultivation system lacking in agricultural technical means had led to a rise in food imports (cereals, meat, sugar, milk) and impoverishment of the Moroccan population (Akesbi, 2011). The turning point came in 2007 when the new Minister of Agriculture, Aziz Akhannouch, commissioned the international research company, McKinsey, to devise a new development strategy for Morocco called the Green Morocco Plan. The World Bank and the Moroccan government subsequently supported the project.

This plan represented a real turning point and challenge for the development of Moroccan agriculture. Indeed, triggered a change from undeveloped and fragmented agriculture to more innovative and industrialised agriculture.

The revolutionary plan aimed to bring innovation to local agriculture and encourage the creation of farmers' cooperatives and associations. Specific attention focused on creating a modern Agricultural Knowledge and Innovation System (AKIS), stimulating collaboration between farmers and public and private stakeholders. The effect of this process was solid economic development compared to the rest of the North African countries, which aroused the interest of foreign stakeholders and investors.

Nevertheless, Moroccan agriculture, especially in rural areas, remains for the most part family-run. Most family farms adopted a traditional cultivation system; they often had limited technical knowledge and limited support from local authorities. As a result, small farmers focused their efforts mainly on producing for their own consumption. One of the goals of the GMP was to support small farmers to become able to produce for the local market (preserving the existing family farmers).

During the project's launch in 2008, the Minister of Agriculture declared that Morocco recognised the importance of introducing and spreading innovation among all actors involved in the agricultural sector (*Département de l'agriculture - Ministère de l'Agriculture, de La Pêche Maritime, Du Développement Rural et Des Eaux et Forêts*, 2018).

The Moroccan Ministry of Agriculture established bilateral cooperation with industrialised countries in various agricultural fields. The goal of this cooperation was to exchange experience and launch technical training and technology transfer programmes. Additionally, the Moroccan government signed conventions (such as the Marrakech Declaration on South-South Cooperation in December 2014) that consider the common challenges of African countries in terms of food security, agricultural and rural development and sustainable development. South-South Cooperation (SSC) is characterised by the exchange of experiences and the sharing of knowledge. This convention is horizontal cooperation

between African countries based on solidarity, which challenges the traditional dichotomy between donors and recipients through mutually beneficial partnerships. Moreover, Morocco has established various international cooperation agreements with the EU, Arab countries, African countries, Canada, Australia, Japan, Russia, USA, and Turkey in terms of exports (Coopération Technique | Ministère de l'agriculture, 2021).

Consequently, the GMP and bilateral cooperation with foreign countries have allowed Morocco to significantly increase production, ensure food self-sufficiency and favour exports to other countries (Coopération Technique | Ministère de l'agriculture, 2021).

In 2020, the Moroccan government extended the GMP by launching two new projects called Green Generation and Forests of Morocco.

The new *Green Generation 2020-2030* strategy aims to consolidate the positive results achieved today through the GMP and create new activities, generating jobs and income, especially for young people in rural areas. Furthermore, the main objective is to promote the emergence of a farming middle class able to exercise its dual vocation as a balancing factor and a lever for socio-economic development, like the urban middle class.

The second strategy is known as *Forests of Morocco* and focuses on developing and promoting 9 million hectares (estimated forest area) that play a central role in environmental, economic and social development (*Coopération Technique | Ministère de l'agriculture*, 2021).

One of the main innovations introduced by the GMP in Moroccan agriculture after the water management projects was the increased use of fertiliser (*The Future of Skills: A Case Study of the Agri-Food Sector in Morocco | ETF*, 2021).

The Observatory of Economic Complexity (*OEC*) reported that in 2018 during the execution of the GMP, the Kingdom of Morocco registered a turnover in importing fertilisers of around 42.1 million dollars compared to 2007 when it was 25.7 million dollars. In this period, the increased turnover achieved was +63%. The main countries Morocco imports fertilisers from are Spain, China, Italy, France, Belgium, Lithuania, Jordan, Saudi Arabia and the United Kingdom. Furthermore, other significant products imported are NPK fertilisers, animal and plant-based fertilisers, potassium sulphate, potassium nitrate, monoammonium phosphate, calcium ammonium nitrate, urea and magnesium sulphate (*OEC - The Observatory of Economic Complexity | OEC - The Observatory of Economic Complexity*, 2021).

1.2 The main results

As reported by the Moroccan Ministry of Agriculture, the GMP has achieved significant results, such as:

- signing of 19 programme agreements,
- implementation of 12 regional agricultural plans,

- creation of four new agencies,
- realisation of 4.5K legal texts,
- benefiting from international funding amounting to 34.8 billion MAD,
- cultivations of 120 million fruit trees,
- adoption of an irrigation water system for 585K hectares.

At the macroeconomic level, the GMP has made it possible to:

- double agricultural GDP (125 billion MAD) and exports (36.3 billion MAD),
- increase the volume of investments (national and international),
- create jobs,
- increase food self-subsistence,
- rationalise water consumption in agriculture in an eco-friendly vision,
- provide the impetus for the dynamic integration of small and medium-sized farms, benefitting 2.7 million farmers.

According to the **Moroccan Ministry of Agriculture**, Morocco has become the first self-sufficient country in the Arab world for food, vegetables, white and red meat, fruit and milk (Coopération Technique | Ministère de l'agriculture, 2021).

1.3 The agricultural context in the Fez-Meknès region

The Fès-Meknès region is located in the north of the kingdom and its capital is Fes. From an administrative point of view, the region covers seven provinces: Fès, Meknès, El Hajeb, Ifrane, Moulay Yaâcoub, Sefrou, Boulemane, Taounate and Taza.

As stated by the Moroccan Ministry of Agriculture, the region's total population is 4,236,892, 39% of whom live in rural areas. Regarding the region's potential in terms of agriculture, the total arable area is 1,235,521 hectares, with 193,542 hectares irrigated and 82,759 hectares irrigated using the drip irrigation system and the workforce involved in the sector is about 55,000.

The region is characterised by meat production with 426,730 head cattle herd, 2,990,000 head sheep flock and 423,900 head goat herd. Moreover, the main crops cultivated are cereals, with a total yield of 1,487,378 tonnes; fruits, with a total yield of 646,139 tonnes; olives, with a total yield of 627,726 tonnes; and red meat, with a total production of 69,200 tonnes (*Coopération Technique | Ministère de l'agriculture*, 2021).

During the execution of the GMP, public investments in the region were as follows:

- **Pillar I**: 371 projects were carried out, allocating 3.41 billion MAD as investment, and 733 professional farmers benefited from public funding.
- **Pillar II**: 152 projects were fulfilled, assigning 2.16 billion MAD as investment, and 96,430 small farmers benefited from public funding.

As declared by the Moroccan Ministry of Agriculture, the main results achieved during the execution of the GMP were:

- Milk production increased from 82,000 (t) in 2008 to 240,000 (t) in 2018.
- The total area cultivated in oilseeds increased from 2,769 (ha) in 2008 to 7,262 (ha) in 2018.
- Oilseed production increased from 2,596 (t) in 2008 to 7,262 (t) in 2018.
- Olive production increased from 228,000 (t) in 2008 to 486,000 (t) in 2018.
- The agricultural pole of Meknés was created that extends over 130 (ha). This agricultural pole has helped to create 212 plots in different areas to implement food industry investments (3 milk factories were established with a capacity of 50.000 (t) per year).
- An additional 3.1 billion MAD were allocated as public funding to carry out another 63,000 small projects. In addition, total private investments in the region amounted to 9.3 billion MAD.

1.4 Assessment of the Export-Import of food products in 2007 and 2018

This paragraph aims to shed light on the exports and imports of food products before and during the implementation of the GMP and to highlight the improvement recorded in the agricultural sector.

The tables below show the volumes of food products exported and imported expressed in million dollars. Data were obtained from the **Observatory of Economic Complexity "OEC"** (*OEC - The Observatory of Economic Complexity | OEC - The Observatory of Economic Complexity*, 2021)**.**

Products exported	Value in 2007 (Million dollars)	Value in 2018 (Million dollars)	Percentage variation
Vegetables and fruits	2030	3120	+54%
Foodstuffs	878	2240	+155%
Cereals	0	0	0%

Table 1 – Assessment of the export of food products in 2007 and 2018.

Products imported	Value in 2007 (Million dollars)	Value in 2018 (Million dollars)	Percentage variation
Vegetables and fruits	107,79	281	+160%
Foodstuffs	808	1730	+114%
Cereals	1420	1370	-3.52%

Table 2 – Assessment of the import of food products in 2007 and 2018.

Analysing the data and focusing particularly on the net balance between exports and imports for the years 2007 and 2018, we noted a positive increase in the net balance for vegetables and fruits (+917 million dollars) and foodstuffs (+440 million dollars). Therefore, the positive increase in the net balance indicates that exports were greater than imports and this result shows that national agricultural production and exports have increased in line with the GMP's goals.

On the other hand, Morocco is not self-sufficient in cereal production. For this reason, the country has to import cereals from other countries. Based on the negative net balance (-50 million dollars), we observed that in 2018 the country imported less compared to 2007. This point indicates that the GMP has encouraged the local cultivation of cereals.

From the data shown in the two tables, it is evident that the GMP was a turning point for the development of agriculture and the country's economy.

1.5 Assessment of the Export-Import of Mixed Mineral or Chemical Fertilizers in 2007 and 2018

This paragraph intends to emphasise the imports and exports of fertilisers before and during the execution of the GMP and highlights the country's need for specific fertilisers.

The tables below show the volumes of fertilisers exported and imported expressed in million dollars. Data were obtained from the **Observatory of Economic Complexity "OEC"** (*OEC - The Observatory of Economic Complexity | OEC - The Observatory of Economic Complexity*, 2021)**.**

Products exported	Value in 2007 (Million dollars)	Value in 2018 (Million dollars)	Percentage variation
Fertilisers (phosphate-based commodities)	648	2860	+341%

Table 3 – Assessment of the export of fertilisers in 2007 and 2018.

Products imported	Value in 2007 (Million dollars)	Value in 2018 (Million dollars)	Percentage variation
Fertilises (NPKs, urea, animal and plant-based products)	25.7	42.1	+63%

Table 4 – Assessment of the import of fertilisers in 2007 and 2018.

Based on the volumes of the purchase and sale of fertilisers (regardless of the type of product) for 2007 and 2018, we observed a positive increase in the net balance of +2195.6 million dollars. This result confirms that fertiliser exports were greater than fertiliser imports.

According to the **Observatory of Economic Complexity (OEC)**, exports of fertilisers recorded in 2018 allowed the country to become the 3rd leading operator globally (*OEC - The Observatory of*

Economic Complexity | OEC - The Observatory of Economic Complexity, 2021). Furthermore, this category of products was the 3rd most traded in the Kingdom of Morocco (fertilisers 9.66%, preceded by cars 16.3% and electrical machinery 16.3%). The reason for this growth in exports is due to Morocco's exclusive access to over 70% of the world's phosphate reserves (*OCPGROUP*, 2020).

Indeed, if we analyse exports, we note that exported products are phosphate-based. Instead, imports concern products the country does not produce, such as NPKs, urea, animal and plant-based products. We want to stress that, to increase the final yield, plants need macroelements (N, P, K), mesoelements (Ca, Mg, S), microelements (B, Fe, Mn, Zn, Mo) and amino acids for their growth and these essential elements are present in imported products. In addition, to achieve certain goals (e.g., increasing food production) fixed in the GMP, Morocco has to import this category of product.

1.6 Public organisations involved in the implementation of development plans

As reported by the Moroccan Ministry of Agriculture, one of the aims of the GMP was the improvement of the institution system, creating public organisations such as the **ADA**, which is responsible for GMP realisation and fulfilment (*Coopération Technique | Ministère de l'agriculture*, 2021).

ADA was founded in 2009 under the supervision of the Moroccan Ministry of Agriculture; it has its legal personality and financial autonomy and is subjected to the government's financial control.

The ADA played a vital role in achieving the strategic objectives fixed by the government for GMP realisation, in particular:

- It had direct access to public and international funding (IFAD, ENABEL, FHII, ISDB, AFD, DARED, FFEM, PACCZO, IRRIG) to finance various projects related to climate change and other vital sectors of agriculture.
- It supported the initiatives of the GMP.
- It was responsible for activating and renewing investments allocated in the sector.
- It was responsible for launching concrete projects.
- It played an essential role as an intermediator between public institutions and social stakeholders.
- It proposed action plans to the Ministry of Agricultural concerning support to farmers in pillar II of the GMP, by encouraging and implementing sustainable projects to improve farmers' income.
- It was responsible for promoting agricultural food products, and encouraging farmers to adopt new technical means, such as drip irrigation systems, fertilisers, pesticides and machines for farm stock processing and packaging. Furthermore, the ADA supported

marketing actions to increase the sales of local food products through participation in national and international events.

- It supported the launch and follow-up of different projects and programmes to develop the value chain of local food products to be marketed both on national and international markets.

The ADA is still active in different agriculture projects, such as *Green Generation* and *Forests of Morocco 2020-2030*.

The second public organisation is the **Regional Directorate of Agriculture (DRA).** It reports directly to the General Secretariat of the Department of Agriculture of the Ministry of Agriculture, Rural Development, Maritime Fisheries and Water and Forests. The DRA exercises its powers over the entire territory of the Fès-Meknès region, El Hajeb, Ifrane, Moulay Yaâcoub, Sefrou, Boulemane, Taounate and Taza). The main missions of the DRA in the region are:

- Representing the Ministery of Agriculture through its local bureau.
- Setting national guidelines for the agricultural sector by preparing regional development plans.
- Preparing, monitoring and evaluating the execution of the annual budget for each production chain.
- Assessing and monitoring public interventions in the agricultural sector to coordinate the activities of all stakeholders involved in the sector.
- Ensuring the coordination of various affiliated organisations, such as the DPAs, and Agricultural Training Institutes.
- Monitoring technical and learning training programmes.
- Monitoring and analysing the market (prices, players, products).
- Carrying out agricultural statistical analysis to guide investors and stakeholders and improve the effectiveness of public interventions.
- Strengthening the partnership between chambers of agriculture and other professional agricultural organisations on programme contracts.
- Supporting the development and establishment of professional agricultural organisations.
- Improving agricultural land structures.

The third public organisation is the **Office of Sanitary Safety of Food Products** (**ONSSA**). It was established under the supervision of the Ministry of Agriculture by Law No. 25-08, article 2 and endowed with a legal personality and financial autonomy (*ONSSA - Accueil*, 2020.). The Office acts on behalf of

the Moroccan government and its jurisdiction relates to the protection of consumer health and the safeguarding of animal and plant welfare.

ONSSA has a central structure composed of a General Executive, five Central Executives and other entities connected to the General Executive. ONSSA is represented by 10 regional branches spread over the entire territory at the regional level.

The missions assigned to ONSSA are:

- Approving registration of agricultural inputs (seeds, pesticides, fertilisers and technical means) and veterinary medicines, regulated by **"CODE DE PROCEDURE N 1, dated on 29 April 2019 CODE CP 01/DCPV, 10, VERSION G, 16éme CAS"** legislation.
- Ensuring the monitoring and health protection of plant and animal heritage at national borders.
- Ensuring the safety of food products from raw materials to the end consumer (humans and animals).
- Applying laws and regulations concerning veterinary and phytosanitary policy.

Under the ONSSA organisation, there is a specific division called the **Plant Protection Division (DPV)**, which is responsible for supervising, monitoring and coordinating plant protection missions, in particular:

- Protecting plant heritage, including crop protection, phytosanitary surveillance and integrated phytosanitary management.
- Checking food and material products at both customs and within the country.
- Following plans to combat harmful sparrows, rodents and locusts. As well as monitoring the phytosanitary protection of the forest.
- Evaluating and managing phytosanitary risks that pathogens can generate on plant health.
- Managing phytosanitary crises.

All these activities are in harmony with standard national and international phytosanitary regulations. Furthermore, to accomplish its tasks, the DPV includes three services: 1) the Plant Heritage Protection Service; 2) the Great Fight Service; 3) the Plants Quarantine Service.

At the regional level, the DPV is represented by **46 Plant Protection Services (SPV)** spread over the ten regional branches of ONSSA, including the **Control and Quality Departments (DCQ)** operating at the ports of Agadir, Casablanca and Tanger Med.

2. THEORETICAL BACKGROUND

This chapter intends to offer a detailed explanation of theories of innovation diffusion processes and social network analysis.

The theories of innovation diffusion processes serve as a basis for our research because they allow for a better understanding of the process in which an innovation develops and spreads within a social context. Consequently, we can identify the variables influencing innovation adoption and diffusion in Morocco.

SNA is one of many scientific approaches to analyse innovation diffusion according to the egos' characteristics and their networks of relationships. Through SNA, we can get relevant information about the network in which each farmer is involved, understand how innovation is diffused and assess the role and importance of different actors.

2.1 Introduction[1]

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

[1] This chapter had already been published at Economia agro-alimentare /Food Economy.
An International Journal on Agricultural and Food Systems
Vol. 24, Iss. 1, Art. 2, pp. 1-59 - ISSN 1126-1668 - ISSNe 1972-4802 DOI: 10.3280/ecag2022oa12059

The association between creativity and new ideas is very close. Organisations and economies must innovate and induce innovation to maintain and reinforce their competitive position. Thus, innovation is a fundamental policy and strategic matter (Baregheh et al., 2009). Rogers developed the diffusion of innovation theory to explain how an idea or product achieves momentum and spreads across a specific community (Rogers, 1983). As a result of this process, people adopt a new idea, product, or behaviour. Adoption means that people do something new that they had in the past, such as using or buying a new product, or acquiring a new practice or tool. The essential point in the adoption is that people must recognise the idea, product, or behaviour as innovative, and only through this recognition diffusion can happen. However, some individuals are more inclined to adopt innovation than other groups of people. Rogers stated that people who adopt innovation early have distinct features from people who adopt the same innovation later (Rogers, 1983). Therefore, promoting a specific innovation to a community is helpful to understand the characteristics of the target population that will speed or block the adoption of that innovation. Rogers established five adopter categories as follows (Rogers, 2003):

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

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

1. Relative advantage: the extent to which an innovation is seen as better than the idea, product, or practice it replaces.
2. Compatibility: that is the consistency of the innovation with the needs and experiences of the potential adopter.
3. Complexity: that is the difficulty the innovator can face to understand or apply the innovation.

4. Triability: the degree to which innovation can be experimented with or applied before a commitment to adoption is made.
5. Observability: the degree to which an innovation yields tangible outcomes.

