Innovative Farming Practices and Information Sources. An Analysis of Trends in the United Kingdom's Arable and Livestock Farming

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DOI: 10.4422/ager.2022.18

ager

Revista de Estudios sobre Despoblación y Desarrollo Rural

Journal of Depopulation and Rural Development Studies

Páginas: 159-194

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Highlights:

1. Mixed methods allow for the identification of innovative actors within a network.
2. Egocentric two-mode network provides a clear picture of the information exchange processes between actors.
3. The exchange of knowledge and the role of influential actors transcends geographical scales..
4. Face-to-face is not necessary to have information that can boost innovations.

Abstract: The adoption and diffusion of innovations are closely related to farmers' characteristics and to the interaction and knowledge sharing with influential agents for the adoption of innovations. This introductory paper analyses the adoption trends of innovations by 28 farmers (15 arable and 13 livestock farmers) and the role of influencers as sources of information for the adoption of eight innovations in a UK survey. The results show, on the one hand, that some of the most innovative farmers are linked to older ages, while, on the other hand, networks composed of formal and informal actors may influence a higher adoption rate of innovations. The adoption rate and speed of innovations have proven to be a useful element of analysis in combination with the average degree of network centrality, thus facilitating the interpretation of the relationship between the farmer and the influential actors.

Keywords: Adoption innovation; diffusion innovation; transfer knowledge; knowledge sharing; social network analysis.

Prácticas agrícolas innovadoras y fuentes de información. Un análisis de las tendencias de la agricultura y la ganadería en el Reino Unido

Ideas clave:

1. Los métodos mixtos permiten la identificación de actores innovadores dentro de una red.
2. La red egocéntrica de dos modos proporciona una imagen clara de los procesos de intercambio de información entre los actores.
3. El intercambio de conocimientos y el papel de los actores influyentes trasciende las escalas geográficas.
4. El cara a cara no es necesario para tener información que pueda impulsar las innovaciones.

Resumen: La adopción y la difusión de innovaciones están estrechamente relacionadas con las características de los agricultores y con la interacción y el intercambio de conocimientos con agentes influyentes para la adopción de innovaciones. Este trabajo, de carácter introductorio analiza las tendencias de adopción de innovaciones por parte de 28 agricultores (15 agrícolas y 13 ganaderos) y el papel de los agentes influyentes como fuentes de información para la adopción de ocho innovaciones, en una encuesta realizada en Reino Unido. Los resultados muestran, por un lado, que algunos de los agricultores más innovadores están vinculados a edades más avanzadas, mientras que, por otro lado, las redes compuestas por actores formales e informales pueden influir en un mayor índice de adopción de innovaciones. El índice de adopción y la velocidad de las innovaciones han demostrado ser un elemento de análisis útil en combinación con el grado medio de centralidad de la red, facilitando así la interpretación de la relación entre el agricultor y los actores influyentes.

Palabras clave: Adopción de innovaciones; difusión de innovaciones; transferencia de conocimiento; intercambio de conocimientos; análisis de redes sociales.

Received: 6th November 2022
Returned for revision: 4th December 2022
Accepted: 14th December 2022

How to cite this paper: Mesa, R. (2022). Innovative Farming Practices and Information Sources. An Analysis of Trends in the United Kingdom's Arable and Livestock Farming. *AGER: Revista de Estudios sobre Despoblación y Desarrollo Rural (Journal of Depopulation and Rural Development Studies)*, (36), 159-194. https://doi.org/10.4422/ager.2022.18

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1. Introduction

The adoption and diffusion of innovations play an important role in agricultural systems and can contribute to economic and environmental sustainability (Cannarella & Piccioni, 2010; Tóth et al., 2020). The processes of adoption and diffusion of innovations are associated with the exchange of information between heterogeneous actors (Klerkx et al., 2010; Spielman et al., 2011). This aspect is considered by the Agricultural Innovation Systems (AIS), defined as, "*a network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organisation into social and economic use*" (World Bank, 2007, p.18). Through the AIS perspective, direct connections between farmers and technology manufacturers have been analysed to shed light on the important role of input suppliers (Hornum & Bolwig, 2021), to investigate information network structures for agrobiodiversity management (Isaac, 2012), and to show the need for greater collaboration between research institutions, agricultural extension systems, civil society and private sector actors to improve innovation processes (Bhatta et al., 2017). However, scholars have identified the need to design multidimensional approaches to the study of the processes of diffusion and adoption of innovations, pointing out that multiple analysis studies remain scarce (Ruttan, 1996; Pathak et al., 2019).

In this sense, in recent years, multivariate approaches based on social capital and social network analysis, in combination with the characterisation of actors through the analysis of innovation dynamics (rate and speed of adoption), have played a more relevant role. The aim has been to understand how an actor's position in the network is linked to the rate and speed of innovation adoption and the quality and strength of links with agricultural extension agents (Aguilar-Gallegos et al., 2016; Susaeta et al., 2018). On the one hand, social capital approaches, the analysis of social networks in agricultural innovation systems, help to understand the importance of interactions and knowledge transfer between groups of agricultural farmers as well as between farmers and other agents (Spielman et al., 2011; Wood et al., 2014; Gailhard et al., 2015; Bavorová et al., 2020; Skaalsveen et al., 2020). On the other hand, through the use of indices, namely the Innovation Adoption Index (InAI) and the Speed of Adoption Index (SAI), they add to the actors the attributive characteristic of the innovator profile. Both the relational aspect and the adoption rates/speed revolve around the ability of the farmers the characteristics of the network and the type of innovations they adopt (Aguilar-Gallegos et al., 2016; Susaeta et al., 2018).

Agriculture and livestock keepers generally adopt a large number of innovations or practices, which are very different from each other. These can range from innovations related to productivity, environmental sustainability, and the structure and organisation of the enterprise, among others. Both the analysis of technological adoption and the adoption of sustainable practices are two aspects frequently studied in the scientific literature (Doss, 2006; Rantala et al., 2018; Bucci et al., 2019). The adoption of sustainable agricultural practices, in this sense, covers a wide spectrum of innovations, ranging from those related to the adoption of conservation tillage (D'Emden et al., 2006; Bavorová et al., 2020), the adoption of environmentally sustainable practices (Mesa & Esparcia, 2021) and the adoption of organic fertilisers (Hasler et al., 2016) as well as other practices based on technical improvements (Ameur et al., 2013; Haji et al., 2020) and machinery adoption (Cavallo et al., 2014).

This paper is an introductory analysis of the trends in innovations adopted by arable and livestock farmers and their sources of information for the adoption of innovations. The main objective of this study is to characterise the innovation profile of selected farmers and to identify the influencing factors for a selection of 28 UK farmers by asking about the adoption of a total of eight innovations, four innovations for farmers (arable and livestock). The specific objectives are: to identify the innovations adopted, to identify the farmer innovators with the highest adoption rates and speed of adoption and to analyse the relationship with influential actors or entities. To achieve these objectives, two types of analysis are carried out, the first based on innovation indices and the second based on social network analysis (see more in section "3.1 Objectives").

2. Theorical-conceptual bases

2.1. Information networks and knowledge sharing

Innovation diffusion processes start with the exchange of information between users (Rogers, 2003). Studies on the diffusion of innovations have highlighted the importance of studying knowledge exchange in a network perspective in order to gain a better understanding of social systems (Conley & Udry, 2010; Magnan et al., 2015). In this way, interactions between farmers and influential actors, such as government representatives, agricultural extension agents, other farmers, representatives of fairs or events, advisers or consultants and NGOs generate knowledge exchange processes by integrating into farming systems (Renting & Wiskerke, 2010; Spielman et al., 2011). Thus, farm advisors are a key stakeholder because of their influential role in providing expert technical advice on farms.

Several research studies have focused on the transfer of information between farmers, agricultural extension agents, influential actors and other stakeholders (Boahene et al., 1999; Wedajo et al., 2019), emphasising the role of opinion leaders in speeding up the diffusion of innovations (Yosua et al., 2019) and to analyse the positive effects provided by interaction with agricultural extension agents (Pachoud et al., 2019), as well as the influence of actors in decision making (Daouda & Bryant, 2016). However, the complexity of knowledge transfer and the importance of focusing on the benefits of innovations, their efficiency and their impact on the environment clear (Concu et al., 2020), and the obstacles posed by low interaction between actors have become apparent (Kebebe, 2019). For this reason, the network perspective in studies on the diffusion of innovations has become increasingly important (Conley & Udry, 2010; Magnan et al., 2015).

2.2. Social Network Analysis

Social Network Analysis (SNA) is a tool frequently used to analyse the processes of adoption and diffusion of innovations (Rogers, 2003; Valente, 2005). Social network analysis can be used to analyse peer-to-peer relationships, also called homophilic networks (members with similar status or similar characteristics) (Rogers, 2003). The

SNA approach has been widely used in agrarian and rural studies to analyse both opinion leaders in rural settings and opinion leaders in rural areas (Esparcia, 2014; Vercher, 2022), such as the role of farmers in knowledge sharing for the adoption of innovations (Wood et al., 2014; Infante, 2020; Skaalsveen et al., 2020; Niang et al., 2022). SNA studies generally have two main approaches: community-based studies (sociocentric networks) and studies focusing on individuals and their relationship with external agents or entities (egocentric networks). Through egocentric networks, key actors, called "ego", are selected and by means of a name generation questionnaire a network of connections is traced on the basis of a sample, with the aim of creating a network that connects the selected actor (ego) with actors with whom he/she is connected (called "alter") (Marsden, 2002; Perry et al., 2018; Scott & Carrington, 2011).

Relationships are not always with specific individuals, but with organisations, institutions, or relationships can be generated from events or fairs, or maintained as a source of information from other media (such as books, internet, magazines, etc.). ARS techniques solve this diversity of actors by means of what is known as two-mode networks (Borgatti & Everett, 1992). Corporate networks would be an example of an application, and they analyse the alterations that are common to various egos, and the reasons for this (Perry et al. 2018). Therefore, this type of methodology is useful for analysing innovation processes, understood as "*interactive learning between actors, between functional areas within a firm or relationships between firms, between users and farmers, and between firms and institutions*" (Etemad, 2004, p.48).

2.3. Rate of adoption and speed of adoption of innovations

Technology adoption models have been widely applied to analyse the adoption or rejection of agricultural technologies (Bass, 1969; Rogers, 2003). The diffusion process follows a cumulative "S" process that explains the probability of adoption by those who have not yet adopted. Following this approach, recent studies have focused on the processes of adoption and imitation, arguing that adopters may themselves be imitators and that the speed and timing of adoption depend on their degree of innovation and the degree of imitation among adopters (Sneddon et al., 2011; Wu et al., 2019). In this respect Rogers (2003) defined the profile of adopters in five categories, according to the moment of adoption of the innovation within a social system, such as "Innovators, Early adopters, Early majority, Late majority and Laggards".