The theory of innovation adoption has been used successfully to explain many sectors' evolution, including agriculture. For instance, according to Pretty et al. organic farming is a complex of agricultural innovations and they affirmed that organic farming becomes more acceptable, when it was seen to be more fruitful than conventional agriculture (Pretty et al., 2010). This result explains what is reported in relative advantage and observability attributes. Similarly, according to Padel, diffusion of innovation theory can help to understand the process of diffusion of organic farming into a community, as well as to understand how this process possibly can be supported and enhanced, i.e., across the agricultural extension or the knowledge and information system in agriculture (Padel, 2001). As affirmed by Finco et al. innovation is not a casual process. In their research, they focused on investigating some factors of innovation making start from small size agri-food firms linked with cluster agri-food in the Marche Region (Italy). Results showed that small enterprises separately cannot get innovation due to some constraints and firms' features, as well as clusters, represent an opportunity to get both innovation and to become more competitive in the local market (Finco et al., 2018).

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

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

This "Note" is structured as follows: Section 1 includes an introduction; Section 2 gives a brief overview of the SNA; Section 3 describes some empirical studies in which SNA was applied to understand how innovation is shared; Section 4 reports on the use of SNA in analysing the innovation diffusion in the

agricultural sector and Section 5 concludes the note. Instead, in the appendix is reported the methodology applied for the literature review.

2.2 Brief overview of Social Network Analysis (SNA)

In this paragraph, our objective is to provide readers with a simple description concerning the SNA and not to compare it with the existing methods applied by several authors to analyse the diffusion of innovation. In the following paragraph, we reported an explanation of SNA, an overview of its origin and application in several disciplines and sectors, as well as we highlighted its importance in analysing how knowledge is shared within a community. We tried to highlight that SNA could be a useful approach to be applied in analysing how innovation is diffused in a social network.

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

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

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

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

1) Social relations*:* include affinity or other types of role relations (e.g., student, friend); affective ties, which are based on members' feelings for one another (e.g., disliking, liking); or cognitive awareness (e.g., knowing).

2) Similarities: take place when two units share any kind of attribute, like locations, attitudes, demographic characteristics, or group memberships.
3) Flows: are relations built on interactions and transfers among nodes. These can include relations in which information and resources spread over the network.
4) Interaction: refers to behaviour-based ties like chatting with, supporting, or hosting someone to house.

In SNA language, in each network units are figured as nodes and are connected by ties, which are information and/or relationships that interchange between nodes. As stated by Scott & Carrington, relations characterised by ties among nodes are essential elements of SNA (Scott & Carrington, 2011).
According to Coulon a network characterised by one kind of node is named homogeneous, conversely is called heterogeneous (Coulon, 2005). Ties linked pairs of nodes could be directed (i.e., bidirectional, unidirectional, such as offering suggestions to somebody) or undirected (as in human being effectively next to) and could be dichotomous (present or absent, as if two individuals are acquaintances or not) or weighted (measured on a scale, as in the intensity of closeness). All ties have values or are weighted; even dichotomous relationships have binary values. When we focus on a single node, we name it "Ego" and we name the set of nodes that ego has ties "Alters".
SNA illustrates how individuals are interrelated and work together, how knowledge and resources flow between and among them, as well as how individuals' roles and relationships are structured (Spielman et al., 2011).

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

2.3 SNA and the diffusion of innovation: some empirical studies

In this section, in order to analyse the diffusion of innovation, we believe that we can take advantage of using SNA also to identify the main stakeholders or brokers that are responsible for specific innovation diffusion.
According to Coulon, from 1999 ahead, it was registered a rise in the number of scientific studies using SNA, in particular, aimed at analysing the structure of the relations among groups/individuals and the effect of network structure on innovation (Coulon, 2005). According to Valente, the weaker ties guarantee that

the small groups will foster the diffusion of innovation within a social system (Valente, 1996). Besides, Rogers, affirmed that any innovation would have a chance to be adopted quickly by individuals if it does not need much time to be recognised and accepted (Rogers, 2003).

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

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

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

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

2.4 The use of SNA and innovation diffusion in the agricultural sector:

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

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

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

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

Hermans et al. focused on investigating the ability to innovate and explore the potential for scaling innovations in three multi-stakeholder platforms (MSPs) in Congo, Rwanda, and Burundi (Hermans et al., 2017). They applied SNA in combination with Exponential Random graph modelling (ERGM) to explore the knowledge exchange, structural properties of the collaborative, and influence networks of three MSPs. Their approach was based on three steps: a) recognise in each country the long-term established partners of the CGIAR (Research Program on Integrated Systems for the Humid-Tropics) centres; b) map the participatory stakeholders based on Humid-Tropics workshops for which the main individuals were invited; c) prepare informative materials related to the program and distribute them in different areas. In each

country, data were collected from questionnaires focused on a name generator and asking participants to list the name of five organisations with whom they cooperate. The analysis of network properties showed an imbalance between knowledge exchange, collaboration, and influence networks for the diffusion of innovation and scaling processes. For example, the private sector and NGOs are respectively under and over-represented in the MSP networks, as well as connections among local and public organisations are weak, and influential public organisations are not actively connected to other groups and are often not part of the MSP. Furthermore, they discovered that organisations with a central position in the network are more appreciated for cooperation, and the diffusion of innovations is mainly among the same type of organisations across various administrative levels, but not among various types of organisations.

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

In the end, Birkenberg & Birner focused on analysing how Costa Rican coffee cooperative "Coopedota" applied certification for carbon neutrality as innovation, which challenges faced, and how it overcame them (Birkenberg & Birner, 2018). Besides, they analysed the main factors that encourage the diffusion of this innovation. Their approach was based on the SNA and Process Net-Map tool which was applied to visualise the network and to identify the role and importance of different types of individuals. Data were collected from depth interviews with thirty experts and semi-structured interviews with one hundred Coopedota's farmers. On this basis, the authors calculated SNA indicators as centrality, betweenness, closeness, and degree. The results confirmed that the certification for carbon neutrality created awareness of emission hot spots alongside the coffee value chain. The major successes include a combination of a) visionary and strong individuals who performed the necessary network functions and b) accomplishments in Coopedota's sustainability policy, which was supported by international and national trends. Results indicated that the network of individuals is extremely centralised, as well as the network analysis confirmed the importance of double linkages among individuals, which points to the role that combined services (advice and funding), acted in the introduction of innovation.

In the second step, the other scientific paper's authors used SNA jointly with the diffusion of innovation theory, learning pathways, social capital, decision-making, and homophily concept, i.e., the approach of

Aguilar-Gallegos et al. was based on the process of diffusion and adoption of innovation, homophily concept and SNA. They stated that in the agricultural sector, networks illustrate the engagement of many stakeholders that provide information and resources to farmers (Aguilar-Gallegos et al., 2015). Those stakeholders could be NGOs, farmer field schools, and extension agents. They are in contact with farmers, establishing and building ties. Moreover, they found that various farmers have different rates of adoption of innovation, as well as innovation is adopted based on farmers' incomes. Growers with high incomes are advanced adopters and they have more contacts with various stakeholders. Furthermore, they found that homophily in the network can impede the diffusion of certain knowledge among actors.

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

Grünbühel & Williams investigated how decisions are made when innovation in cattle management is introduced in two Indonesian areas (Grünbühel & Williams, 2016). They focused on the decision-making concept and Homo oeconomicus model of classical economic theory. They developed the decision narratives through 296 in-depth interviews collected through snowball sampling techniques. They used SNA to assess the diffusion of knowledge and identify different stakeholders that influence the farmers' decisions. They found that it is easy for farmers located in South Sulawesi to test and adopt an innovation because the land is more plentiful in comparison to farmers located in Lombok, where land is insufficient and more dedicated to crop production. Innovation is applied and adapted by farmers through cultural rationality. Furthermore, innovation is diffused through a range of existing social networks when it is compatible with farmers' livelihood strategies.

The research of Wood et al. was based on innovation systems theory by investigating the significance of the networks in which New Zealand shepherds discuss scientific issues (Wood et al., 2014). The authors analysed how farmers share their knowledge (pastoral farming) with scientists and other individuals, concentrating on communication and facilitation in the network. Their approach was based on ego network and sociometric analysis. The sample was gathered by identifying 17 farmers who are in direct contact with

five scientists, to explore the network cohesiveness and to evaluate the significance of networking. Personal interviews were carried out to collect sociometric data for the quantitative analysis. Also, free form interviews with the farmers were carried out to collect data for the qualitative analysis using a mix of roster formats and a name generator. Using a mix of tools (NVivo, Ucinet and statistical software), they found that farmers characterised by dense ties and homogenous contacts increased their network compared to other farmers characterised by soft and dissimilar ties.

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

Hoffman et al. applied SNA to study knowledge networks and social learning in Central Coast, Lodi, and Napa Valley –three American viticulture regions in California - (Hoffman et al., 2015). They used a different approach based on learning pathways (social, formal, and experiential), diffusion of innovation, social capital, and cultural evolution theories. These theories provided a basis to explain farmers' behaviour and understand how and why knowledge is or is not assessed, accepted, and adopted by people. They collected data through an e-mail survey from 25 farmers and 12 types of stakeholders and calculated the response rates using AAPOR guidelines (AAPOR 2009). Their surveys were based on asking interviewers to rate on a scale of one to three the usefulness of 21 information resources for learning about vineyard management. Furthermore, they used conventional network data collection methods asking farmers to list the names of other farmers and stakeholders with whom they speak about vineyard management. Besides, matrices of relational data were constructed from this survey. Other surveys were addressed to farmers to investigate if they had participated in learning activities. Using a linear regression model, they finally assessed the hypothesis that farmers' position in the network is a function of their participation in learning

activities. The results confirmed that empirical and social learning are more essential to get information about farm management than formal learning. Natural Resources Cooperative Extension (UCCE) and UC Agriculture are well-positioned to get and disseminate knowledge through the farmers' networks. Farmers' participation in technical activities, e.g., gathering and field trials, is essential for their knowledge-sharing relations. Moreover, UCCE and other agricultural support associations have an essential role to play in reinforcing networks.

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

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

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

Bourne et al. applied SNA to assess the performance of agricultural advisory systems in Kenya, Tanzania, and Rwanda (Bourne et al., 2017). Their approach was based on measuring knowledge flow and capacity for collective action, considering that the improvement of these two elements is the basis of a modern advisory system. For this purpose, they applied ego network analyses to eleven sites in East Africa. Actors and network boundaries were chosen using a two-step approach. A personal interview was carried out by locally trained personnel, and SN data were collected using a list of questions and coded in an adjacency matrix of binary variables. SNA was processed using UCINET and homophily, density, core-periphery, and average degree of nodes were calculated. The core-periphery structure was measured utilising the model from Borgatti and Everett (2000) and expressed as the correlation between the tested and ideal model. The research shows a limited capacity for collective action within farmer groups and communities in Rwanda and some areas of Kenya. Also, in Tanzania, low connections with external actors were found. These results have shown that there is both a limit and a delay in the introduction of innovation within the population.

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

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

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

In the end, the approach of Fafchamps & Lund was based on Udry's approach with several variations and SNA to analyse the risk-sharing behaviour of Philippine rural households (Fafchamps & Lund, 2003). They surveyed four villages in the Cordillera mountains with 206 rural households. Three interviews were carried out with each household at three-month intervals and recorded. Everyone was asked to identify several people on whom it could be dependent in case of need or to whom the respondent gives support, and they called it the network of insurance. Data were collected on loans, gifts, and asset sales of each individual and all its network partners (household composition, cultivated area, professional skills, and age of head). They discovered that shocks have a dominant effect on informal loans and gifts, but a weak effect on sales of grain and farm animals. The households receive support primarily through networks of families, friends, and acquaintances without a charge of interest on the loans used.

2.5 Conclusions

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

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

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

In the agriculture sector, most of the research - reported in our note - in which SNA was applied are conducted in developing countries. Furthermore, we noted that in a few research authors have only used SNA to calculate the SNA's indicators, instead in most scientific papers authors have used SNA with other methods, frameworks and theories. That means that SNA is a flexible tool and can be applied jointly with several approaches and theories. Other essential points are that in all research SNA was applied: a) to analyse how the existing networks can spread the diffusion of the existing innovation; b) to analyse communication networks and knowledge exchange between actors concerning an existing innovation; c)

to analyse the role acted by the actors involved in the network during the diffusion of innovation and d) to identify how relations support actors to enhance both themselves and their communities.

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

3. Diffusion of innovation in agriculture

In the previous chapters, we saw how Moroccan agriculture has evolved (existing projects, increase in agricultural production and exports), and reported the theoretical bases that can guide the study and interpretation of innovation diffusion, especially in developing countries, such as Morocco.

The theme is particularly relevant because, as stated by Kurt Larsen et al. we cannot underestimate the role of agriculture in supporting socio-economic development and poverty diminution, particularly in developing countries. Guaranteeing agriculture development requires improvement in the sector because agriculture will provide a source of occupation, reduce poverty in rural areas, increase farmers' incomes and stabilise food prices. As is known, the potential of agricultural development to solve the poverty problem is four times greater than other economic areas (Larsen et al., 2009.).

According to Diao, agricultural development determines a change in all economic sectors because increasing farmers' incomes leads to an increase in demand for technical means for agriculture, encourages the private sector, stabilises food prices and limits inflation. This development process allows new activities to come to light, such as the emergence of the food processing industry, diversification into new products and development of new markets (Diao, 2008).

The World Bank reveals that 45% of the developing world's community lives in households dedicated to agriculture, 27% of people live in smallholder households, and most of the population depends on agriculture for their economic sustainability. The sector engenders 29% of Gross Domestic Product (GDP), hires 65% of the labour force, and is recognised as a vital economic development engine.

As stated by the United Nations Food and Agriculture Organization (FAO), the African continent hosts most of the world's agriculture-based countries; a continent where 70% of the individuals live in rural areas, and 90% of the rural community depends on agriculture as a font of revenue (*Africa Review Report on Agriculture and Rural Development (Main Report)*, 2007).

Unfortunately, African countries face several challenges and problems such as market instability, climatic change and economic and political instability, and are often linked to aiding from industrialised countries. Furthermore, considering the international scenario, the World Bank stated that market instability, particularly the rise in food prices, creates a daily problem for more than 2 billion individuals, threatens to increase malnutrition and causes the death of more than 3.5 million children per year (Larsen et al., 2009.). Meanwhile, the global demand for cereals is projected to grow by about 70% from 2010 to 2050 (International Assessment of Agricultural Knowledge, Science, and Technology for Development (Project) & McIntyre, 2009). Espitia et al. announced that the global export supply of food could decrease between 6% and 20%, and global prices could increase 18% on average due to the Covid-19 pandemic. This situation will affect the importation of food by developing and underdeveloped countries such as African countries (Espitia et al., 2020).

Furthermore, the Russian invasion of Ukraine has interrupted the export of cereals from the black sea – considering that the two countries produce more than a quarter of the world's wheat needs. As a consequence, the global food prices increased to their highest levels in 2022, the United Nations has stated (*Ukraine War Drives International Food Prices to 'New All-Time High' | | UN News*, 2022). In addition, FAO declared that cereals, meats, and cooking oils prices rose to all-time, meaning that foods cost a third more than the same last year (*FAO Publications Catalogue 2021*, 2021).

It is evident that all these factors influence African socio-economic stability differently, including Morocco, given that the Moroccan economy is based mainly on agriculture, fishing and tourism. In 2020, the Covid-19 pandemic caused a significant decline in tourist flows throughout the country, but the agriculture sector never stopped; indeed, it has continued to be a source of employment and income for many Moroccan citizens. For this reason, it is necessary to continue to support the development of national agriculture and tackle climate change (e.g., drought and desertification) by introducing innovation.

3.1 Case studies on innovation diffusion in Morocco

With particular reference to Morocco, the study of the processes of innovation diffusion has been tackled by some authors; e.g. Mohamed El Amrani et al. analysed the external and internal factors that encourage the diffusion of innovation, particularly the use of water pumps by farmers in the Fès-Meknès region (el Amrani, 2001). Fatimaezzahra Fouad explored the process of innovation and innovative actions, promoting a fishery product in the Souss Massa region (Fouad, 2017).

Furthermore, the European Training Foundation (ETF) assessed the impact of the innovation process on technologies and skills needed in the Moroccan agri-food sector (*The Future of Skills: A Case Study of the Agri-Food Sector in Morocco | ETF*, 2021.). Instead, Pierre-Arnaud Chouvy et al. analysed the innovation process in which Moroccan growers adopt farming techniques to enhance the quality of cannabis (Chouvy & Macfarlane, 2018).

On the other hand, Basma Okbi et al. studied the process of innovation diffusion, in which Moroccan farmers exchanged their experience, resources and skills with other stakeholders. Moreover, they identified that growers adopt innovations and technologies to improve food legumes production and marketing (Okbi & AMZILE, 2018).

Ilias Majdouline et al. investigated the factors that encourage or impede the diffusion of innovation in Moroccan companies. In this regard, they developed a conceptual model to study the innovation activities carried out by entrepreneurs and identified the main barriers to such initiatives (Majdouline et al., 2020). Kabak Safia et al. investigated the implementation of the direct sowing technique and the determinants of its adoption and diffusion in the province of El Hajeb by local farmers. They analysed whether this innovation is a possible alternative to conventional sowing (El Amrani Mohamed, 2020.).

However, none of the studies cited above considers a particular type of innovation, such as the use of PBs, and no one has conducted studies on the innovation diffusion of PBs in Morocco. This category of products can represent a helpful input in dealing with abiotic stress (such as a jump in temperatures, salinity and drought) that causes a reduction in final yield and quality, and these problems often occur in African and Arabic countries. In addition, through these products, we can guarantee crop harvest, increase farmers' incomes and create new jobs. In a certain way, we will support socio-economic development and stability and regulate internal and external immigration flows.

3.2 Definition and benefits of PBs

PBs became one of the most significant innovation solutions to tackle critical challenges in the agriculture sector. The European Biostimulant Industry Council (EBIC) described PBs as follows:

- *PBs are "materials which contain substance(s) either microorganisms, whose function when applied to plants or rhizosphere is to stimulate natural processes to enhance/benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, either crop quality, independent of its nutrient content"* (*EBIC – The European Biostimulants Industry Council*, 2020).

Du Jardin, contributed, defining PBs as:

- "*any elements or microorganisms distributed on the plants aiming to improve nutrition efficiency, abiotic stress tolerance or crop quality traits, regardless of its nutrient content*" (du Jardin, 2015).

As stated by the EBIC, PBs have no direct effect on biotic stress (fungi, bacteria, insects) and are not part of the regulatory framework for pesticides. Last year, a new Fertilising Products Regulation (FPR) (EU) 2019/1009 entered into force and recognised PBs as a distinct category of agricultural inputs. This regulation will be adopted in the EU area from July 2022. (*EBIC – The European Biostimulants Industry Council*, 2020).