The rate and speed of adoption are characteristics applied both to the adoption of new agricultural technologies and to the analysis of traditional practices (Batz et al., 2003). Innovation Adoption Indexes (InAI) and Speed of Adoption Indexes (SAI) have proven to be useful in characterising the dynamics of adoption and behaviour of adopters, both at the individual and community level, in arable and livestock farmers (Muñoz Rodríguez et al., 2007; Aguilar-Gallegos et al., 2017). InAI refers to the farmer characteristics that determine innovation adoption, while SAI describes the speed of adoption of innovations.

2.4. Innovations in arable and livestock farming

A large part of the innovations available to farmers can be integrated in different systems, such as conventional, regenerative, certified organic, non-certified organic and agroecological agriculture, both in agriculture and livestock.

In agricultural production, zero tillage has been the subject of research in most countries in Europe, Canada, Australia and elsewhere (D'Emden et al., 2006; Soane et al., 2012; Zikeli & Gruber, 2017; Skaalsveen et al., 2019). In the adoption of no-tillage, the role of intermediaries in knowledge sharing has been highlighted (Skaalsveen et al., 2020) and the importance of social capital, innovation networks and the active role of farmers in the transfer of knowledge (Ingram, 2010; Micheels & Nolan, 2016). The adoption of precision farming is a type of innovation that gives the farmer greater control over the farm, improves productivity, reduces economic waste, and increases environmental sustainability (Barnes et al., 2019; Eastwood et al., 2019). Some of the determinants of technology adoption in both UK and US organic farmers were associated with age and level of education (Adrian et al., 2005; Tiffin & Balcombe, 2011). The Farm Practices Survey Autumn 2019 - England (Defra, 2019) showed that 47 % of cereal growers had adopted technology for soil mapping, 75 % adopted precision farming to reduce costs and 77 % because it increases productivity.

As far as livestock husbandry practices are concerned, pasture improvement is a frequent activity to increase yields and its potential depends on soil structure, biodiversity and fertility. Correct pasture management and improvement has a high potential from the point of view of economic performance, improving the product but also for biodiversity (Coppa et al., 2011; Agriculture and Horticulture Development Board, 2018). Similarly, animal grazing involves numerous feeding practices such as dietary change, mob grazing or feeding supplementation. Some studies have looked at different grazing systems (Coppa et al., 2011; Wallis De Vries et al., 2007). Decision-making to adopt changes in food management has been analysed taking into account the personal attributes of farmers and the adoption of mental calculation, intuition and experience to make these decisions (Nuthall & Bishop-Hurley, 1996).

Related to landscape conservation, hedgerows are a means of conserving biodiversity and are a part of the English landscape and culture. The implications of landscape management have led researchers to analyse its links to people, policy and protection (Oreszczyn & Lane, 2000). Finally, animal welfare is one of the most motivating aspects for farmers and is an improvement adopted by 95 % of farms, according to the Farm Practices Survey Autumn 2019 - England. According to this survey, 41 % of farmers said that financial barriers were the biggest obstacle to improving animal welfare, while 62 % of farms said they had already done all they could and were satisfied with their current level of animal welfare. This provides the rationale for the choice of innovations included in the survey.

3. Objectives, methodology and sources, areas or case studies

3.1. Objectives

The aim of this study is to undertake an introductory approach to characterise the innovativeness profile of the selected producers, and to identify the influential agents or entities of a selection of 28 farmers. Given its introductory nature, it is not intended that the results be representative of the processes of adoption and diffusion of innovations among British farmers or of a specific area. It is only intended to obtain an approximation to the innovativeness profile of a series of producers. From this point of view, it is a prospective study that should serve to subsequently define new lines of research and, through representative samples, analyse which processes create bottlenecks or facilitate the exchange of knowledge and, therefore, the adoption of innovations. In order to achieve the objectives, the farmers were asked about the adoption of a total of eight practices that had been previously selected: four innovations for arable farmers (non-inversion tillage, precision farming, alternative fertilisation and machinery improvements) and four innovations for livestock farmers (pasture improvements, grazing improvements, animal welfare and hedgerow improvements). The specific objectives of this study are: 1) to identify the innovations with the highest proportion of adoption; 2) to identify the farmers with the highest rate of adoption of innovations; 3) to identify the farmers with the highest speed of adoption of innovations; and 4) to analyse the influential agents in the adoption of agricultural innovations. To do this, we will address the following research questions: 1) Which innovations are the most adopted? 2) Which farmers have the highest rates of innovation? 3) Which farmers who have innovated have the highest speeds of innovation? and 4) Which agents influence the adoption of innovations?

To answer the research questions, we have designed two types of analysis. The first one answers the first three research questions and is linked to the specific objectives 1, 2 and 3 and is based on a model of adoption index of innovations (cumulative frequency, innovation adoption index and speed of adoption index). The second, linked to objective 4, answers the last research question, and is based on the analysis of social networks (two-mode egocentric network) to identify the sources of information through influential agents on a time scale from 1990 to 2021.

3.2. The survey and area of study

In order to carry out the data collection, a survey was designed to fit our research objectives, structured in three parts: the attributes of the surveyed farmers, the innovations adopted (to calculate cumulative, adoption index and speed of adoption index) and the relationships with influential agents (to ascertain farmers' egocentric network) (see the survey in the annex). This also explains the dispersion of the surveys collected, as we shall see in the following paragraphs (Table 1).