On the one hand, many authors have confirmed several beneficial effects of PBs, especially on: improving plant vegetative growth (foliar and root apparatus) (Bulgari et al., 2015); increasing final yield and quality in many crops (Parađiković et al., 2011); (*Effect of Ascophyllum Extract Application on Plant Growth, Fruit Yield and Soil Microbial Communities of Strawberry*, 2013); (Brown & Saa, 2015); boosting plant tolerance to abiotic stress, such as salinity, drought, jump in temperatures and UV radiation (Petrozza et al., 2014); enhancing water and nutrients uptake, reducing the stress caused during transplantation, allowing a reduction in the dosage of chemical fertilisers (Adani et al., 1998); (Vernieri et al., 2006), and fostering soil restoration (Tejada et al., 2011).

3.3 Diffusion and adoption of PBs

Industrialised countries lead the diffusion and adoption of PBs to a broader number of countries (within Europe and the rest of the world) (*EBIC – The European Biostimulants Industry Council*, 2020). In this regard, makers create relationships and synergies with different stakeholders (ministries, universities, research institutes, agronomists, distributors) to encourage the diffusion of PBs in a social context.

The use of PBs is widespread around the world. Data provided by respondents to the EBIC's survey reveal that more than 3 million hectares are treated using PBs every year in the EU area (*EBIC – The European Biostimulants Industry Council*, 2020). Indeed, FAO stated that the total global area of agricultural lands is approximately 4,869 million hectares. As such, 0.3% of all agricultural land in Europe is treated with PBs (*FAOSTAT*, 2020). Moreover, as stated by Markets&Markets in their "PBs Market – Global forecast to 2025" report, the global PBs market in 2016 covered an area of around 14.3 million hectares and is expected to reach 27.6 million hectares in 2022, resulting in a CAGR of more than 11% per year (*Biostimulants Market by Active Ingredient, Crop Type, Application Method, Form - Global Forecast 2025*, 2017).

In terms of turnover, the global market size for PBs in 2016 was approximately 1.45 billion euros and is expected to reach approximately 2.66 billion euros in 2022. The main drivers for global PBs market growth beyond Europe are North America, South America and Asia Pacific (*Biostimulants Market by Active Ingredient, Crop Type, Application Method, Form - Global Forecast 2025*, 2017).

As stated by EBIC, the reasons for this growth worldwide are:

- growing production of innovative and eco-friendly products targeting specific needs. Often those products are allowed in organic farming therefore, farmers are more inclined to adopt innovation.
- a rise in global demand for food and limited natural resources.
- increased consumption of organic food linked to consumer health awareness.
- the constant fluctuation in commodities prices has encouraged growers to optimise the use of mineral fertilisers.
- restriction on the use of commercial PPPs imposed by the EU guidelines according to European Parliament Resolution of 20 October 2021 on a farm-to-fork strategy for a healthy, fair and environmentally-friendly food system.
- focus on increasing final yield and food quality, which influence farmer profitability and consumer satisfaction. PBs were initially adopted in organic farming and then have gradually been introduced in conventional agriculture to tackle economic and sustainability imperatives (*EBIC – The European Biostimulants Industry Council*, 2020).

Considering the constant increase in PBs use in the world, we believe that the diffusion and adoption of these products in Africa, particularly in North Africa, will allow Maghreb countries to overcome the

challenges related to climate change and market-agricultural production instability. Moreover, it will permit these countries to produce and export quality food products according to international market standards, ensuring sustainable economic development and socio-political stability.

For this reason, our research aims to compensate for the lack of studies related to the diffusion of PBs in Morocco. It analyses the diffusion and adoption of innovation in Morocco based on a network approach (ego network) to explain how the egos' characteristics and their network of relations influence the diffusion and adoption of innovation. Based on the final results, we will be able to understand how to support and improve the diffusion of innovation in Morocco.

4. MATERIALS AND METHODS

This section introduces the overall study setting, study design, sampling, data collection, data preparation and data analysis used to achieve our research goals. The study was carried out by analysing agriculture in the Fès-Meknès region and adopting a personal network approach to investigate innovation diffusion.

4.1 Study setting

The study is focused on the Fès-Meknès region. It is located in the north of the kingdom and its capital is Fès. We chose this region for several different reasons:

- As already highlighted in the first chapter, this region has been characterised by an effective growth in agricultural production.
- The relative proximity to Europe and the presence of The National School of Agriculture of Meknès (ENA) favour the creation of a cultural climate more inclined to introduce innovations (see Figure 18).
- ENA is located in Meknès and is considered a prestigious public institute, appreciated for its high education, research, services and collaboration with various public and private organisations and institutes in Morocco and outside (France, Italy, the USA, Spain, the Netherlands, Arab countries).

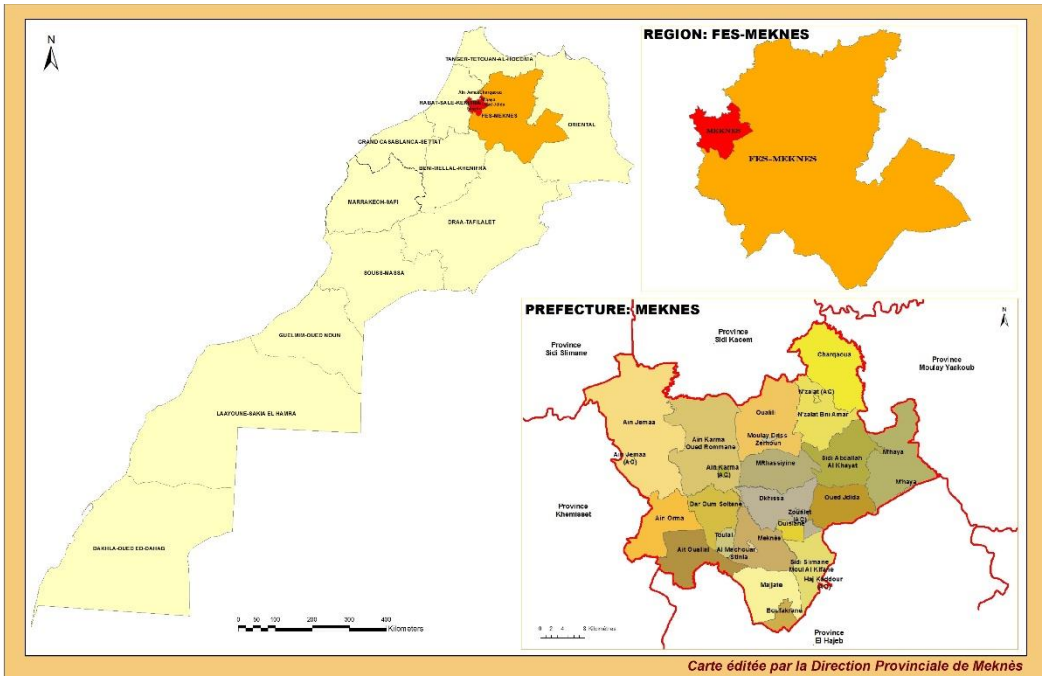
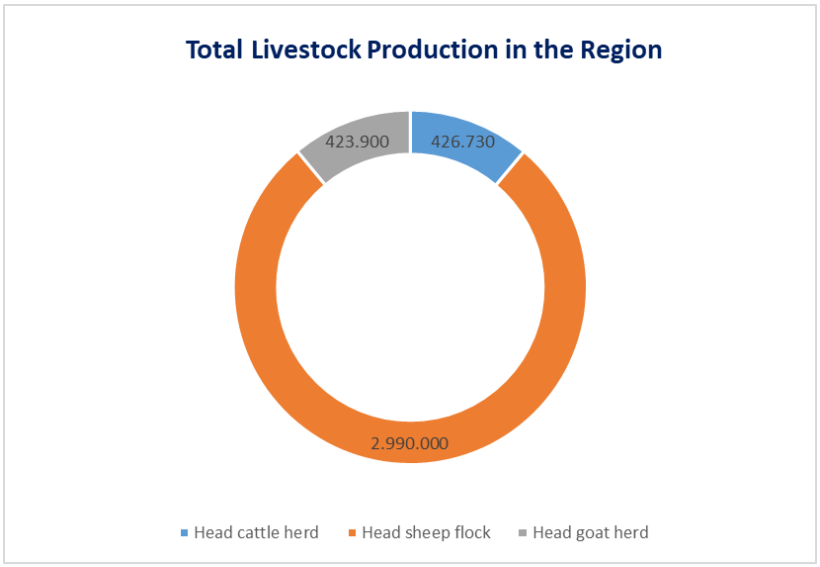


Figure 1 - Fès-Meknès geographic map according to Regional Directorate (جهة فاس مكناس, ٢٠٢٠)

Figure 2 shows the region's livestock sector distinguished by 426,730 head cattle herd, 2,990,000 head sheep flock and 423,900 head goat herd. In addition, the main crops cultivated are cereals, with a total yield

of 1,487,378 tonnes; fruit, with a total yield of 646,139 tonnes; olives, with a total yield of 627,726 tonnes; and red meat, with a total production of 69,200 tonnes.



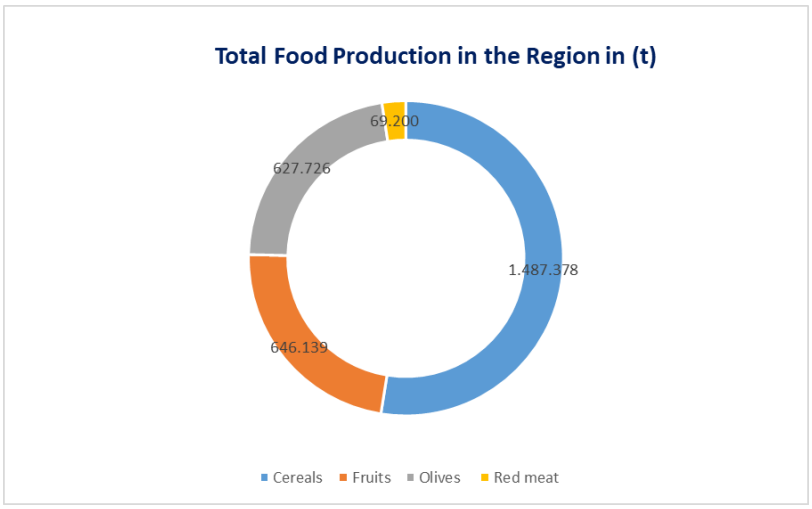


Figure 2 - Actual food and livestock production in the region.

4.2 Study design

We adopted a two-phase analysis methodology to achieve the research objectives based on the theoretical background: 1) the first phase aimed to understand and characterise the network of relationships in which farmers operate. For this phase, we used social network analysis, particularly the ego network approach, for the reasons illustrated below, and 2) the second phase intended to identify the factors that significantly influence knowledge diffusion and adoption (or not) of innovation, particularly PBs. In a regressive model, the farmers' attributes and the characteristics of the networks were included as independent variables, adopting a binary logistic regression.

To use SNA there are two types of network research designs: the personal network design and the whole network design.

As we tried to underline in the chapter on the theoretical background, SNA can be developed based on techniques and modalities that are very different. The first is the substantial difference between the approaches that represent the whole network design and those that aim to represent the ego network. The first represents an entire social system, and the second describes the relationships maintained by the egos (which in this research are farmers).

We pursued the objectives of our research by adopting a **personal network research design (PNRD)**, according to which the subjects under investigation - egos - are called to directly describe the network of relationships they have, without the subjects identified in that phase (alters) becoming, in turn, the object of investigation.

As reported by Borgatti et al., personal (egocentric) network design has several characteristics and advantages, such as (Borgatti et al., 2018):

- It allows analysis of a specific network characterised by its small size.
- Interviewees can be sampled at random from a large population.
- It fits well within a standard survey approach (Marin & Hampton, 2007).
- Personal network questions can be readily added to a standard survey instrument.
- The personal network approach makes it possible to sample randomly from a large population and then generalise results to that population.
- It makes it possible to obtain detailed and quality data about the local network because surveys can be completely anonymous, and the alters' real names are not required. This means respondents feel protected in providing data.
- There is no restriction to consent to the respondent mentioning any individual they like.
- The information collected about alters' characteristics and alter-alter ties are collected entirely from the respondent (ego).
- There are no problems concerning the processing of data and visualisation of the results.
- It limits costs and the time required to collect data.
- It creates many stand-alone networks.

Personal network design has some limitations, such as:

- In contrast to the whole network, the personal network approach avoids follow-up interviews of named alters, and therefore the ego operates as the informant for both his relations with the alters and his perception about alters' relations with each other (accuracy of data).
- Calling egos to report on every alter can be very time-intensive.
- We lose data on the global pattern of connections.

In case we apply a personal network, we need to sample a population to obtain a set of respondents and then collect from each ego the list of alters they are connected to, along with the nature of the ties connecting them to egos, alters' characteristics, and the respondent's perceptions of the ties between the alters.

For our research, we adopted a personal network design because the adoption of innovative practices by the egos does not depend only on their attributes (demographic or socio-economic) but also on factors connected to their social environment and on their relationships with other subjects (alters). For this reason, we need to adopt an ego network approach to include all classes of factors that influence the adoption and diffusion of innovation.

Using an ego network design, we can create a personal network for each farmer, and we can identify: the alters responsible for the diffusion of knowledge related to PBs, the brokerage position, farmer's attributes, farmer-alters relationships, the type and quantity of information exchanged between them, the farmer's perception about alter-alter relationships.

Below, we list the characteristics of the ego network collected through the survey:

1) Ego Attributes: makes it possible to collect different information about egos (farmers), such as specialisation, age, educational level, profession, farm size, membership in professional organisations, knowledge about PBs, use of PBs, and reuse of PBs.
2) Ego-Alter ties: makes it possible to identify ego-alters relations, analyse the information exchanged related to technical topics (agricultural techniques, fertilisers and PBs), and assess ego-alters relationship intensity.
3) Alter-Alter ties: makes it possible to collect information related to the ego's perception about alter-alter relationships. The survey of Alter-Alter ties offers certain potential advantages and disadvantages:
    - Advantages: determining the presence in the ego networks of so-called "structural holes", potentially highlighting brokerage positions. In this regard, structural holes are detected by measuring degree, density, efficiency, effective size, constraint and hierarchy measures.
    - Disadvantages: egos may have limited knowledge of the ties between their alters. This leads to cumbersome and longer individual interviews, with the risk of running out of resources available to the interviewer or obtaining unreliable answers from the interviewees.

Information obtained from all points (ego attributes, ego-alter ties and alter-alter ties) enables the calculation of SNA indicators, such as crosstabs ego-alter, crosstabs alter-alter, composition, heterogeneity and structural holes.

The other method used in our research is **Binary Logistic Regression.** It predicts the probability of an observation falling into one of two categories of a dichotomous dependent variable (e.g., know PBs, use PBs and reuse PBs) based on more independent variables that can be either continuous or categorical (farmer attributes and network of relationships). We aimed to identify the significant variables that influence farmers to know PBs, use PBs and reuse PBs in the future.

4.3 Sampling

The survey covered farms in the Fès-Meknès region, particularly farmers who specialise in high-value STAR crops. This category of entrepreneurs belongs to Pillar I of the GMP.

These entrepreneurs are more sensitive to adopting and diffusing innovation than traditional farmers (who belong to the Pillar II of the GMP). Furthermore, these entrepreneurs are professional landowner farmers, are usually members of agricultural cooperatives, usually have solid connections and relationships with the main stakeholders in the sector and have the skills and economic power to introduce new certified technical means to their farms, which will enable them to produce and market certified food to the most profitable markets (EU, USA, GCC, Russia).

In Morocco, obtaining a database with farmers' contacts proved to be hard work due to several reasons, such as:

- Organisation: digitalisation in the country has not been extensively adopted by the public institutes; therefore, farmers are not IT codified yet.
- Collaboration: people and public organisations tend to conceal information.

Nevertheless, we coped with these barriers through the academic co-supervisor (from ENA) support who has in-depth knowledge of the local context and strong relationships with the ADA, cooperatives, farmers, and other stakeholders.

We planned in our research to carry out at least 70 interviews with local farmers. Individuals were identified from a list provided by ADA.

This list contains some names of agricultural cooperatives in which farmers are members, but the information reported in the list does not furnish precise information about the number of the farmers belonging to Pillar I of the GMP in the region. Therefore, other growers were identified through snowball methods.

Therefore, we visited the agricultural cooperative in the locus to obtain farmers' contacts (name and mobile phone).

All stakeholders (farmers, cooperatives, ADA) were informed about the aim of the thesis and existing cooperation between the ENA and UNIBO (Alma Mater Studiorum, University of Bologna, Italy) by phone and e-mail.

We collected 135 farmers' contacts and got in touch with them to gain their willingness to take part in an interview. Taking into account the burdensome questionnaires only 80 farmers out of 135 accepted our request.

Before visiting the farmers, appointments were fixed by phone to ensure the growers' availability.

Therefore, the sample made contains all types of farmers, which are very limited compared to other realities as an entire population (which requires statistical analysis). The sample made is sufficiently significant for the Fès-Meknès region as confirmed also by the academic co-supervisor.

However, despite the limited investments for the survey activity in a period of almost total paralysis due to the pandemic, it was possible to interview only a small sample, but still helpful in characterising the region. All types of farmers (specialised in fruits, vegetables, cereals and other crops farming) are present in our sample.

Even if the sample had been larger, part of the data would remain perfectly aligned with the data of the analysed sample because the data obtained are not entirely quantitative but most of them are qualitative.

Indeed, the qualitative data that refer to the egos' characteristics and the contents of the information flowing on the network do not undergo significant variations in comparison to the sample dimension. Moreover, each class's needs (more or less numerous) do not vary according to the size of the class itself. For this reason, the sample is significant because it includes a sufficient number of all types of farmers, even if the sample does not represent the farmers' universe of the region.

On the other hand, the quantitative data that define the number of different types divided into classes, more sensitive to innovation, may undergo numerical variations, which give an economic indication and an orientation for the actions to be carried out in the marketing field.

4.4 Data collection

We collected data through questionnaires, carried out "face-to-face" at the individual's farm in April and May 2021. Each interview lasted 90 minutes and was recorded.

A draft questionnaire was prepared in English and then translated into French to collect data. Arab is an official language in Morocco, and French is a second language usually used in universities, public offices and the private sector. However, the predominant language of the middle classes is Arab. For this reason, interviews were carried out only in this language.

We decided to adopt a mixed interview technique using a questionnaire comprising two sections, to simplify data collection.

The first section adopted a paper questionnaire. The interviewer compiled the document and then reported all data on file at the end of the day, taking advantage of the recordings.

The second section was carried out in CAI (computer-aided interview) mode by filling out a specially-prepared Excel file.

The paper questionnaire comprised 8 sections as follow:

- **First section**: a general section aimed at collecting information about the farm name, farm specialisation, the location of the farm and whether the farm has branches or not.
- **Second section**: this section was dedicated to collecting information about the respondent, such as name, age, educational level, job position, contacts, years of experience in the sector, and whether or not the respondent is the technical manager of the farm.