Survey design: the design process of this survey was iterative, taking into account advice from both practitioners and academics. To ensure the accuracy of the survey, a pilot-test was first conducted with three volunteer farmers with a long background in arable and livestock development. Through this test, it was found that some of the questions on personal network analysis added complexity, as well as some of the innovations being too complex. As a result, a second phase of consultation with academics and farmers was conducted, leading to the selection of eight general innovations that could encompass different practices, e.g. hedgerow improvements, erosion reduction, and improved animal welfare.

When we started the survey, we encountered numerous difficulties in conducting face-to-face fieldwork because of the fear of COVID-19 infection. For this reason, the final survey was adapted to an online survey format. This was done using the online platform JISC, which allows for the design of surveys focused on research domains.

Survey implementation: the survey was then implemented in two ways. First, through a combination of purposive sampling through known contacts and snowballing to ensure that a large number of farmers were aware of the survey. Secondly, a link was shared in September 2021 through multiple channels, email with known contacts, advertised, posted on relevant websites, agricultural forums and social media.

Among all sources used, the survey had a reach of 642 (based on total views on the JISC platform) with only 28 complete responses, representing 4.4 % of total views. Of the 28 responses received, 15 were from arable farmers and five of them indicated that they had not introduced the innovation practices they were asked about, while the remaining 13 were from livestock farmers and all of them had adopted at least one of the four innovations they were asked about. The survey was collected from farmers and livestock breeders in diverse locations in UK, thus explaining the dispersion of the information sources (Table 1).

As can be seen, the low response rate is in line with some recent studies (Ambrose-Oji et al., 2022; Maye et al., 2022). The scattering of the study is explained by the means used for the survey, due to the limitations resulting from the pandemic, both the scope of the surveyed and limitations to delimit the study area. It is for this reason that this work reaffirms its introductory character, as the available sample is not representative to analyse the diffusion and adoption processes of innovations, and it also does not allow for significant differences between farmers and livestock farmers in the United Kingdom. Given that the results are of a qualitative nature, this study can be useful to analyse trends and establish future lines of research.

In addition, the limited choice of innovations may also have excluded some innovations that farmers are undertaking. As such these results can be seen as indicative rather than definitive. It cannot be concluded that some farmers are more innovative than others, but rather, that for specific innovations those who responded had higher indices.

3.3. Methodology: attributes data collection and analysis

Attributes of the farmers: we asked about age, gender, level of education, type of crop, location, form of sale, form of ownership, area, type of production (horticultural, cereal, animal) and production system, (agro-ecological, conventional, organic non-certification, organic with certification, regenerative farming) (Table 1). These attributes and other aspects such as relationships can determine the ability to innovate, understood as a type of aptitude or skill (Aguilar-Gallegos et al., 2016).

Adopted innovations: we selected eight innovations (four arable and four livestock) described above from three main sources: 1) innovations that frequently appear in the scientific literature on adoption and diffusion processes, both in arable and livestock; 2) innovations collected in Defra Farm Practice survey (Defra, 2019); 3) consultation of agricultural experts, both farmers and academics. The selected innovations are: for the arable farmers, a) non-inversion tillage; 2) alternative fertilisation; 3) precision farming; 4) machinery improvements; and for the livestock farmers 1) animal welfare improvements 2) Pasture improvements 3) hedgerow management improvements 4) Animal grazing improvements. This data was used to calculate the cumulative index which indicates which innovations are the most adopted.

Adoption index and Speed of innovation adoption index: data was collected for respondents' years of innovation adoption (1990 to 2021) in order to analyse the rates of adoption and speed of innovations.

Analysis: following the analysis of Muñoz Rodríguez et al. (2007), we use the indicators referred to by the authors. These are the cumulative index, the innovation adoption index and the innovation speed index.

Table 1.
Crop types, location and characteristics (age and education level) of respondents

	Arable N = 15 (53,6 %)	Livestock N = 13 (46,4 %)	Total
	Arable/Livestock		
Cereal	3 (10 %)		3 (10 %)
Horticulture	12 (42 %)		12 (42 %)
Beef cattle		4 (14 %)	4 (14 %)
Dairy cattle		2 (7 %)	2 (7 %)
Sheep		7 (25 %)	7 (25 %)
	Location		
East Midlands	(0 %)	1 (3 %)	1 (3 %)
East of England	3 (11 %)	1 (3 %)	4 (14 %)
North East	(0 %)	1 (3 %)	1 (3 %)
North West	2 (7 %)	2 (7 %)	4 (14 %)
Scotland	2 (7 %)	1 (3 %)	3 (11 %)
South East	4 (14 %)	3 (11 %)	7 (25 %)
South West	2 (7 %)	2 (7 %)	4 (14 %)
Wales	1 (3 %)	1 (3 %)	2 (7 %)
West Midlands	1 (3 %)	1 (3 %)	2 (7 %)
	Sex		
Female	6 (21 %)	6 (21 %)	12 (42 %)
Male	9 (32 %)	7 (25 %)	16 (57 %)
	Age		
25 - 34	3 (11 %)	1 (3 %)	4 (14 %)
35 - 44	2 (7 %)	3 (10 %)	5 (17 %)
45 - 54	3 (11 %)	1 (3 %)	4 (14 %)
55 - 64	6 (21 %)	6 (21 %)	12 (42 %)
65 - 74	1 (3 %)	1 (3 %)	2 (6 %)
75 +	0 (0 %)	1 (3 %)	1 (3 %)
	Studies		
A-Level or equivalent	2 (7 %)	2 (7%)	4 (14 %)
Below GCSE	1 (3 %)	0 (0 %)	1 (3 %)
Doctoral degree or equivalent	2 (7 %)	2 (7 %)	4 (14 %)
GCSE or equivalent	2 (7 %)	0 (0 %)	2 (7 %)
HND/BA/BSc degree or equivalent	4 (14 %)	7 (25 %)	11 (39 %)
MA/MSc degree or equivalent	4 (14 %)	2 (7 %)	6 (21 %)

Source: own elaboration

The indicators have been developed as described below:

Cumulative index:

$$f_i \frac{n_i}{Ni}$$

Cumulative index : where is the absolute frequency, the number of times the value is in the set; and is the sum of the cumulative absolute frequency.

Innovation Adoption Index (InAI):

$$InAI_i \frac{IA}{k}$$

$InAI_i$: adoption index of innovations of the i-th farmer; : innovations adopted; : Total number of innovations

Speed of Adoption Index (SAI):

$$SAI_i \frac{(survey\ year + 1) - YIA}{(survey\ year + 1) - minimum\ year}$$

SAI_i: indicator of speed of adoption of the i-th individual in the j-th innovation; : year in which field data is collected; : Year of innovation Adoption: year in which the individual adopted the innovation; : minimum year of adoption.

3.5. Farmers' ego networks two mode network: data collection and analysis

Data collection: Based on Perry et al. (2018), questions were adapted under a personal network analysis approach for the online survey. These were as follows:

1. For each of the innovations, respondents were asked to list the type of agent that had influenced the adoption of innovations. For this, they were provided with a list of potential influential agents and asked to select one agent for each adopted innovation from (Representative of Advisers/Consultant (private or public), Family or Friends, Farmer neighbour, Farmers in event or fair, NGO's (e.g., FWAG, Soil Association, Innovative Farmers), Industries bodies (NFU, AHDB), Internet or books influencers and Others. This list was derived from other studies of the AKIS in UK (Skaalsveen et al., 2020).

2. Next respondents were asked whether they were aware of any exchange of information between the above-mentioned people in relation to the innovations listed above. In this way, a relationship is drawn between various "alters" in order to identify groups where agricultural knowledge exchange is taking place.

Analysis: In order to compare the arable and livestock networks on the basis of the farmers' responses, we divide the innovation networks into three time periods, where in each one we add the accumulated years of the previous period: a first period of 10 years from 1990 to 2000; a second period of 20 years, from 1990 to 2020; and a third period from 1990 to 2021 (Figure 3). In this way, not only do we have a visual sequence with which to interpret the relationships, but by means of a simple calculation, such as the average degree, we can identify which networks have a higher proportion of connections with respect to the nodes (Perry et al., 2018).

$$Average\ Degree = \frac{Total\ Edges}{Total\ Nodes}$$

$Average\ Degree$: average number of edges per node in the graph.

$Total\ Edges$: total number of ties (connections between nodes) in a network.

$Total\ Nodes$: total number of actors or entities in a network (with or without connections).

4. Results

4.1. Farmers' attributes

Half of the farmers surveyed are over 55 years old (53 %) and of these, 42 % are in the 55-64 age group. Divided by gender, 12 respondents are women and 16 are men.

The highest number of farmers is found in the agro-ecological systems with six women and four men, representing 35 % of the total. The next highest number of responses belong to conventional agriculture, with three women and five men, representing 28 % of the sample. Both the agroecological and conventional farmers are the only ones with doctoral levels degrees. Non-certified organic farming and regenerative farming have the same number of responses, one woman and three men, respectively, representing 14 % in each case. The lowest number of responses were for certified organic agriculture (two), one woman and one man, together representing 7 % of the sample.

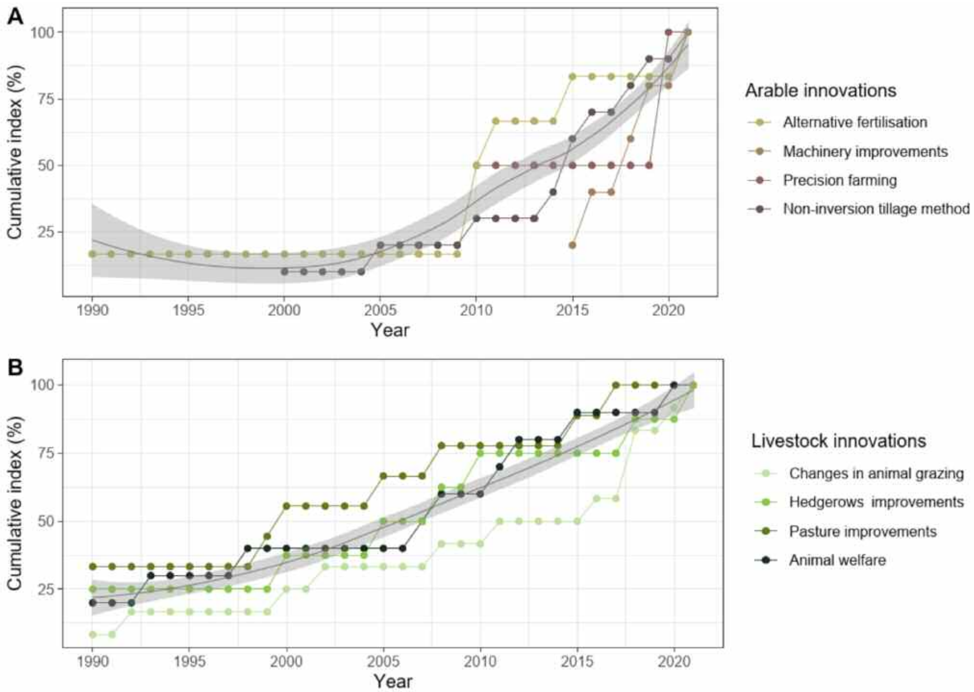
In the arable farming, the main crops are grown in conventional and regenerative farming systems and oriented to cereal production, while the other systems, such as agroecological and organic (with or without certification) have horticultural production (vegetables and fruits). In livestock farming, we observed the absence of organic certification but a high number of agroecological sheep (four) and beef cattle (one) farmers and one organic beef cattle farmer. On the other hand, conventional farmers who responded produce beef cattle (two), dairy cattle (two) and sheep (two). Finally, one regenerative agriculture farmer is mainly beef cattle production.