  Information concerning the educational level and years of experience in the sector makes it possible to understand how the respondent makes decisions and identifies the sources of information that would enable him to access knowledge.

  Information about the job position and whether the respondent is the technical manager makes it possible to understand their decision-making power.
- **Third section**: was dedicated to collecting data about the farm's size and origin (property or rental), the surface irrigated, the crops cultivated and final yield based on the surface, awareness of organic farming and the cultivation regime adopted.
- **Fourth section**: was focused on collecting information about the labour units. In Morocco, a farm with a high number of labourers means that the farm is large and consequently, would have a production capacity to justify the use of fertilisers and PBs. We believe that a farmer who uses fertilisers would be more likely to use PBs.
- **Fifth section**: was dedicated to collecting information about the farm's production and commercialisation. This section collects information about the crops cultivated, total production and the commercialisation of food products for national and foreign markets. In the latter case, it was necessary to report the names of the countries which the food products were destined for. The goal was to understand whether all production is destined for the local market. In this case, farmers will not be obliged to use specific technical means for agriculture. Instead, if part or all production is destined for the foreign market, the farmer must comply with international parameters. Consequently, the farmer would be obliged to use certified products.
- **Sixth section:** the goal was to know whether the farmer belongs to a local cooperative or farmers' group, which allows him to access knowledge. Another goal was to understand if the farmer has obtained any certification for food commercialisation as a proxy of his ability to export abroad and use certified technical means.
- **Seventh section**: we listed the names of the best-known PBs sold in Morocco. Then we asked the respondent if he knew about PBs, if he had ever used them, if he currently uses them and if he intends to use them in the future.
- **Eighth section**: in this section we asked the farmer to indicate the farm's turnover recorded in the last three years, to understand whether the farm grew or not.

From this questionnaire, we collected two kinds of data for our regression analysis: a) the ego's attributes represent part of the independent variables, and b) the answers related to knowing PBs, using PBs and reusing PBs represent the dependent variables.
The paper questionnaire is reported in the annex section (Appendix A).

The Excel file questionnaire was finalised for use in SNA. The aim was to collect data related to ego-alters relationships and ego's perceptions concerning alter-alter relationships.
Based on the two goals mentioned above, we created two sheets in the Excel file:

- **First sheet**: aimed to collect data relating to ego-alters relationships. To reach this result, we structured the sheet into four sections:

  a) Name generators:

  - First part: the aim was to invite the respondent (ego) to list a maximum of 20 individuals (alters) with whom the respondent had discussed matters relating to the agricultural sector.
  - Second part: the goal was to ask the ego to define the relationship with each alter listed. In this regard, to facilitate ego, the interviewer had a list containing different types of relationships (e.g., family, friend, consultant, farmer and the rest).

  b) Agriculture techniques section:

  - A sub-section to investigate the type of information provided by each alter to the ego concerning agricultural techniques.

    For agricultural techniques, we prepared a list containing a series of specific topics. A simple code number was assigned to each specific topic to facilitate the completion of the questionnaire; see the table below:

Agricultural Techniques Topics:	Code
Fertilisers (NPK, commodities, nutritional deficiencies, nutritional plan)	1
Pesticides (PPP, PGR, herbicides)	2
New varieties (seeds, crops, grass planting)	3
Soil (tillage, fertility, salinity, drought)	4
Biotic stress	5
Abiotic stress	6
Irrigation (irrigation system)	7
Agricultural Production Systems	8
National funding	9

    Then ego was invited to indicate the specific topic (s) discussed with his alter (s). Consequently, the interviewer had to report the code number related to each topic (s) in the specific box. This part aimed to identify the information provided by alter (s) to the ego.

- A sub-section with the same function aimed to identify the specific topic (s) that the ego provided to his alter (s).
- A sub-section to investigate the intensity of the relationship between the ego and alter (s). The interviewer asked the ego the number of times he had spoken to each alter in the last six months.

c) **<u>Fertiliser section</u>**: this section reported alters who the ego talked to about soil fertility and fertilisers. This section had four parts:

- First part: the purpose was to identify the specific topics provided by each alter to the ego.

  For fertilisers, we set up a list that contains a series of specific topics. As with the previous section, a simple code number was assigned to each specific topic to facilitate the completion of the questionnaire; see the table below:

Fertiliser topics:	Code
Needs/reasons we may use fertilisers (NPK, microelements, commodities such as urea, DAP, MAP)	1
Technical positioning (period of application, dosages, crops)	2
Benefits expected (increase soil fertility, increase final yield and quality)	3
Organic fertilisers	4
Fertiliser selection (features, chemical composition, benefits expected, prices, technical positioning)	5
How to use it in a nutritional plan?	6

  Then ego was invited to specify the specific topic (s) discussed with his alter (s).
- Second part: the intent was to identify the specific topic (s) that the ego provided to his alter (s), reporting the code number (s) related to the topic (s) discussed.
- Third part: we asked each ego which of his alter (s) supported him in preparing a nutritional plan.
- Fourth part: we asked each ego whether or not he helped each of his alters in drafting their nutritional plan.

d) **Biostimulants section**: this reported alters with whom the ego discussed PBs matters. This section had four parts:

- to investigate the specific topics provided by each alter to the ego concerning PBs, we developed a list that contains specific topics (see the table below):

PBs Topics:	Code
Knowledge of PBs	1
Needs/reasons we may use PBs (stimulate I and II plant metabolism)	2
Technical positioning (period of application, dosages, crops,)	3
Organic PBs	4
How to use it in a nutritional plan?	5
Possibility to mix it with PPPs, PGRs and fertilisers.	6
PBs selection (features, chemical composition, benefits expected, prices, technical positioning)	7
Benefits expected (increase plant resistance to abiotic stress, increase fruits quality and final yield)	8

Then the ego was invited to detail the specific topic (s) discussed with his alter (s).

- Second part: aimed to examine the information provided by the ego to alter (s).
- Third part: the interviewer asked each ego which (if any) of his alter (s) suggested the use of PBs.
- Fourth part: to ask the ego if he suggested the use of PBs to his alter (s).

- **Second sheet:** aimed to collect data related to the ego's perceptions about alter-alter relationships. The interviewer asked the ego to report if, according to his perceptions, a certain alter has a relationship with another alter present in his network. To collect data, we built a matrix in which the alters are reported in one column and one row (20 alters x 20 alters).

The data collected through these questionnaires were used to perform SN analysis. The questionnaire is reported in the annex section (Appendix B).

4.5 Data preparation

The data obtained from the 80 double questionnaires were carefully controlled, taking advantage of the recordings.

Data from the paper questionnaire (available in Appendix A) were set up in an Excel file, focusing on variables more frequently used in analysing farmers' behaviour, such as specialisation, age, profession, education level, farm size, employee numbers, and membership of a professional organisation. Also, data about the knowledge, use and reuse of PBs were retained, to perform binary logistic regression analysis.

To test different modelling options, we also performed data transformation of three continuous variables (age, education level and farm size) into class variables, retaining in the dataset both the original and the transformed variables. More specifically:

- Age: we divided ego age into three classes 20-40, 41-60 and 61-80.
- Education level: we classified ego's education level into five classes, based on the Moroccan study system.

- Farm size: we organised farm size into classes, 01-10 (ha), 11-20 (ha), 21-30 (ha), 31-40 (ha), 41-50 (ha), and 51-1400 (ha).

A selection and recodification of data were performed for the second questionnaire too. Specifically:

- Alters were recorded in five typologies (public organisation, research institutes, acquaintances, professionals and suppliers of technical means).
- Information about agricultural techniques: we reported the total number of topics provided by alter-ego and ego-alter.
- Intensity of the relationships: we reported the number of times the ego spoke with each of his alters in the previous six months.
- Information about fertilisers: we reported the total number of topics provided by the alter to the ego.
- Information about PBs: we reported the total number of topics provided by the alter to the ego.
- Alter-alter ties: we retained data about the existence (or not) of ties, as perceived by the respondent.

Combining data retained from the two questionnaires, we prepared a dataset which could be analysed and uploaded onto E-net software.

4.6 Data Analysis

First, we developed a frequency analysis of the specific topics discussed between the ego and the ego's alters. After identifying the most relevant specific topics, we related them to the ego's characteristics, such as education level, age, specialisation, farm size, membership in a professional organisation and professional role. Then, we processed the data into a Pivot table, computed the relative frequency and represented the data in tables.

The second step aimed to analyse the data network using E-Net software. It processed data concerning the ego's attributes, ego-alters ties, and alter-alter ties, permitted the visualisation of the ego network and provided various standard network measures. Based on literature (Halgin & Borgatti, 2012; Introduction to Social Network Methods: Table of Contents, 2005) we report below the explanations for each measure created and generated by the software:

- **Crosstabs (ego-alters and alter-alter)**: we can create the aggregate crosstabs of node attributes, e.g., we can compute the total number of personal network ties within and across the acquittances category (e.g., how frequently did farmers nominate friends alters?). Alternatively, we can do crosstabs of alter characteristics with other alter characteristics, e.g., we can compute the number of farmers' alters that had ties with agronomist alters (data reported in chapter 5, tables 62, 63, 67, 68, 71 and 72).

The software computes the chi-square (and a p-statistic which is not adjusted for autocorrelation) and Yule's Q statistics during data processing. We report below Yule's Q values and the related interpretations.

Yule's Q values	Interpretation
0	means no association between the variables
0 to ± 0.29	means a very small association between the variables.
-0.30 to -0.49 or 0.30 to 0.49	means a moderate association between the variables.
Q = 0.50 and 0.69 or -0.50 and -0.69	means a substantial association between the variables.
Q > 0.70, or < -0.70	means a very strong association between the variables.
1 or -1	means that there is a perfect association between the variables.

Table 5 – Yule's Q values and interpretation of the values.

- **Composition**: is based on the resources an ego can access through his relationships with different alters. Composition computes categorical and continuous variables. For example, we might be interested in evaluating the information obtained about PBs regarding alters' relations type (data reported in chapter 5, tables 64, 68 and 73).
- **Heterogeneity**: it is appropriate to examine the diversity of alters in each ego's network for specific continuous and categorical variables. For categorical variables, E-NET offers measures of heterogeneity, such as "Agresti's IQV" (*Statistical Analysis of Qualitative Variation on JSTOR*, 1978).

  Egos whose alters are the same with respect to some categorical attribute (e.g., role) will have small heterogeneity scores, while those with more diversity in their ego networks will have a value closer to 1. For continuous variables such as age and farm size, E-Net computes the standard deviation of the alters' values (data reported in chapter 5, tables 65, 69, and 74).
- **Structural holes**: indicates the absence of ties between two alters within an ego network. The unrelated alters allow the ego not to have redundant information, and also permit the ego to benefit from a good position in the network (being recognised as the source of knowledge). A network abundant in structural holes allows the ego to control knowledge and have visibility within the network. Measures corresponding to the potential for brokerage are degree, density, effective size, efficiency, constraint and hierarchy.
- **Density** is the number of ties divided by the number of pairs. It relates to the percentage of all possible ties present in each ego network. When the score is higher, all alters spread information to all other alters, implying that alters are integrated into very dense local structures. Instead, when the score is lower, it indicates that alters live in a small network and are

unconnected. Therefore, in all ego networks, when the density value is 0, it reveals that alters are unconnected to each other.

- **Effective size** can be described as ego's **degree** (the total number of ego's alters) minus the average number of ties each alter has to other alters. The effective size of the ego's network indicates something about the ego's impact.
- **Efficiency** rules the effective size of the ego's network by its actual size. Efficiency reveals how much impact the ego is getting for each unit invested in using ties.
- **Constraint** refers to the extent to which the ego's ties are to alters connected to other alters.
- **Hierarchy** describes the nature of the constraint on an ego. If the total constraint on the ego is concentrated in a single other alter, the hierarchy will have a higher value. Indeed, a lower hierarchy value means that alters do not have a solid position to control the information flow in the network because small groups of alters do not hierarchically organise themselves into the network (data reported in chapter 5, tables 66, 70, and 75).

Therefore, the **minimum brokerage opportunities** are depicted by limited efficiency and effective size, and high constraint and density measurements. This result means that the ego's network has all alters connected, creating a closed network.

Instead, **maximum brokerage opportunities** are described by high efficiency and effective size, and low constraint and density. The ego has many alters unconnected to the other alters in the network.

For personal network analysis, we examined the following data:

- The number of specific topics discussed between egos and egos' alters depending on the main topics (agricultural techniques, fertilisers and PBs).
- Egos' perceptions about alter-alter ties.
- Egos' attributes.

Each variable was represented as reported below:

- Specialisation: egos' specialisation (cereals, fruits, oils, vegetables and viticulture).
- Alters' relations: public organisations, research institutes, acquaintances, professionals, and suppliers of technical means.
- Agricultural technique topics discussed: the total number of agricultural technique topics discussed between egos and egos' alters.
- Fertiliser topics discussed: the total number of fertiliser topics discussed between egos and egos' alters.
- PBs topics discussed: the total number of PBs topics discussed between egos and egos' alters.
- Public organisations.

- Research institutes.
- Acquaintances.
- Professionals.
- Know PBs.
- Use PBs.
- Reuse PBs.

After processing the network data on E-Net software, we obtained three outputs: output for agricultural techniques, output for fertilisers and output for PBs.
The three outputs measure the characteristics of the networks and differ from each other because, each time, all the existing relationships for agricultural techniques, fertilisers and PBs were considered. The measures mentioned above characterise ego networks.

In the third step, we used the new variables obtained from E-net software for further analysis; in particular, we employed SPSS software to make a binary logistic regression.
Binary logistic regression is helpful when we are looking to model event probability for a categorical response variable with two values.
The aim of using binary logistic regression is to relate variables regarding the respondent profile and those characterising his network with the egos' attributes, to investigate which variables could influence:

- Ego's knowledge of PBs.
- Ego's adoption of PBs.
- Ego's decision toward possible reuse of PBs.

The variables related to the respondent's profile considered in the definition of the model were the following:

- Specialisation:
- Age or age class;
- Education level or education level class;
- Profession;
- Farm size or farm size class;
- Employee numbers;
- Member of a professional organisation.

As regards the variables relating to networks, having examined the results of ego network analysis, we selected as possible independent variables:

- Network composition: PBs topics discussed AVG or PBs topics discussed TOT.

- Network heterogeneity: alters' relationships HET or alters' relationships IQV or PBs topics discussed SD.
- Network structural holes: SH Constraint (isolates and pendants alter-alter ties) or SH Hierarchy (nature of the constraint on an ego).

The independent variables were selected for each network related to agricultural techniques, fertilisers and PBs.

To make a binary logistic regression analysis, we have to create models. To appraise the model, we used three different models: Backward Elimination (Conditional), Backward Elimination (Likelihood Ratio), and Backward Elimination (Wald).

- Backward Elimination (Conditional): the system eliminates the variables gradually. Elimination testing is centered on the probability of the likelihood-ratio statistic based on conditional parameter estimates.
- Backward Elimination (Likelihood Ratio): the system eliminates the variables gradually. Elimination testing is based on the probability of the likelihood-ratio statistic centred on the maximum partial likelihood estimates.
- Backward Elimination (Wald): the system eliminates the variables gradually. Elimination testing is centred on the probability of the Wald statistic.

Therefore, we used the three methods with egos' profile variables and variables relating to networks in different combinations to create 72 models for each data network (agricultural technique, fertilisers and PBs) and dependent variable (know PBs, use PBs, reuse PBs) for a total of 1080 (*) probability models.
(*) each data set: agricultural techniques, fertilisers and PBs. Since the dataset relating to PBs contains a lower number of records (because of 80 egos, only 59 egos answered the PBs section), it was considered appropriate to carry out an analysis also concerning two other data sets also relating to agriculture techniques and fertilisers but containing records relating only to the egos also present in the smaller dataset related to PBs. Therefore, we reached 1080 estimated models (72*5*3).

Based on our goal, we ran the analysis on SPSS software, and for each model, we analysed the following outcomes to select the effective model:

- case processing summary.
- dependent variable encoding.
- Block 0: Beginning Block:
    - classification table.
    - variable in the equation.
    - variable not in the equation.

- Block 1: depends on the method used, e.g., Method=Backward Elimination (Wald):
    - omnibus tests of model coefficients.
    - model summary.
    - classification table.
    - variables in the equation (examined based on significance value and odds ratios).
    - variables not in the equation.
    - casewise list.

Based on the outputs obtained from SPSS software, we selected some models, focusing on the models characterised by a statistical significance:

- Cox&Snell R square and Nagelkerke R square values: are interpreted in the same manner, when $0<R^2<1$ indicates that variables fit the selected model. Instead, $R^2>1$ indicates that variables do not fit the selected model.
- Significance fixed at 5%: $P<0.05$ indicates that the variable is significant to the model selected. Otherwise, if $P>0.05$, the variable is insignificant, and we cannot consider it in the selected model.
- Exp(B) "odds-ratio": if the value Exp $B>1$, it means that the variable is preparatory to the final result; instead, if the value Exp $B<1$ it means that the variable under consideration is not important, even if it is significant. In this case, we can eliminate the variable from the model because it does not affect the final result (e.g., know PBs, use PBs or reuse PBs), and if the value Exp $B=1$, it means some probability of the event occurring between two situations.

5 RESULTS

5.1 Frequency of the topics discussed by egos and their alters

This section reports analysis results concerning the total number of main and specific topics discussed by egos and their alters, in relation to certain ego attributes. The main topics are agricultural techniques, fertilisers and PBs.

We observed that the total number decreased for each main topic as we analysed specific topics, from agricultural techniques to fertilisers and PBs.

Before analysing each main topic, we want to describe the sample of 80 farmers, given that our sample is not representative of the Fès-Meknès region because we do not have all the data relating to the region's farmers region. Below are four tables that describe our sample.

Age	Total number of egos based on their education level					
	Illiterate	**Primary school**	**High school**	**Degree**	**PhD**	**Total**
20-40	0	2	33	4	2	**41**
41-60	2	7	20	6	0	**35**
61-80	0	3	0	1	0	**4**
Total	**2**	**12**	**53**	**11**	**2**	

Table 6 - Distribution of farmers classified by age and education level.

Farm's size	Total number of farms based on their specialisation					
	Cereals	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01-10	13	12	1	3	0	**29**
11-20	4	22	0	4	1	**31**
21-30	0	7	0	0	0	**7**
31-40	1	1	0	0	0	**2**
41-50	0	1	0	0	0	**1**
51-1400	0	10	0	0	0	**10**
Total	**18**	**53**	**1**	**7**	**1**	

Table 7 - Distribution of farms classified by farm size and specialisation.

Member of a professional organisation	Total number of egos
No	**18**
Yes	**62**

Table 8 – Egos' membership to a professional organisation.

Professional role	Total number of egos
Extension agents	**1**
Managers	**68**
Technicians	**11**

Table 9 – Egos' professional role.