4.2. Arable and livestock farmers' innovations and their networks

4.2.1. Arable and livestock innovations

Of the 15 arable farmers surveyed, five responded that they had not introduced any innovations. Considering the farmers who did adopt the innovations, the arable farmers showed a lower adoption compared to the livestock farmers. If we compare the average adoption rate over the cumulative frequencies, only one producer in the arable farmers had introduced a practice during 1990, whereas, in the same year, eight of the 13 farmers in the livestock farmers reported having introduced any of the proposed practices. Thus, while the arable farmers, composed of 10 farmers, adopted any of the four selected practices on 23 occasions, the livestock farmers, composed of 13 farmers, did so on 39 occasions (Figure 1).

Figure 1.
Cumulative index per year. Adoption of innovations according to type of innovation and type of farmer (arable and livestock) 1990 — 2021

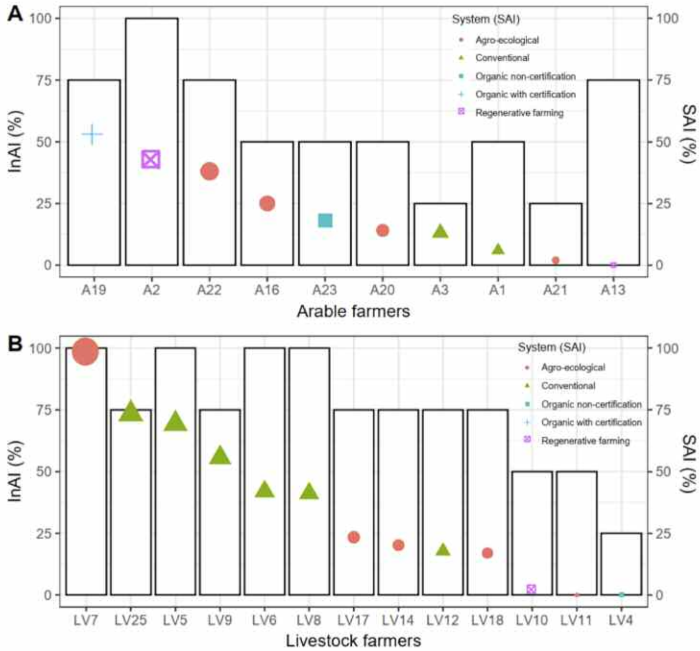


Source: own elaboration.

4.2.2. Farmer's innovation adoption and two mode ego networks

Through the InAI and SAI indicators, relationships can be established between the proportion of innovations adopted by each farmer, the innovative character of the farmer and the influence of networking through connections with their information sources. In this way, and in relation to the categorisation of Rogers (2003) based on the SAI, we observe from "Innovators" farmers (A19 and LV7), for their speed and for being the first to innovate, to others categorised as "Laggards" farmers, as late adopters (A21, A13 and LV10, LV11, LV4) (see SAI in Figure 2). Thus, the categorisation based on the indicators can be related to the network characteristics according to the information sources of each farmer such as those shown in the study: innovative farmers based on self-knowledge, farmers whose networks are exclusively formal or informal, farmers with mixed networks (formal and informal) and farmers without knowledge sharing network. Below, in Figure 3, the white triangle represents formal connections, while the white circles represent informal ones.

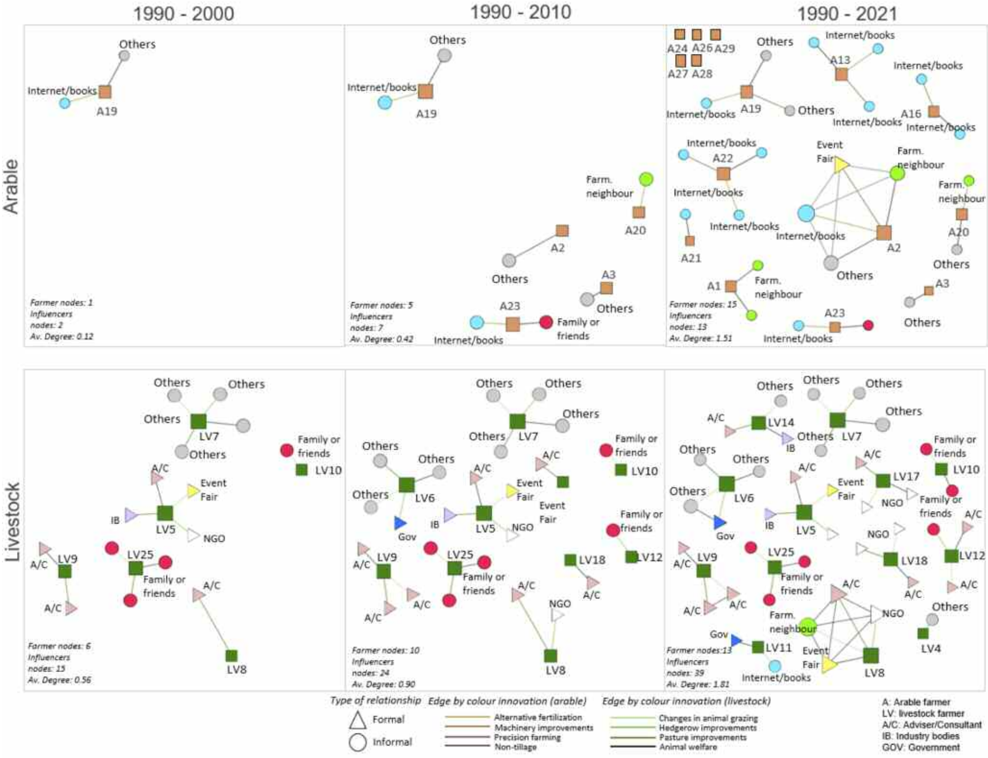
Figure 2.
Arable (A) and livestock (B) farmers adopters (InAI & SAI)