The tables above describe the sample from different points of view. Our sample consists of farmers with high school education. Most of them are young individuals aged 20-40, and others are 41-60 years old. Next are farmers with a primary school level of education and a bachelor's degree. In this case, most farmers are aged 41-60.

Most of the growers specialise in fruit farming, especially on farms of 11-20 (ha) and 01-10 (ha). To a lesser extent, we observed the presence of other farmers specialising in cereal crops. This category of farmers is concentrated on farms of 01-10 (ha) and 11-20 (ha).

Furthermore, we noted that 77.5% of farmers belong to a professional organisation, 85% are managers and 14% are technicians.

5.1.1 Frequency of the specific topics concerning agricultural techniques

Agricultural techniques	Absolute Frequency	% ego-alters relations
New variety	359	4.48
Fertiliser	358	4.47
PPPs	339	4.23
Soil	317	3.96
Biotic stress	214	2.67
Abiotic stress	196	2.45
Irrigation	186	2.32
Cultivation system	172	2.15
Public funding	157	1.96

Table 10 - Frequency of the main topics discussed by egos-alters concerning agricultural techniques.

Table 10 shows the absolute frequency of the specific topics discussed by egos-alters concerning agricultural techniques. The left column lists the specific topics, while the right column shows the absolute frequency for each specific topic discussed by egos and their alters. The absolute frequency reported relates to the number of times egos talked to their alters about a specific topic (e.g., for new varieties it was 359 times, for fertilisers it was 358 times, and so on) based on the total number of egos (80).

We noted that when egos talked to their alters about "agricultural techniques", the specific topics most frequently dealt with were new varieties, fertilisers, pesticides and soil matters.

Moreover, we noted that, on average, each ego discussed new varieties, fertilisers, PPPs and soil topics four times with alters. Nevertheless, this tendency diminished as the ego discussed biotic and abiotic stresses, irrigation, cultivation system and public finding topics with alters.

We hypothesised that farmers might prioritise these technical topics because they considered them more essential to tackling natural adversities (insects, fungus, bacteria) and increasing final yield than other topics. Another reason could be the GMP, which supported farmers in introducing agricultural means, such as seeds, fertilisers and pesticides.

As we mentioned, there are specific topics discussed less frequently by egos and their alters, such as biotic and abiotic stresses, irrigation, cultivation system and public funding. Possibly, this is due to:

- Geographic location: farms are located in the north of Morocco, an area with a favourable climate for crop farming.
- Public efforts: farmers who belong to pillar I of the GMP have adopted the irrigation water system, which is not the primary issue nowadays.
- GMP: questionnaires were carried out in April and May 2021, and the GMP ended in 2020. For this reason, perhaps farmers are not talking about public funding as much as they did in the past.
- Farm specialisation: farmers who belong to pillar I of the GMP are recognised as experts in the agricultural sector for both cultivation and exports. For this reason, we found that more farmers were interested in new varieties, fertilisers and PPPs.

We focused on fertilisers because these products give us an idea of farmers' needs relating to plant nutrition. We believe that farmers who discussed fertiliser matters are more inclined to discuss PBs (consider that PBs are under fertilisation regulation). Therefore, focusing on fertilisers, we need to analyse the frequency that egos talked to their alters about fertilisers based on egos' attributes.

	Education level					
Age	**Illiterate**	**Primary School**	**High School**	**Degree**	**PhD**	**Total**
20-40		12	145	10	23	190
Relative frequency		6	4.4	2.5	11.5	
41-60	8	26	81	37		152
Relative frequency	4.0	3.7	4.0	6.2		
61-80		12		4		16
Relative frequency		4.0		4.0		
Total	8	50	226	51	23	358

Table 11 - Frequency of discussions about fertilisers, based on egos' age and education level.

From table 11 and based on the absolute frequency maximum values, we observed that egos who spoke about fertilisers can be broken down as follows, based on their education level and age: high school (egos aged 20-40 and 41-60), degree (egos aged 41-60 and 20-40), primary school (egos aged 41-60), PhD (egos aged 20-40) and illiterate (egos aged 41-60).

For further analysis, we want to understand in detail for each ego how many times he talked about fertilizers with his alters based on the ego's education level and age. Therefore, we used table 6 to calculate the relative frequency.

In addition, we will describe all tables in the first section of results based on relative frequency.

Analysing table 11 and based on the relative frequency, we can deduce:

- For the class of young people aged 20-40, we can see that farmers with a primary school qualification have a higher frequency than those with a high school qualification and a bachelor's degree. Farmers in this class probably realise they do not have enough information about fertilisers and therefore need to look for them.

  The class with the highest frequency of discussing fertilisers is composed of farmers with a doctorate diploma. Farmers in this class have a higher cultural level than others in other classes. This result means that these farmers are familiar with fertilisers and are looking for constant updates.
- For the class aged 41-60, it is evident that the first three classes have equal frequency to search for information; therefore, the qualification may not be relevant for these three classes. Conversely, farmers with a bachelor's degree seek more information than farmers in other classes. In this case, the level of education is more relevant.
- For farmers in the 61-80 years of age class, the frequency of seeking information is the same for those with a primary school qualification and those with a bachelor's degree. In this case too, the education level is not relevant.

Proceeding with our analysis, we calculated the relative frequency based on farm size and egos' specialisation using table 7.

	Specialisation					
Farm size (ha)	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	62	64	3	13		142
Relative frequency	4.8	5.3	3	4.3		
11--20	21	97		15	7	140
Relative frequency	5.2	4.4		3.7	7	
21--30		32				32
Relative frequency		4.6				
31--40	4	2				6
Relative frequency	4	2				
41--50		3				3
Relative frequency		3				
51--1400		35				35
Relative frequency		3.5				
Total	87	233	3	28	7	358

Table 12 - Frequency of discussions about fertilisers based on egos' farm size and specialisation.

Examining table 12 and based on relative frequency, we can observe the following:

- For the class of small farms, 0-10 (ha): the farmers most interested in information on fertilizers are those who specialise in fruit, cereal and vegetable crops because these crops are the main ones cultivated in the region and these farms are small and poorly organised. For this reason, we reckon that farmers are more motivated to seek information from other sources.
- For farms in the 11-20 (ha) class: the farmers most interested in fertilisers are those who specialise in viticulture, cereals and fruits. We must consider that the viticulture farm sample comprises only one farm. Therefore, we cannot generalize this result to all viticulture farms.
- For farms in the 21-30 (ha) class: we found only farmers specialised in fruit farming.
- For farms in the 31-40 (ha) class: we found two types of farms looking for information - farms specialised in cereals and those specialised in fruit farming. It appears that cereal farmers are looking for more information than fruit farmers but in this case too, both samples comprise only one farm and therefore are not representative.
- For farms in the 41-50, and 51-1400 (ha) classes: we found only medium-sized and large-sized farms specialised in fruit farming. In this case, we noted that farmers discussed fertilisers less. Probably these farms are well organised and have complete autonomy about fertilisers and therefore, the search for information is limited.

Member of a professional organisation	Frequency
No	85
Relative frequency	4.7
Yes	273
Relative frequency	4.4
Total	358

Table 13 - Frequency of discussions about fertilisers based on egos' membership in a professional organisation.

The search for information on fertilisers is identical for farmers associated with a professional organisation and farmers not associated with one.

Therefore, being a member of a professional organisation does not affect the search for information on fertilisers.

Professional role	Frequency
Extension agents	1
Relative frequency	1
Managers	294
Relative frequency	4.3
Technicians	63
Relative frequency	5.7
Total	358

Table 14 - Frequency of discussions about fertilisers based on egos' professional role.

Egos' professional role affects their search for information concerning fertilisers. Indeed, technicians seek more information than managers because technicians are more concerned with technical matters than managers.

5.1.2 Frequency of specific topics concerning fertilisers

Fertilisers	Absolute Frequency	% ego-alters relations
Technical positioning	314	3.9
Need to use it	253	3.2
Benefits expected	239	2.9
Selection of fertilisers	214	2.7
Use in a Nutritional Plan	199	2.5
Organic fertilisers	197	2.4

Table 15 - Frequency of the main topics discussed by egos-alters concerning fertilisers.

To create table 15, we followed the same logic applied to create table 8. In table 13, we noted that the primary information exchanged by egos and their alters on "fertilisers" are technical positioning, the need to use them during the agricultural season, the benefits expected from possible use and how to select fertilisers.

In addition, we noted that as we move from topics relating to technical positioning to those relating to organic fertilisers, the total number of alters with whom each farmer discussed these specific topics decreased.

Accordingly, we selected the first four specific topics and analysed their absolute and relative frequency based on egos' attributes. We used tables 4 and 5 to calculate the relative frequency.

a) Technical positioning

	Education level					
Age	Illiterate	Primary school	High School	Degree	PhD	Total
20-40		8	127	17	21	173
Relative frequency		4.0	3.8	4.2	10.5	
41-60	3	22	82	29		136
Relative frequency	1.5	3.1	4.1	4.8		
61-80		1		4		5
Relative frequency		0.3		4		
Total	3	31	209	50	21	314

Table 16 - Frequency of discussions about technical positioning, based on egos' age and education level.

From table 16, we observe that:

- For the class of young people aged 20-40: the highest number of information seekers are farmers who have a higher cultural education level. Probably, farmers' comprehensive knowledge of the needs of the crops allows them to search for more information relating to the technical positioning of fertilisers. Instead, other farmers with different education levels have the same interest in seeking information. In this case, the education level does not particularly affect the search for information.
- For the class aged 41-60: farmers who differ in the number of contacts have a bachelor's degree compared to farmers with a high school or a primary school diploma. This category of farmers is more interested in the technical positioning of fertilisers. Conversely, for illiterate farmers, there is a decrease in interest in the technical positioning of fertilisers. Probably they do not have the cultural knowledge to deal with this specific topic.
- For the class aged 61-80: only farmers with a bachelor's degree are interested in seeking information on technical positioning compared to farmers with a primary school diploma (they have limited interest).

	Specialisation					
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	28	78	5	8		119
Relative frequency	2.1	6.5	5	2.6		
11--20	18	73		15	6	112
Relative frequency	4.5	3.3		3.7	6	
21--30		25				25
Relative frequency		3.6				
31--40	4	4				8
Relative frequency	4	4				
41--50		6				6
Relative frequency		6				
51--1400		44				44
Relative frequency		4.4				
Total	50	230	5	23	6	314

Table 17 - Frequency of discussions about technical positioning, based on egos' specialisation and farm size.

From the table analysing technical positioning by cross-referencing farm size with farm specialisation, we can observe that:

- For farms in the 01-10 (ha) class: farmers who are looking for more information on technical positioning are those who specialised in fruit and oil crops. Indeed, fruit farming is an agricultural niche that requires more intervention and attention than other crops and represents a high-yielding and good income for the farmer. For oil farming, the sample comprises only one farm and, therefore, is less representative of this category.
- For farms in the 11-20 (ha) class: farms specialised in viticulture and cereal farming are more interested in seeking information on the technical positioning of fertilisers. This result is due to

the size of farms, which are small and less organised, with professional figures. For this reason, farmers are obliged to seek information externally.

- For farms in the 31-40 (ha) class: we found only two types of farms - the first specialised in cereal farming and the second in fruit farming. In this case, specialisation does not influence the search for information.
- For farms in the 41-50, and 51-1400 (ha) classes: we observed that as farm size increases, farmers are more specialised in fruit farming and the search for information decreases. We can hypothesise that large and medium-sized farms are more organised and independent, and this result implies that farmers seek information externally to a lesser extent.

Professional Role	Frequency
Extension agents	4
Relative frequency	4
Managers	252
Relative frequency	3.7
Technicians	58
Relative frequency	5.3
Total	314

Table 18- Frequency of discussions about technical positioning, based on egos' professional role.

The professional role influences the search for information relating to the technical positioning of fertilisers. Indeed, technicians seek more information than managers because technicians are more concerned with technical matters than managers.

Members of a professional organisation	Frequency
No	50
Relative frequency	2.8
Yes	264
Relative frequency	4.2
Total	**314**

Table 19- Frequency of discussions about technical positioning, based on egos' membership in a professional organisation.

The search for information about technical positioning is higher for farmers associated with a professional organisation than those not associated with one. In this case, being a member of a professional organisation influences the search for information on the technical positioning of fertilisers.

b) Need to use fertilisers

	Education level					
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40		7	107	16	21	151
Relative frequency		3.5	3.2	4.0	10.5	
41-60		10	67	19		96
Relative frequency		1.4	3.3	3.2		
61-80		1		5		6
Relative frequency		0.3		5.0		
Total	0	18	174	40	21	253

Table 20 - Frequency of discussions about the need to use fertilisers, based on egos' age and level of education.

	Specialisation					
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	26	62	5	9		102
Relative frequency	2.0	5.2	5.0	3.0		
11--20	14	77		15	3	109
Relative frequency	3.5	3.5		3.7	3.0	
21--30		13				13
Relative frequency		1.8				
31--40	5	2				7
Relative frequency	5.0	2.0				
41--50		5				5
Relative frequency		5.0				
51--1400		17				17
Relative frequency		1.7				
Total	45	176	5	24	3	253

Table 21 - Frequency of discussions about the need to use fertilisers, based on egos' specialisation and farm size.

Professional role	**Frequency**
Extension agents	2
Relative frequency	2.0
Managers	209
Relative frequency	3.1
Technicians	42
Relative frequency	3.8
Total	253

Table 22 - Frequency of discussions about the need to use fertilisers, based on ego's professional role.

Member of a professional organisation	**Frequency**
No	40
Relative frequency	2.2
Yes	213
Relative frequency	3.4
Total	253

Table 23 - Frequency of discussions about the need to use fertilisers, based on egos' membership in a professional organisation.

c) Expected benefits of using fertilisers

	Education level					
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40		9	97	16	20	142
Relative frequency		4.5	**2.9**	4.0	10.0	
41-60	1	10	63	17		91
Relative frequency	0.5	1.4	**3.1**	2.8		
61-80		3		3		6
Relative frequency		1.0		3.0		
Total	**1**	**22**	**160**	**36**	**20**	**239**

Table 24 - Frequency of discussions about the expected benefits, based on egos' age and education level.

	Specialisation					
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	32	55	4	9		100
Relative frequency	2.5	4.6	4.0	3.0		

11--20	12	60		15	2	89
Relative frequency	3.0	2.7		3.7	2.0	
21--30		12				12
Relative frequency		1.7				
31--40	3	4				7
Relative frequency	3.0	4.0				
41--50		5				5
Relative frequency		5.0				
51--1400		26				26
Relative frequency		2.6				
Total	47	162	4	24	2	239

Table 25 - Frequency of discussions about the expected benefits, based on egos' specialisation and farm size.

Professional role	**Frequency**
Extension agents	4
Relative frequency	4.0
Managers	199
Relative frequency	2.9
Technicians	36
Relative frequency	3.3
Total	239

Table 26 - Frequency of discussions about the expected benefits, based on egos' professional role.

Member of a professional organisation	**Frequency**
No	33
Relative frequency	1.8
Yes	206
Relative frequency	3.3
Total	239

Table 27 - Frequency of discussions about the expected benefits, based on egos' membership in a professional organisation.

d) Selection of fertilisers

	Education level					
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40		3	105	9		117
Relative frequency		1.5	3.2	2.2		
41-60	3	6	64	16		89
Relative frequency	1.5	0.8	3.2	2.7		
61-80		4		4		8
Relative frequency		1.3		4.0		
Total	3	13	169	29		214

Table 28 - Frequency of discussion about the selection of fertilisers, based on egos' age and education level.

	Specialisation					
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	24	29	4	10		67
Relative frequency	1.8	2.4	4.0	3.3		
11--20	13	59		16	4	92
Relative frequency	3.2	2.7		4.0	4.0	
21--30		17				17
Relative frequency		2.4				
31--40	4	3				7

Relative frequency	4.0	3.0				
41--50		4				4
Relative frequency		4.0				
51--1400		27				27
Relative frequency		**2.7**				
Total	41	139	4	26	4	214

Table 29 - Frequency of discussions about the selection of fertilisers, based on egos' specialisation and farm size.

Professional role	**Number of ego**	**Frequency**
Extension agents	1	5
Relative frequency		5.0
Managers	68	180
Relative frequency		2.6
Technicians	11	29
Relative frequency		2.6
Total		**214**

Table 30 - Frequency of discussions about the selection of fertilisers, based on egos' professional role.

Member of a professional organisation	**Number of ego**	**Frequency**
No	18	23
Relative frequency		1.3
Yes	62	191
Relative frequency		3.1
Total		**214**

Table 31 - Frequency of discussions about the selection of fertilisers, based on egos' membership in a professional organisation.

5.1.3 Frequency of specific topics concerning PBs

Biostimulants matters	**Absolute Frequency**	**% ego-alters relations**
Technical positioning	127	1.6
Need to use it	124	1.5
Know PB	109	1.4
Organic PBs	103	1.3
Use it in NP	78	0.9
Chance to mix it	68	0.8
Selection of PBs	53	0.7
Benefits expected	47	0.6

Table 32 - Frequency of the main topics discussed between egos-alters concerning biostimulants.

Table 32 reveals the relevant topics discussed between egos and their alters concerning the topic of PBs, such as the technical positioning of PBs, the need to use PBs, the knowledge acquired on PBs and the organic PBs. We selected the first four specific topics and analysed their relative frequency based on egos' attributes.

Moreover, we observed that as we move from the topic of technical positioning to expected benefits, the total number of alters with whom each farmer discussed these specific topics decreased.

a) Technical positioning of biostimulants

	Education level					
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40		2	53	9		64
Relative frequency		1.0	1.6	2.2		
41-60		3	45	12		60
Relative frequency		0.4	2.2	2.0		
61-80				3		3
Relative frequency				3.0		
Total		5	98	24		127

Table 33 – Frequency of discussions about technical positioning, based on egos' age and education level.

	Specialisation					
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	20	18	1	2		41
Relative frequency	1.5	1.5	1.0	0.6		
11--20	7	35		10		52
Relative frequency	1.7	1.6		2.5		
21--30		12				12
Relative frequency		1.7				
31--40	3	2				5
Relative frequency	3.0	2.0				
41--50		1				1
Relative frequency		1.0				
51--1400		16				16
Relative frequency		1.6				
Total	30	84	1	12		127

Table 34 – Frequency of discussions about technical positioning, based on egos' specialisation and farm size.

Professional role	**Frequency**
Extension agents	3
Relative frequency	3.0
Managers	114
Relative frequency	1.7
Technicians	10
Relative frequency	0.9
Total	**127**

Table 35 – Frequency of discussions about technical positioning, based on egos' professional role

Member of a professional organisation	**Frequency**
No	15
Relative frequency	0.8
Yes	112
Relative frequency	1.8
Total	127

Table 36 – Frequency of discussions about technical positioning, based on egos' membership in a professional organisation.

b) Need to use biostimulants

Education level						
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40		2	53	9		64
Relative frequency		1.0	**1.6**	2.2		
41-60		4	41	10		55
Relative frequency		0.6	**2.0**	1.7		
61-80				5		5
Relative frequency				5.0		
Total		6	94	24		124

Table 37 – Frequency of discussions about the need to use PBs, based on egos' age and education level.