Source: own elaboration.

As described we observe farmers who adopt innovations and are fast innovators (InAI and SIA= 100 %) whose information source is not linked to any entity but are farmers with self-taught behaviour (LV7), farmers with exclusively formal networks linked to information sources such as Advisor/Consultant Event or Fair, Industry bodies and NGOs (LV5 with InAI= 100 % and SIA= 75 %), farmers with mixed networks (A2 and LV8) and others whose networks are exclusively with "Family and friends" (LV25) or informal networks linked to self-knowledge through books or internet (A22, A13, A16).

Figure 3.
Farmers and Influencers networks development over time (1990–2021)



Source: own elaboration.

We also show that farmers who mentioned complete interaction networks in which all actors know each other, as shown by arable (A2) and livestock (LV8) farmers in Figure 3. This type of information exchange networks between formal and informal actors indicates, by the diversity of links, a heterogeneous type of network, where a group of actors' exchange information with each other. Each type of innovation comes from a different type of information source, and therefore, we understand that this diversity of innovation sources indicates greater possibilities to innovate by having information from several sources. In this sense, the characteristics of the individual farmer in terms of personality (predisposition to innovate), farming system (conventional or organic) and attributes such as age and level of education can be considered in the definition of the individual profiles.

The farmers' network has been represented in three time periods corresponding to the total study period, which is 31 years (1990 - 2000; 1990 - 2010; 1990 - 2021). In the first period (1990 - 2000), farmers have a degree of centrality of 0.12 while that of livestock farmers is five times higher (0.56). This suggests a significant difference in the initial network, which is maintained over time. Thus, in the second period, between 1990 - 2010, livestock farmers have a total of ten farmers (four more than in the first ten years) and a total of 24 connections with influential actors, of which 12 are formal and 12 informal. In this period, while farmers have a network with an average degree of centrality of 0.42, that of livestock farmers is more than double (0.90). Finally, in the last period (1990 - 2021) the average degree between both farmers is close to 1.69 for arable crops and 1.81 for livestock farmers, indicating a proximity between nodes and connections. Farmers added a considerable number of nodes in the last period. In addition, farmers have only one connection to formal agents, which corresponds to "Companies at events or fairs". Livestock farmers, on the other hand, with 13 farmers, have a total of 39 connections with agents that are divided between formal and informal. Of these, 20 correspond to formal agents "Advisors/Consultants" and 19 to informal networks, mainly with "Family and friends" and "Others".

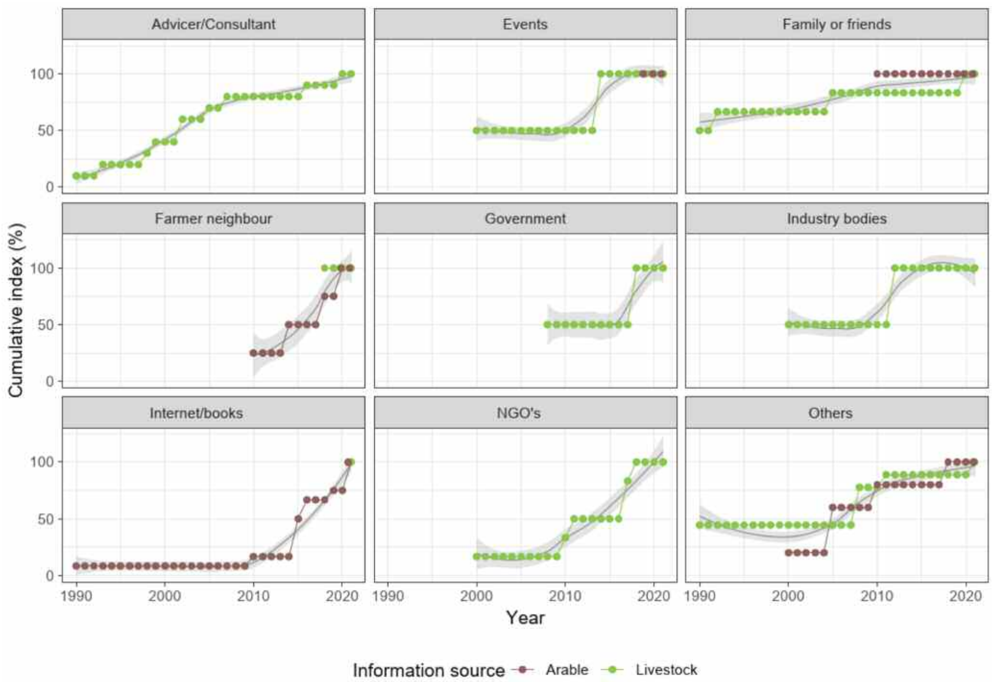
4.2.3. Source of innovations

The sources of information selected in the survey are listed above (Figure 4). The results showed that there is a clear difference in the relationships with influencers between arable and livestock. This can be seen both in Figure 3 on the cumulative index and in Figure 4, where the connections between farmers and influencers as sources of information for the adoption of innovations are observed.