Specialisation						
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	10	22		2		34
Relative frequency	0.8	1.8		0.6		
11--20	6	48		5		59
Relative frequency	1.5	2.2		1.2		
21--30		10				10
Relative frequency		1.4				
31--40	5	2				7
Relative frequency	5.0	2.0				
41--50		2				2
Relative frequency		2.0				
51--1400		12				12
Relative frequency		1.2				
Total	21	96		7		124

Table 38 – Frequency of discussions about the need to use PBs, based on egos' specialisation and farm size.

Professional role	**Frequency**
Extension agents	2
Relative frequency	2.0
Managers	109
Relative frequency	1.6
Technicians	13
Relative frequency	1.2
Total	**124**

Table 39 – Frequency of discussions about the need to use PBs, based on egos' professional role.

Member to a professional role	**Frequency**
No	17
Relative frequency	0.9
Yes	107
Relative frequency	1.7
Total	124

Table 40 – Frequency of discussions about the need to use PBs, based on egos' membership in a professional organisation.

c) Knowledge of Biostimulants

	Education level					
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40			46	8		54
Relative frequency			1.4	2.0		
41-60			41	12		53
Relative frequency			2.0	2.0		
61-80				2		2
Relative frequency				2.0		
Total			87	22		109

Table 41 – Frequency of discussions knowledge of PBs, based on egos' age and education level.

	Specialisation					
Farm size size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	14	17	1	3		35
Relative frequency	1.1	1.4	1.0	1.0		
11--20	5	30		9		44
Relative frequency	1.2	1.4		2.2		
21--30		11				11
Relative frequency		1.6				
31--40	2	1				3
Relative frequency	2.0	1.0				
41--50		1				1
Relative frequency		1.0				
51--1400		15				15
Relative frequency		1.5				
Total	21	75	1	12		109

Table 42 – Frequency of discussions knowledge of PBs, based on egos' specialisation and farm size.

Professional role	**Frequency**
Extension agents	2
Relative frequency	2.0
Managers	97
Relative frequency	1.4
Technicians	10
Relative frequency	0.9
Total	109

Table 43– Frequency of discussions knowledge of PBs, based on egos' professional role.

Member of a professional organisation	**Frequency**
No	6
Relative frequency	0.3
Yes	103
Relative frequency	**1.7**
Total	109

Table 44 – Frequency of discussions knowledge of PBs, based on egos' membership in a professional organisation

d) Organic Biostimulants

	Education level					
Age	**Illiterate**	**Primary school**	**High School**	**Degree**	**PhD**	**Total**
20-40			42	11		53
Relative frequency			1.3	2.7		
41-60		3	35	8		46
Relative frequency		0.4	1.7	1.3		
61-80				4		4
Relative frequency				4.0		
Total		3	77	23		103

Table 45 – Frequency of discussions about organic PBs, based on egos' education level and age

	Specialisation					
Farm size	**Cereals**	**Fruits**	**Oils**	**Vegetables**	**Viticulture**	**Total**
01--10	14	12	1	4		31
Relative frequency	1.1	1.0	1.0	1.3		
11--20	6	28		10		44
Relative frequency	1.5	1.3		2.5		
21--30		10				10
Relative frequency		1.4				
31--40	4	3				7
Relative frequency	4.0	3.0				
41--50		2				2
Relative frequency		2.0				
51--1400		9				9
Relative frequency		0.9				
Total	24	64	1	14		103

Table 46 – Frequency of discussions about organic PBs, based on egos' specialisation and farm size.

Professional role	**Frequency**
Extension agents	2
Relative frequency	2.0
Managers	90
Relative frequency	1.3
Technicians	11
Relative frequency	1.0
Total	103

Table 47 – Frequency of discussions about organic PBs, based on egos' professional role.

Member of a professional organisation	**Frequency**
No	18
Relative frequency	1.0
Yes	85
Relative frequency	1.4
Total	103

Table 48 – Frequency of discussions about organic PBs, based on egos' membership in a professional organisation.

Considerations:

This section aimed to analyse the absolute and relative frequency of specific topics discussed between egos and their alters according to the variation of egos' attributes.

We noted that the total numerousness and the percentage of egos-alters relationships decreased for each main topic as we analysed specific topics, from agricultural techniques to fertilisers and PBs.

We deduced from the results obtained (based mainly on the absolute frequency) in all pivot tables that for:

- Agriculture topics: the analysis of the frequency in which egos discussed with their alters about fertilisers based on egos' attributes shows that the egos with high school education level aged between 20-40 years old are more inclined to converse about fertilisers. In the second-order of importance, there are egos with Bachelor's degree and primary school education level and aged between 41-60 years old.

  This result is in line with the government's efforts. In fact, with the fulfilment of the GMP, agricultural schools were established to train students (who have already acquired a high school diploma) to become qualified experts in agriculture (those figures are different to agriculture engineers, who have a bachelor's degree and PhD diploma).

  Concerning the egos' specialisation in the first order, most farmers are specialised in fruit cultivation, and they have medium and small farm sizes (11-20 and 01-10 hectares). In the second-order of importance, we found egos specialised in cereals farming characterised by small and medium firm's size (01-10 and 11-20 hectares), and in the third order of importance, we noted that egos are specialised in vegetable cultivation, and they have medium and small firm's size (11-20 and 01-10 hectares).

  The three types of cultivation (fruits, cereals, and vegetables) are the main crops cultivated in the Fès-Meknès region.

- Fertiliser topics: the analysis of the frequency in which egos discussed with their alters about the four specific topics based on egos' attributes reveals that for technical positioning, benefits expected using fertiliser and fertiliser selection, most of the egos have a high school diploma and are aged between 20-40 years old; followed by egos with a Bachelor's degree and aged between 41-60 years old and in the end by egos with primary school diploma and aged between 41-60 years old.

  Concerning the need to use fertilisers, the only difference compared to other specific topics is that we found egos with a PhD diploma and aged between 20-40 years old as the third order of importance (instead of egos with a primary school diploma).

  The analysis shows that most of the egos are specialised in fruits, cereals and vegetables cultivation, and generally, they have small and medium firm's sizes (01-10 and 11-20 hectares).

- PBs topics: the analysis of the frequency in which egos conversed with their alters about the four specific topics based on egos' attributes disclosed that for technical positioning of PBs, the need to use PBs and, the knowledge of PBs most of the egos have a high school diploma and aged between 20-40 years old; followed by egos with Bachelor's degree diploma and aged between 41-60 years old.

  Instead, for the organic PBs, the only difference compared to the other specific topics is that most egos who have a Bachelor's degree are aged between 20-40 years old.

  To the greatest extent, egos are specialised in fruits, cereals and vegetables farming, and they have medium and small firm's sizes (11-20 and 01-10 hectares).

In all three main topics analysed, we found that most of the farmers who discussed specific topics are members of a professional organisation and are mainly managers (take into account that our sample was composed of 58 egos who are managers and 22 egos who have a different professional role).

5.2 Analysis of Personal Network Data

This section describes the results obtained from E-net software analysing the egos' networks data. During the interview with each ego, we observed that as we moved from agriculture techniques to fertiliser to PBs topics, the number of interactions and the number of alters with whom the ego interact decreased. The reason is that only 59 egos answered the PBs topics compared to the agricultural techniques and fertiliser topics (all 80 egos). In the following subgraphs, we reported the results obtained for each main topic.

5.2.1 Analysis of Personal Network Data for Agricultural Techniques

a) Ego-alter crosstabs

Variables	Chi-square	Significance (acceptable <5%)
specialisation (rows) versus agricultural technique topics discussed (cols)	1258.476 with 48 degrees of freedom	5.0E-0232
specialisation (rows) versus alters' relations (cols)	142.769 with 24 degrees of freedom	0.000

Table 49 - Ego-alter crosstabulation for agricultural techniques

We made several crosses using the eleven variables, and we obtained 28 crosstabulations. All crosstabulations were considered, and in table 26 we report the two significant ones. Other crosstabulations did not give significant results and were abandoned.

The first result reported in the table shows a correlation between egos' specialisation and information obtained from alters concerning the agricultural techniques topics discussed. This result explains that the total number of agricultural techniques topics discussed between egos and their alters is higher depending on egos' specialisation.

The second result reveals a correlation between egos' specialisation and alters' relations. This result explains that the typology of alters with whom egos tend to relate is different depending on egos' specialisation.

b) Alter-alter crosstabs

Variables	Average Yule's Q	Interpretation
Y_agricultural techniques topics discussed_alters' relation	**0.10**	small association
Y_fertilisers topics discussed_ alters' relation	**-0.05**	small association
Y_ PBs topics discussed_ alters' relation	**-0.02**	small association
Y_ fertilisers topics discussed _ agricultural techniques topics discussed	**-0.17**	small association
Y_ PBs topics discussed_ agricultural techniques topics discussed	**0.24**	small association

Y_ PBs topics discussed_ fertilisers topics discussed	**-0.40**	moderate association

Table 50 - Alter-alter crosstabulation for agricultural techniques

We considered the four alter variables (alter relations, agricultural technique topics discussed, fertiliser topics discussed and PBs topics discussed), and obtained six crosstabulations, as reported in table 50.

We pursued the first goal of crossing alters' relations with the three variables (agricultural techniques topics discussed, fertiliser topics discussed and PBs topics discussed) to understand if alters' relations could influence the information obtained concerning agricultural techniques, fertilisers and PBs.

The second goal aimed to understand if there is a connection between alters who discuss agricultural techniques, fertilisers and PBs with egos.

As shown in the table, we can deduce:

- There is a small association between the information obtained from alters regarding agricultural techniques and alters' relations. This result signifies that alters' relations relatively influence information diffusion concerning agricultural technique topics.
- There is a small association between the information obtained from alters regarding fertilisers topics and alters' relations. This result means that alters's relations influence the information diffusion related to fertilisers topics to some degree.
- There is a small association between alters' relations and the PBs information obtained from alters, meaning that alters' relations hardly have any influence on the exchange of knowledge related to PBs topics.
- There is a small association between the information obtained about fertilisers from alters and information acquired about agricultural techniques from alters,
  which indicates that the knowledge exchange of agricultural techniques between egos and their alters influences the diffusion of fertilisers information to some extent.
- There is a small association between the interchange of information related to PBs and the knowledge obtained about agricultural technique topics.
  This result implies that the exchange of information related to agricultural techniques affects the diffusion of knowledge about PBs topics to a relative extent.
- There is a moderate association between the information exchanged about PBs topics and fertiliser topics. We noted that when egos acquired information about fertilisers from their alters, egos were inclined to obtain information about PBs. This result indicates that the information exchanged about fertilisers is associated with the information obtained on PBs and implies that egos have a moderate knowledge of PBs. PBs topics seem to become a relatively common topic for egos who already exchange information about fertilisers with their alters.

c) Composition

Variable	Number of Agricultural technique topics discussed	% Public organisation	% Research institutes	% Acquaintances	% Professionals
Average	**29,3**	2,6	5,5	64,9	27,1

Table 51 – Network composition for agricultural techniques

The table indicates that in the egos' networks (80 egos), 29.3 represents the average number of the agricultural technique topics discussed between egos' and their alters. Therefore, on average, each ego discussed 1.5 topics with each alter. This result indicates that the farmer becomes more specialised when discussing agricultural techniques topics with his alters.

Knowledge is obtained from **acquaintances** (64.9%) and **professionals** (27.1%). Generally, farmers rely mainly on acquaintances and moderately on professionals to access knowledge related to agricultural techniques. Public organisations and research institutes rarely establish ongoing relationships with farmers.

This result is the tendency of the 80 egos' networks to obtain information about agricultural techniques. However, there are three different cases of farmers (specialised in fruit farming) with a different tendency, e.g., ego 40 refers to public organisations 20%, acquaintances 55% and professionals 25% but not to research institutes 0%. Instead, ego 68 consults public organisations 30%, research institutes 45%, acquaintances 10% and professionals 15%. The last case, ego 79, refers to public organisations 20%, research institutes 15% and acquaintances 65% but not to professionals 0%.

d) Heterogeneity

Variable	Alters' relations:Het (categorical variable)	Alters' relations:Iqv (categorical variable)	Agricultural technique topics:SD (continuos variable)
Average value	0.41	0.64	0.66

Table 52 – Network heterogeneity for agricultural techniques

We investigated the diversity in egos' networks and calculated the average value of categorical and continuous variables. Heterogeneity was measured using Agresti's IQV index.

Egos whose alters are mostly the same for a categorical variable (alters' relations) will have small heterogeneity scores. In contrast, those with more diversity in their networks will have a value closer to 1. As shown in the table, generally, we have moderate heterogeneity in egos' networks.

The results explain that egos have access to agricultural techniques information from different sources. Indeed, the composition indicator shows that acquaintances, professionals, public organisations and research institutes are the source of information for egos concerning agricultural techniques matters.

We computed the "agricultural techniques topics" standard deviation value. The low standard deviation indicates that the value tends to be close to the expected value, while a high standard deviation indicates that the value is spread out over a broader range.

e) Structural holes

Variable	SH: Degree	SH: Density	SH: Effsize	SH: Efficiency	SH: Constraint	SH: Hierarchy
Average value	19,3	0,27	9,33	0,48	0,18	0,02

Table 53 – Network structural holes for agricultural techniques

Minimum brokerage opportunities are represented by small effective size and efficiency and high density and constraint. This means that the ego has all connected alters, creating a closed personal network. **Maximum brokerage opportunities** are represented by high effective size and efficiency and low density and constraint. In the network, the ego has many alters unconnected to other alters.

The table shows that, on average, egos generally have alters unconnected to each other. Egos also have a brokerage position in the network. This result could provide egos with access to new information, power and control in the networks.

As the output shows, **density** is the number of ties divided by the number of pairs. That is the percentage of all possible ties in each ego network. When the score is higher, all alters send information to all other alters; they are embedded in very dense local structures. Instead, when the score is lower, individuals live in a small network where the members are not tightly connected. On average, in ego networks, the density value is 0.27, which means that alters are poorly connected to each other.

Hierarchy depicts the nature of the constraint on an ego. If the total constraint on ego is concentrated in a single other actor, the hierarchy measurement will have a higher value. Indeed, if the ego network has a lower hierarchy value, it indicates that alters do not have a solid position to control the information flow in the network because small groups of alters do not hierarchically organise themselves into a network.

f) Consideration

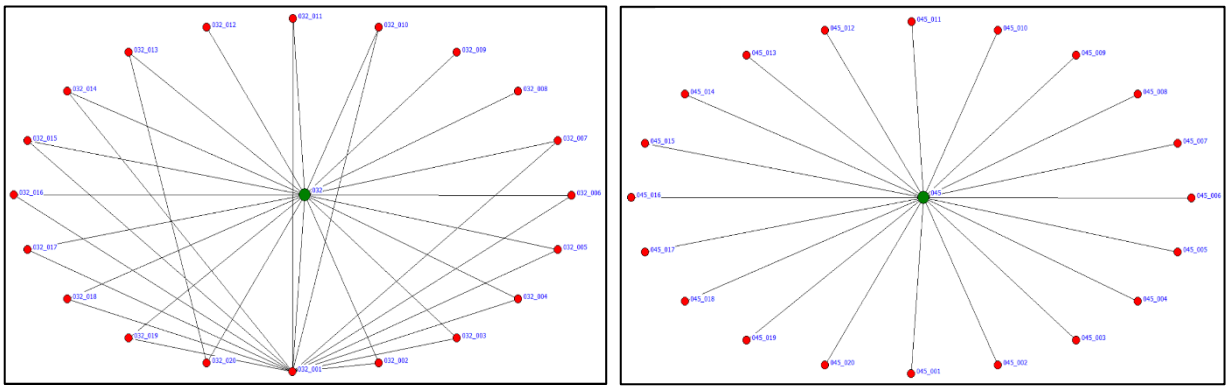


Figure 3 - An example of some ego's network related to agricultural techniques (ego n.32 and n.45, both have 20 alters).

Evaluating the results from social ego network analysis, we can summarise that generally, social networks have the following characteristics:

- Farmers are more inclined to get information about agricultural techniques topics from different alters based on farmers' specialisation. This result implies that alters play an essential role in spreading information to farmers. This advantage helps farmers get knowledge from a different category of alters and could help farmers increase and improve their production.
- Farmers are moderately familiar with PBs and this category of products has become a relatively common topic in which egos discuss and exchange information with their alters.
- Growers are specialised when discussing agricultural techniques topics with their alters.
- Generally, ego networks have moderate heterogeneity, and farmers have access to knowledge from alters who are mainly acquaintances and professionals.
- On average, ego networks have low density and low hierarchy, which means that alters are not tightly connected to each other and do not have a solid position to control the knowledge flow.
- The Eff.size and efficiency values denote that, on average, farmers have a brokerage position in the network, playing a dominant role in obtaining information.

5.2.2 Analysis of Personal Network Data for Fertilisers

a) Ego-alter crosstabs

Variables	Chi-square	Significance (acceptable <5%)
specialisation (rows) versus fertiliser topics discussed (cols)	751.205 with 24 degrees of freedom.	4.1E-0143
specialisation (rows) versus alters' relations (cols)	85.996 with 24 degrees of freedom.	0.000

Table 54 – Ego-alter crosstabulation for fertilisers topics

We made numerous crosses using the eleven variables, obtaining 28 crosstabulations. Most crosstabulations did not give significant values, which were rejected. In table 67, we report only two crosstabulations with significant values.

The table reveals a correlation between egos' specialisation and information obtained from alters concerning fertilisers. Furthermore, there is a correlation between egos' specialisation and alters' relations. These two results imply that the total number of fertiliser topics discussed by egos and their alters is higher with reference to egos' specialisation. In addition, this information is reached from different types of alters with regard to egos' specialisation.

b) Alter-alter crosstabs

Variables	Average Yule's Q	Interpretation
Y_agricultural techniques topics discussed _alters' relations	**-0.09**	small association
Y_fertilisers topics discussed_ alters' relations	**-0.12**	small association
Y_ PBs topics discussed_ alters' relations	**0.25**	small association
Y_ fertilisers topics discussed _ agricultural techniques topics discussed	**-0.10**	small association
Y_ PBs topics discussed _ agricultural techniques topics discussed	**0.05**	small association
Y_ PBs topics discussed _ fertilisers topics discussed	**-0.40**	moderate association

Table 55 – Alter-alter crosstabulation for fertilisers topics

Considering four alter variables, we adopted the same criterion adopted previously to get six crosstabulations, as reported in table 68.

Here below, we explain the results obtained from alter-alter crosstabulation:

- There is some association between the information obtained from alters regarding agricultural techniques topics and alters' relations, signifying that alters' relationships influence knowledge diffusion related to agricultural techniques to some extent.
- There is some association between the information obtained from alters regarding fertiliser topics and alters' relations, which implies that alters' relations somewhat influence knowledge diffusion regarding fertilisers.
- There is some association between the information obtained from alters regarding PBs topics, and the alters' relations, which attests that alters' relations influence the diffusion of information related to PBs to some degree.
- There is some association between the information obtained regarding fertiliser topics and the information obtained regarding agricultural techniques topics. This result shows that information obtained from alters regarding agricultural techniques topics influences the spread of information related to fertiliser topics to some extent.
- There is some association between the information obtained regarding PBs topics and the information obtained related to agricultural techniques topics from alters. This outcome confirms that sharing information about agricultural techniques topics influences the diffusion of information related to PBs topics to some extent.
- There is a moderate association between the information exchanged about PBs topics and fertiliser topics. Also, in this case, it was affirmed that the knowledge acquired about fertilisers is associated with the knowledge obtained about PBs, which means that egos somehow know PBs.

c) Composition

Variable	Number of fertilisers topics discussed	% Public organisation	% Research institutes	% Acquaintances	% Professionals
Average	**18.3**	3.1	5.3	65.2	26.4

Table 56 – Network composition for fertilisers topics

The table describes that in the ego networks (80 egos), 18.3 represents the average number of fertiliser topics discussed by egos and their alters. Furthermore, on average, each ego discussed one topic with each alter, which means that farmers discuss a few fertiliser topics.

Information is obtained from **acquaintances** (65.2%) and **professionals** (26.4%). This result shows that farmers depend mainly on acquaintances and, to some degree, on professionals to get information about fertilisers. Conversely, research institutes and public organisations rarely create ongoing connections with farmers.

This outcome describes the tendency on the 80 egos' networks to access knowledge about fertilisers. However, there are two cases of growers (specialised in fruit farming) with unusual tendencies, e.g., ego 41 refers to both public and research organisations 25% and acquaintances 50% but not professionals 0%, and ego 79 consults public organisations 27.3%, research institutes 9.1% and acquaintances 63.6% but not professionals 0%.

d) Heterogeneity

Variable	Alters' relations :Het (categorical variable)	Alters' relations:Iqv (categorical variable)	Fertilises topics discussed:SD (continuos variable)
Average value	0.38	0.62	0.43

Table 57 – Network heterogeneity for fertilisers topics

We calculated network heterogeneity, and the 0.62 IQV index value shows moderate heterogeneity in the egos' networks, which implies that egos generally have access to information about fertilisers from diverse sources. This outcome is also confirmed by the composition measure, which reveals that acquaintances, professionals, public organisations, and research institutes are the source of information for egos concerning fertiliser matters.

In addition, we calculated the "fertiliser topics discussed" standard deviation. The low value calculated is 0.43, indicating that the value tends to be close to the expected value.

e) Structural holes

Variable	SH: Degree	SH: Density	SH: Effsize	SH: Efficiency	SH: Constraint	SH: Hierarchy
Average value	18,4	0,2	11,8	0,7	0,2	0.0

Table 58 – Network structural holes for fertilisers topics

The table reveals **Maximum brokerage opportunities** represented by high effective size and efficiency and low density and constraint. This result suggests that generally, egos have alters unconnected to each other, and egos have a brokerage position in the networks (access to new information and control in the networks).

Considering the egos' network density (SH: density 0,2) we deduce that alters are poorly connected to other alters.

The low Hierarchy value (SH:Hierarchy 0.0) confirms that alters do not have a solid position to control the information flow in the network because small groups of alters do not hierarchically organise themselves into networks.

f) Consideration

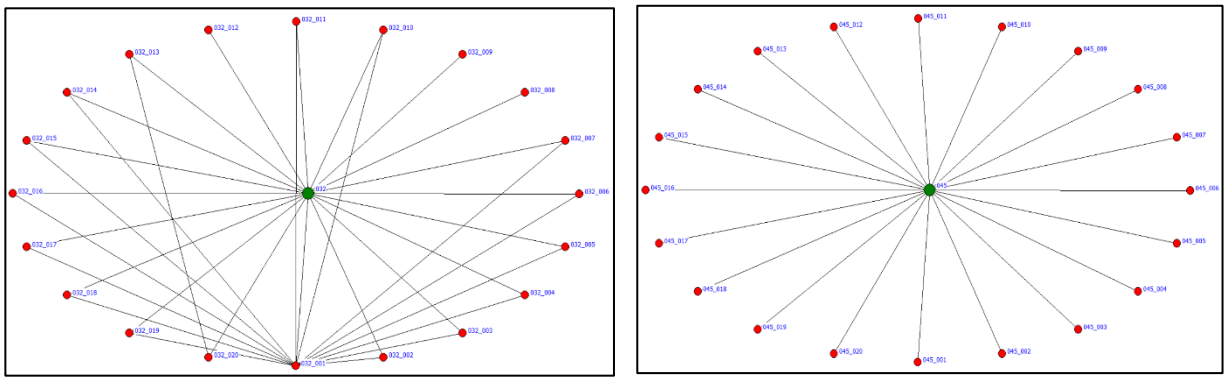


Figure 4 - An example of some ego's network related to fertilisers (ego n.32 and n.45, both have 20 alters).

Based on the results obtained from social egos network analysis, we can assume that:

- Generally, farmers have the advantage of obtaining information about fertilisers based on farmers' specialisation.
- Farmers have moderate knowledge about PBs.
- On average, there is a decrease in the number of specific topics discussed in fertilisers (18.3) compared to agricultural techniques topics (29.3).
- The main source of information for farmers are acquaintances and professionals.
- Alters are poorly connected to each other, and they do not spread information to other alters. In addition, farmers have a maximum brokerage opportunity in the networks, allowing them to be unique in obtaining and spreading knowledge.

5.2.3 Analysis of Personal Network Data for PBs

a) Ego-alter crosstabs

Variables	Chi-square	Significance (acceptable <5%)
Know PBs (rows) versus alters' relations (cols)	Chi-square = 22.625 with 3 degrees of freedom.	Significance = 0.000
Use PBs (rows) versus alters' relations (cols)	Chi-square = 9.378 with 3 degrees of freedom.	Significance = 0.025
Reuse PBs (rows) versus PBs topics discussed (cols)	Chi-square = 11.399 with 4 degrees of freedom.	Significance = 0.022

Table 59 – Ego-alter crosstabulation for biostimulants topics

In the first step, we crossed four ego variables (egos' specialisation, know PBs, use PBs and reuse PBs) with "alters' relations" to understand if alters' relations could influence the variables taken into consideration. In the second step, we crossed the same four ego variables with "PBs topics discussed" with alters to understand if the information obtained from alters about PBs could influence the egos' variables taken into consideration. Most of the crosstabulations obtained did not give significant values and were rejected. In table 72, we report only three crosstabulations that had significant values.

Below we report the explanation of the outcomes obtained:

- There is a correlation between "alters' relations" and "know PBs". This outcome implies that alters' relations influence farmers' knowledge about PBs.
- There is a correlation between "alters' relations" and the "use of PBs", which means that alters influence the farmers to get the experience of using PBs.
- There is a correlation between the "PBs topics discussed" and the intention to "reuse PBs" by egos, which means that the information obtained from alters influences farmers to reuse PBs.

b) Alter-alter crosstabs

Variables	Average Yule's Q	Interpretation
Y_agricultural techniques topics discussed_alters' relations	**0.06**	small association
Y_fertilisers topics discussed_ alters' relations	**-0.01**	small association
Y_ PBs topics discussed_ alters' relations	**0.33**	moderate association
Y_ fertilisers topics discussed _ agricultural techniques topics discussed	**-0.31**	moderate association
Y_ PBs topics discussed _ agricultural techniques topics discussed	**0.0**	no association
Y_ PBs topics discussed _ fertilisers topics discussed	**-0.44**	moderate association

Table 60 – Crosstabulation alter-alter for biostimulants topics

We considered the four alters' variables (alters' relations, agricultural techniques topics discussed, fertiliser topics discussed and PBs topics discussed), and we obtained six crosstabulations, as reported in table 60.

We followed the first aim of crossing alters' relations with the three variables (agricultural techniques topics discussed, fertiliser topics discussed and PBs topics discussed) to understand if alters' relations could influence the information obtained concerning agricultural techniques, fertilisers and PBs. The second goal was to understand if there is a connection between alters who discussed agricultural techniques, fertilisers and PBs with egos.

From the results reported in the table above, we observed that:

- There is some association between alters' relations and information obtained from alters regarding agricultural techniques topics, signifying that alters' relationships influence knowledge diffusion related to agricultural techniques to some extent.
- There is some association between the information obtained from alters regarding fertiliser topics and alters' relations, implying that alters' relations influence knowledge diffusion regarding fertilisers to some degree.
- There is a moderate association between the information obtained regarding fertiliser topics and the information obtained regarding agricultural techniques topics. This result shows that information obtained from alters regarding agricultural techniques influences the dissemination of information related to fertiliser matters.
- There is a moderate association between the information obtained from alters regarding PBs topics and the alters' relations, which confirms that, on average, the alters' relations influence the spread of information related to PBs.
- There is no association between the information obtained regarding PBs and the information achieved related to agricultural techniques. This result attests that obtaining information on agricultural techniques indirectly influences the dissemination of information concerning PBs.
- There is a moderate association between the information about PBs and fertiliser topics. This indicates that talking about fertilisers (between egos and their alters) encourages farmers to discuss and get information about PBs.

c) Composition

Variable	Number of PBs topics discussed	% Public organisation	% Research institutes	% Acquaintances	% Professionals
Average	**12.71**	1.36	4.70	46.55	21.14

Table 61 – Network composition for biostimulants topics

The table depicts that in the egos' networks (59 egos), 12.71 represents the average number of PBs information obtained from alters, which means that, on average, each farmer discusses 0.63 topics with each alter. This result indicates that, generally, farmers discussed a few topics related to PBs.

Knowledge about PBs is obtained mainly from **acquaintances** (46.55%) and **professionals** (21.14%). This result illustrates that farmers depend mainly on acquaintances and less on professionals to get information about PBs matters. Also, in this case, it reveals that research institutes and public organisations rarely create ongoing connections with farmers.

We reported the tendencies on 59 ego networks related to PBs, but there are some exceptions, e.g., ego 79 (farmer specialised in fruit farming) refers to public organisations 28.6%, research institutes 21.4% and acquaintances 50% but not professionals 0%.

d) Heterogeneity

Variable	Alters' relations:Het (categorical variable)	Alters' relations:Iqv (categorical variable)	PBs topics discussed:SD (continuos variable)
Average value	0.41	0.70	0.30

Table 62 – Network heterogeneity for biostimulants topics

In general, the 0.70 IQV index value indicates a moderate heterogeneity in egos' networks. This result shows that those egos access knowledge about PBs from different sources (alters). This result is also confirmed by the composition measurement, which discloses that acquaintances, professionals, public organisations and professionals are the sources of information for egos about PBs.

We calculated the "PBs topics discussed" standard deviation value. The low value calculated is 0.30 and it indicates that the value tends to be close to the expected value.

e) Structural holes

Variable	SH: Degree	SH: Density	SH: Effsize	SH: Efficiency	SH: Constraint	SH: Hierarchy
Average value	17.36	**0,12**	**13.32**	**0.80**	**0.16**	0.05

Table 63 – Network structural holes for biostimulants topics

The table reveals **Maximum brokerage opportunities** represented by high effective size and efficiency and low density and constraint. This outcome indicates that egos have alters unconnected to each other and that egos have a brokerage position in the network. In addition, egos' networks have a density value of 0.12, which confirms that alters are poorly connected to each other and do not share information with other alters.

The low **Hierarchy** value of 0.05 implies that alters do not have a solid position to control the information flow in the network because small groups of alters do not hierarchically organise themselves into networks.

f) Considerations

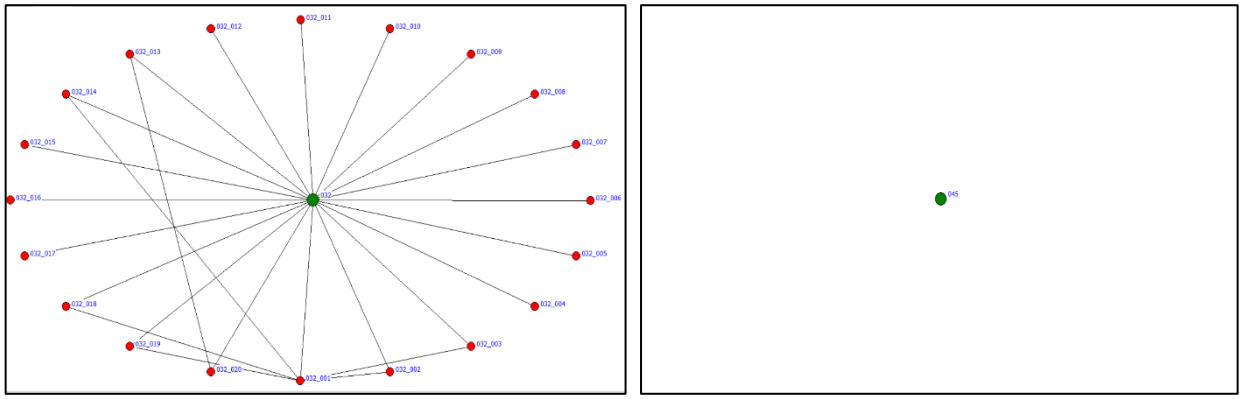


Figure 5 - An example of some ego's network related to biostimulants (ego 32 has 20 alters and ego 45, has no alters).

Analysing the results obtained from egos social network analysis, we can conclude that:

- On average, there is a decrease in the number of specific topics discussed in PBs topics (12.71) compared to fertiliser (18.3), and agricultural technique topics (29.3).
- Farmers obtained information about PBs from different sources, mainly from acquaintances and professionals. Take into account that for PBs networks too, public organisations and research institutes still have weak connections with farmers.
- Farmers are usually familiar with agricultural techniques, fertilisers and PBs topics, which means that these topics have become quite normal subjects about which egos discuss and exchange information with their alters.
- Structural holes analysis indicates that alters are poorly connected to other alters and do not share information with them. In addition, farmers generally have a maximum brokerage opportunity in the network, making them unique in obtaining knowledge about PBs.

5.3 Factors influencing the knowledge, use and reuse of PBs

This section aimed to predict the knowledge or lack of knowledge, use or lack of use, and intention to reuse or not reuse PBs based on a set of predictor variables (egos' attributes and egos' networks characteristics). Binary logistic regression was applied.

As we explained in the data analysis section of the "Materials and Methods" chapter, we used a set of variables and covariates and three methods to appraise the model: Backward Elimination (Conditional), Backward Elimination (Likelihood Ratio), and Backward Elimination (Wald).

Therefore, we ran the analysis on SPSS software, creating 1080 probability logistic regression models. Consequently, we analysed the methods and variables to select the relevant method.

We finally found that "binary logistic regression, backword stepwise (WALD)" is the most effective method. Successively, we selected nine models of which:

- three models for agricultural techniques topics: where know PBs, use PBs and reuse PBs variables are related to egos' variables and SN's variables;
- three models for fertiliser topics: where know PBs, use PBs and reuse PBs variables are related to egos' variables and SN's variables;
- three models for PBs topics: where know PBs, use PBs and reuse PBs variables are related to egos' variables and SN's variables;

The first six models (related to agricultural techniques and fertilisers topics) were processed, including all the network data of 80 egos. Instead, the last three models (related to PBs topics) were elaborated, using the network data of 59 egos because the last 22 egos have no information exchanged concerning PBs.

We report each covariate's significant value and odds ratio as shown in all tables. For the significant value, we accepted values of less than 5%. Instead, for the odds ratio, we accepted values > 1, which means we have a high probability of an event occurring. We report the results obtained for each dataset below.

a) Agricultural techniques

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, agricultural techniques topics discussedAVG, alters' relationsHET; alters' relationsIQV,	**Know PBs**	Specialisation	0.012	20.318
		Education	0.011	1.446
		professional role	0.022	25.450

agricultural technique topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.		Alters' relationsIQV	0.003	20,249

Table 64 –"Know PBs" analysis according to significant covariates.

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of a professional organisation, agricultural technique topics discussedAVG; alters' relationsHET, alters' relationsIQV, agricultural technique topics discussedSD SHdegree, SHdensity, SHeff.size, SHefficiency, SHconstraint and SHhierarchy.	**Use PBs**	Specialisation	0.002	106
		Alters' relationsIQV	0.001	83,537

Table 65 –"Use PBs" analysis according to significant covariates.

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member to a professional organisation, agricultural technique topics discussedAVG; alters' relationsHET, alters' relationsIQV, agricultural technique topics discussedSD SHdegree, SHdensity, SHeff.size, SHefficiency, SHconstraint and SHhierarchy.	**Reuse PBs**	Specialisation	0.005	11.687
		Education	0.001	1.482

Table 66 – "Reuse PBs" analysis according to significant covariates.

From all tables, we deduced that in the egos' networks, when egos discussed agricultural techniques topics with their alters, generally: besides the farmers' attributes (specialisation, education and profession), the alters' relations influence farmers to learn about PBs; specialisation and alters' relations influence farmers to use PBs, and the farmers' specialisation and education level allow them to reuse PBs.

We can deduce that farmers' specialisation is transversal and influences knowledge of PBs and the use and reuse of PBs. Furthermore, based on our sample, most farmers are specialised in specific crops known as STAR crops, and probably need to overcome some problems or enhance final yield and quality (e.g. flowering, fruit-setting, fruit-swelling, fruit-ripening, and so on). For this reason, the farmers' specialisation encourages farmers to learn about PBs, use PBs and reuse PBs. Education level probably represents a cultural basis that allows the farmers to create relationships with other individuals to learn about PBs and reuse PBs.

b) Fertilisers

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, fertilisers topics discussedAVG, alters' relationsHET; alters' relationsIQV, fertilisers topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.	**Know PBs**	Specialisation	0.002	23.123
		Education	0.001	1.452
		Alters' relations IQV	0.013	13.736

Table 67 – "Know PBs" analysis according to significant covariates.

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, fertilisers topics discussedAVG, alters' relationsHET; alters' relationsIQV, fertilisers topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.	**Use PBs**	Specialisation	0.000	86.586
		Age	0.045	1.094
		Education	0.011	1.610

Table 70–"Use PBs" analysis according to significant covariates.

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, fertilisers topics discussedAVG, alters' relationsHET; alters' relationsIQV, fertilisers topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.	**Reuse PBs**	Specialisation	0.022	6.451
		Education	0.004	1.417
		Alters' relationIQV	0.014	323

Table 71 – "Reuse PBs" analysis according to significant covariates.

From all tables, we observed that in the farmers' networks, when farmers talked to their alters about fertiliser topics generally: the knowledge acquired about PBs is influenced by farmers' specialisation, education level and alters' relations. Once knowledge of PBs is acquired, farmers, based on their attributes (specialisation, age, and education level), are encouraged to use PBs. On the other hand, the

reuse of PBs is due to the farmers' attributes (specialisation and education) and, above all, to alters' relationships that stimulate farmers to reuse PBs.

Generally, we noted that farmers' specialisation and education level are transversal and influence knowledge of PBs, use of PBs and reuse of PBs.

c) Biostimulants

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, fertilisers topics discussedAVG, alters' relationsHET; alters' relationsIQV, fertilisers topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.	**Know PBs**	Education	0.001	1.805

Table 72 – "Know PBs" analysis according to significant covariates.

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, fertilisers topics discussedAVG, alters' relationsHET; alters' relationsIQV, fertilisers topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.	**Use PBs**	Education	0.028	1.478

Table 73– "Use PBs" analysis according to significant covariates.

Variables considered in the model	Predictor variables	Covariates	Significant value	Exp(B) Odds-ratio
Specialisation, age, education, professional role, farm's size, employee number, member of professional organisation, fertilisers topics discussedAVG, alters' relationsHET; alters' relationsIQV, fertilisers topics discussedSD, SHdegree, SHdensity Sheff.size, SHefficiency, SHconstraint and SHhierarchy.	**Reuse PBs**	Education	0.022	1.481
		Specialisation	0.017	18.552

Table 74– "Reuse PBs" analysis according to significant covariates.

From all tables, we deduced that in the farmers' network, when farmers discussed PBs topics with their alters, the knowledge acquired about PBs and the use of PBs are influenced significantly by farmers' education level. This result suggests that education level probably encourages farmers to use PBs. In addition, farmers' education level and specialisation generally influence the reuse PBs. This result means that farmers' specialisation is essential for the reuse of PBs.

6. CONCLUSIONS

Our research has been sponsored by a PBs manufacturer and it focused on analysing the agricultural innovation in the Fès-Meknès region (Morocco) and whether the farmers' attributes and the characteristics of their networks could influence them to learn about, use and reuse PBs. We intended to develop a new idea to make market research more incisive by PBs manufacturers.

In connection with the research goals, we analysed the PBs' knowledge diffusion, information exchanged in the network, and farmers' attributes and their networks that could influence the adoption of PBs. We reached our research goals by adopting an ego network approach to analyse the farmers' network characteristics. Then we used a binary logistic regression to identify the variables that influence farmers' knowledge, use, and reuse of PBs. We conducted interviews with 80 professional farmers during the pandemic period to collect data.

The method used could be improved, but results confirm that the probability that a farmer knows and adopts innovative products such as PBs is the result of farmers' characteristics (which is in line with literature) and the nature of the social network in which farmers are involved.

The first result of our survey revealed that the main PBs specific topics discussed between farmers and alters were the technical positioning, the need to use PBs, the knowledge of PBs, and the organic PBs. Considering absolute frequencies of topics discussed between farmers and their alters, we observe that farmers dealing with topics related to PBs have specific characteristics. They have a high school diploma and a bachelor's degree, they are specialised in fruits and cereals farming, and they are managers and members of a professional organisation. We obtained similar results analysing relative frequencies.

Furthermore, in the case of agricultural techniques and fertilisers topics, we noted that the number of alters with whom the farmer discussed remains approximately constant. In contrast, the number sharply decreases when we consider the PBs topics. This result indicates that the information received from alters regarding PBs is limited. Moreover, the analysis has been helpful to identify farmer categories to target with appropriate marketing communications to increase the PBs' use and diffusion in the region.

SNA provided some interesting suggestions, helping to develop a marketing strategy:

- PBs topics seem to become generally a common argument for farmers who have already exchanged fertiliser information with their alters. This result probably is due to three reasons: 1) the research was developed in the North of Morocco, near Spain, and most local distributors imported technical means from this country. For this reason, over time, farmers have begun to know about this category of products; 2) PBs represent a new category of products under Moroccan fertiliser legislation, and that

helps all stakeholders, including farmers, to know the existence of this new category of products; 3) Fertilisers are always included in a nutritional plan, but often farmers are interested in innovative products, such as PBs, to face specific problems related to plant physiological disorders (flowers, fruits drop and so on).

We noted that the average number of topics discussed regarding agricultural techniques (29.3) is 60% greater than the topics discussed on fertilisers, which in turn are 43% greater than the topics discussed on PBs. Therefore, farmers discussed fewer topics concerning PBs, which means that they know the existence of PBs. Still, they do not know the characteristics and benefits derived from the use of PBs. In this case, appropriate actions are required to increase the knowledge of PBs.

- We revealed a moderate heterogeneity in farmers' networks, as farmers have access to information (agricultural techniques, fertilisers, and PBs) mainly from acquaintances and professionals. We believe it is appropriate to supply more information about PBs to acquaintances and professionals. In this way, both figures can spread the correct information to farmers and encourage farmers to use the PBs.
- Based on the egos' perceptions, we disclosed that the farmers' networks have a relatively low density and alters are not tightly connected to each other. This result implies that the diffusion of innovation in the network is somewhat limited among alters. On the other hand, farmers become prominent in the networks and control the flow of information about the PBs.

Therefore, we believe that specific interventions are needed for farmers and their acquaintances and professionals to enhance the dissemination of the knowledge about PBs.

The third result obtained from the logistic regression revealed that: 1) the knowledge of PBs depends on alters' relations and on farmers' attributes (specialisation, education level, and professional role); 2) the use of PBs is influenced by the farmers' attributes (specialisation, education level and age) and alters' relations, and 3) the reuse of PBs relies on farmers' attributes (specialisation and education) and the alters' relationships.

In all three cases, we observed that both the farmers' attributes and the networks' characteristics influence growers to know PBs, use PBs and reuse PBs.

The analysis of the diffusion of PBs in the Fès-Meknès region carried out using the SNA compared to traditional approaches and methods (used for market research) allows obtaining valuable and detailed information related to the characteristics of the network in which different actors are involved and interact with each other.

We believe that the results generated by our research can be helpful in evaluating how to enter and develop the Moroccan market. The PBs players can use the results obtained by our study to increase further the dissemination and adoption of PBs.
Furthermore, the results obtained can also be helpful for other PBs producers and constitute a basis on which companies can act directly on the influencers of the network with suitable investments and marketing activities to increase the diffusion of PBs in the region. The approach used in our research could be replicated in other Moroccan regions, the Maghreb area, and other areas of the Arab world to develop the local market with innovative products, such as PBs.

In addition, the results can be helpful for the PBs producers and the distributors of technical means for agriculture because these results constitute a detailed analysis of the local market concerning the end-users of PBs and the influencers. They most stimulate the dissemination of knowledge, use and the reuse of PBs. The results are also valuable because they allow the PBs manufacturer to make decisions, such as:

1. decide whether to open branches directly on the locus to act directly on the stakeholders analysed.
2. act indirectly by choosing a qualified local distributor who can, in turn, act on the stakeholders analysed. In this case, the company can provide the distributor with technical and marketing support in line with the main crops cultivated and the farmers' needs, such as brochures, nutritional plans, crop dossier, technical notes, PBs dossier, newsletter, district meetings and field trials useful to disseminate the features, technical positioning, and the benefits of using PBs.

In the case of the distributor, we believe that the results obtained allow him to contact the analysed stakeholders to create relationships with them and scale up his commercial network. In addition, involving the manufacturer makes it possible to invite stakeholders to technical meetings and learning days related to the importance of the use of PBs.

Below we report some suggestions addressed to the producer of PBs and distributors of technical means for agriculture to increase the diffusion of PBs in the Fès-Meknès region:

- It is possible to create fruitful collaborations with the main influencers in the network, such as professional figures.
- It is possible to participate in the international fair exhibition “SIAM” in Meknès, where it will be possible to organise, conferences dedicated to PBs topics. On this occasion, it is possible to invite professional farmers, professional figures, and farmers’ acquaintances.

Furthermore, during the fair exhibition, it is possible to find local distributors who have good knowledge and expertise regarding the local market and the needs of the farmers. In this case, creating collaboration with a local distributor, the professional farmers (object of this research) who are more sensitive to innovation will be scarcely involved. Therefore, the diffusion of PBs will be limited in the region.

Conversely, as we mentioned before foreign companies can create a commercial branch aimed to have deep knowledge about the market and act directly on professional farmers and influencers.

- Preparation of specific promotional materials to distribute to professional farmers and influencers. This technical material will explain the importance of PBs, the agronomic characteristics of PBs, the correct technical positioning of PBs on the main crops cultivated in the region (mainly fruits and cereals), and the benefits obtained.
- Organise learning days to explain the importance of PBs in agriculture (organised in a locus or remotely using a webinar platform).
- Involve the ENA in studies and analyses on the applications of PBs on different crops cultivated in the region.
- Organise field trials at farms inviting the farmers' acquaintances and professional figures to illustrate to them the benefits derived from the use of PBs.
- In collaboration with ENA, it is possible to publish technical articles related to PBs in agricultural magazines. In these articles, it is possible to report the results obtained from the field trials.
- Taking advantage of social media such as Facebook, YouTube, LinkedIn, and Spotify, it is possible to make short podcasts and posts oriented to farmers and other stakeholders.

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8. ANNEXES

8.1 Paper Questionnaire

QUESTIONS FOR PERSONAL INTERVIEW ADDRESSED TO FARMERS (Pillar I)
(Before Appendix B)

1. GENERAL INFORMATION

1.1 Company name……..……..

1.2 Company specialization……..

1.3 Location / Village……

1.4 Does your company have branches? ☐ Yes No ☐

If Yes, please indicate how many branches are and where are located:

……

……..……...……

2. INFORMATION ABOUT THE RESPONDENT

2.1 Name of the Respondent……..

2.2 Respondent's Age……

2.3 Respondent's level of education…….....

2.4 Respondent's job position……....

2.5 Respondent's telephone number…….……..……..

2.6 Respondent's mail……...

2.7 Respondent's expertise (years)……..……..

2.8 Is the Respondent the technical manager of the farm (Yes/No)? ……

If not, who is the technical manager?

……..…

……..……

3. LAND AVAILABILITY AND USE, CROPS

3.1 Please, specify the total surface (ha):…….

3.2 Origin of the farm: Property (ha)……. Rental (ha)……...….

3.3 Irrigation: Irrigated land (ha)……. Dry land (ha)…….

3.4 Crops

Crop	Cultivation (ha)	Breeding (ha)

3.5 Are you aware about organic farming? ☐ Yes ☐ No

3.6 Which is the adopted regime of cultivation?

- ☐ Organic farming (% of cultivated land): …….
- ☐ Conventional farming (% of cultivated land): …….

4. LABOUR UNITS

4.1 Family units (number): …….

4.2 Permanent employees (number): …….

4.3 Temporary workers (number): …….

5. PRODUCTION AND COMMERCIALISATION

Crop	Production (mton)	%		%	%	Export %	Countries %

The main purpose of the table is to differentiate between domestic and export production. Information on sales methods and distribution channels can also be collected.

6. OTHER INFORMATION

6.1 Are you a membership of a professional agricultural organization? (Yes/No)

Cooperative	Association	Economic interest group	Interprofessional	

6.2 Are you a membership of an agricultural aggregation? (Yes/No)

6.3 Did you get any certification, like GLOBAL G.A.P, FIBL, ECOCERT, BCS, OMRI.?

- ☐ No
- ☐ Yes

Which?.....……..

7. ABOUT PBs

7.1 Do you know PBs and their properties? ☐ Yes No ☐

7.2 Have you ever used PBs? ☐ Yes No ☐

7.3 Have you used PBs this year? ☐ Yes No ☐

7.4 If the answer is different: why?

7.5 Do you plan to use PBs in the future?

I thank you for the answers provided. Hereafter I will propose some questions relating to the sources of information you use about agricultural techniques

AFTER EXCEL

8. Could you specify the total amount of your company' s turnover in the last 3 years ?

- ☐ 2017:……MAD.
- ☐ 2018:……MAD.
- ☐ 2019:……MAD.

Thank you so much for your cooperation

Date and time: Place:

8.2 Excel file Questionnaire

8.1 First Sheet

Table: Name generator and Ego-Alter ties

Agriculture techniques Section					Fertilizers Section	Considering only the people you talk about soil fertility and fertilizers			PB's Section	Considering only the people you talk to about PBs		
Who are the people you talk to about agricultural techniques?	What do these people represent to you?	What topics do the information you get from each of these people relate to?	What topics do the information you provide to each of these people relate to?	How many times have you spoken to each of these people in the last 6 months?	what are the topics related to fertilizers on which you get information from them?	what are the topics related to fertilizers on which you give them information?	which people give you suggestions for setting up your fertilization plan?	which people do you give suggestions for setting up their fertilization plan?	what are the topics related to PBs on which you get information from them?	what are the topics related to PBs on which you provide them with information?	which people suggested you use PBs?	to which people have you suggested the use of PBs?

8.8 Second Sheet

Alter-Alter Ties Matrix

As far as you know, who's talking to whom about agricultural techniques?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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The Methodology applied for the Literature Review of SNA and Diffusion of Innovation: Research Issues and Insights for Future Research:

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

a) Information data source,

b) The approach applied to select different articles,

c) The guidelines.

a) Information data source:

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

b) Approach applied to select different articles:

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

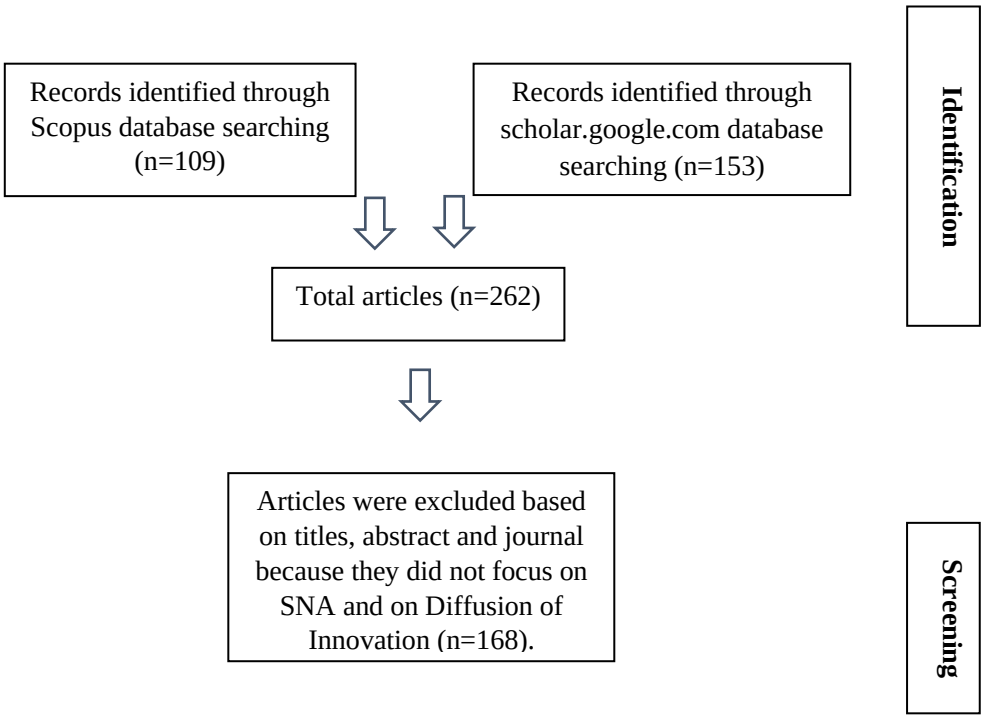
-**Keywords**: typing Social Network Analysis; Diffusion of Innovation, Application of Social Network Analysis; Social Network Analysis in agriculture.

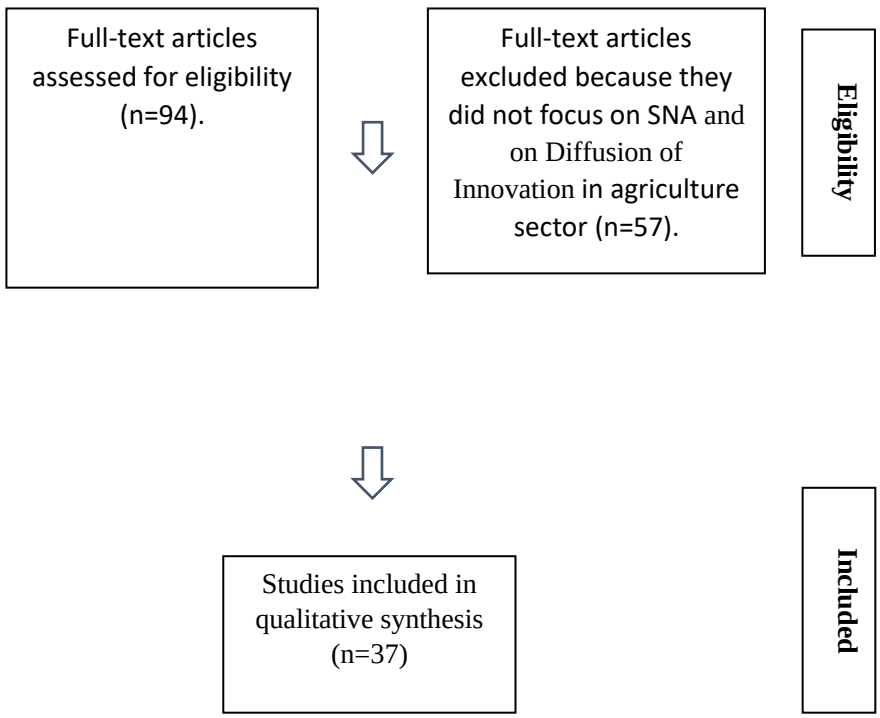
-**Methodological approach** used to select the papers:

Database	Search String
Scopus	*TITLE-ABS-KEY (social AND network AND analysis AND in AND agriculture) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA,"ECON")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBYEAR, 2019)) AND (LIMIT-TO (LANGUAGE, "English"))* *TITLE-ABS-KEY (social AND network AND analysis AND diffusion AND of AND innovation) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (SUBJAREA,"ECON")) AND (LIMIT-TO (SUBJAREA,"AGRI")) AND (LIMIT-TO (LANGUAGE, "English")).* *TITLE-ABS-KEY* (application AND of AND social AND network AND analysis) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (SUBJAREA, "ECON")) AND (LIMIT-

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

c) The guidelines:




Full-text articles assessed for eligibility (n=94).
Full-text articles excluded because they did not focus on SNA and on Diffusion of Innovation in agriculture sector (n=57).
Eligibility
Studies included in qualitative synthesis (n=37)
Included