The arable farmers had a total of 23 connections and there were agents that did not influence the adoption of any of the innovations (government, Industry bodies, NGO's and Adviser/Consultant). In other words, none of the agents considered as formal, with the exception of "Event or Fair", influenced the adoption of innovations in the arable farmers. In contrast, the livestock farmers had a total of 39 connections with influencers, where all the agents listed in the survey influenced the adoption of innovations.

Adviser/Consultant agents were the most influential in the adoption of innovations in the livestock farmers (pasture improvement, animal welfare improvement on four occasions and on two occasions with changes in animal grazing). Two livestock farmers (LV9 and LV12) indicated that most of their innovations came from sources such as Adviser/Consultant, (three and two innovations, respectively). Both LV9 and LV12 run their livestock activity under a conventional system with sales to intermediaries.

Figure 4.
Cumulative index per year. This graph represents the source of innovations according to type of influencer (arable and livestock) 1990 – 2021



Source: own elaboration.

For the arable farmers, the most important source of information was influential people from "Internet or books", which was mentioned up to 12 occasions. The practice most related to consultation of "Internet or books" was the non-inversion tillage method (five occasions), alternative fertilisation (four occasions), machinery improvements (three occasions) and the use of alternative fertilisation (four occasions).

Both the arable and livestock farmers indicated "Other" (personal reasons without the intervention of influential agents) as the second most important source, up to five and nine occasions, respectively. Within this source of information, the causes are mostly related to self-knowledge and the adoption of innovations based on their own experience.

"Family and friends" influenced the adoption of livestock practices up to six occasions. L10, a regenerative farming farmer, also indicated that the innovations he had adopted (animal welfare and changes in animal grazing) were influenced by family or close friends. With respect to neighbouring farmers influencing the adoption of innovations, the arable farmers indicated that they had been influential on up to four occasions. For livestock farmers, neighbours in the area would have had a low influence with only one influential input coming from a nearby neighbour.

5. *Discussion*

The first observation from the results is that higher innovation adoption index (InAI) and speed of innovation index (SIA) are associated with older producers, who have not only earlier starts in the adoption of innovations but also more practical experience and accumulated knowledge (García et al., 2007). This is in contrast Zarazúa et al., (2012), who link a lower adoption index to older ages, and contrary to the received wisdom that older farmers are less innovative. This is an area worthy of further investigation.

The second observation is that the innovation adoption index (InAI) and the speed of innovation adoption index (SAI) are higher overall for livestock farmers than for arable farmers. They also differ by farming system type, while the highest innovation adoption index and rapidity of innovation index in the arable farmers corresponds to farmers who have alternative systems such as regenerative agriculture and agroecological, the highest index in the livestock farmers corresponds to conventional farmers with only one agroecological farmer. Studies have highlighted the dynamic and innovative profile of agroecological producers (Mesa & Esparcia, 2021), however the distinction between the innovative of arable and livestock farmers with respect to these systems has not been unpacked.

A third observation concerns the heterogeneity of information sources, between formal and informal actors. The arable farmers were far less likely to use 'formal' agents as sources of innovation information compared to livestock farmers. In this sense, the heterogeneity of the actors is what has been defining agricultural innovation systems (Klerkx et al., 2010; Spielman et al., 2011). The relational aspect based on knowledge transfer has highlighted the usefulness of a typology to describe heterogeneous modes of adoption (Choi, 2016). This study differentiated between transitions to agroecology through state- and community-driven agro-innovations, i.e., between hierarchical governance (referred to in our study as "formal") and community or "informal" governance, whose relationships are based on actors such as other farmers, friends and family, internet or book influencers and other aspects, such as those related to self-knowledge. The complementarity between formal and informal networks has demonstrated a specialisation in agroecological systems (Choi, 2016). Thus, while formal links have the direct advantage over objective issues such as advice, regulatory actions, etc., informal networks have the advantage of being able to make use of local social capital and the accumulated knowledge of close networks, such as spousal relationships, friendships or relationships with other farmers. As other research has shown, proximity relationships are extremely important (Brinkley, 2018). This aligns with our results that show the livestock farmers having a higher number of innovations, both driven by informal and formal influences, although with a low participation of neighbouring producers (see Figure 3 and 4).

The presence of two cohesive sub-networks in both arable and livestock indicates that there are a limited number of networks where multi-directional knowledge exchange is taking place (this can be seen in period three of Figure 3). While it could be thought that cohesive networks of knowledge exchange respond to a geographical logic given the proximity between producers and influential agents (Niang et al., 2022), it is not clear whether this is the case in the case of arable and livestock in our study. This only occurs in the livestock network, while the arable network does not respond to the logic of geographical proximity but to other variables.

A fourth observation is related to the creation of links with influential networks that are located in digital spaces such as the internet, as a place of knowledge transfer. In the case of the arable farmers, the connections and knowledge transfer through the internet for the adoption of innovations was significantly higher than in the livestock farmers. This study also takes one step by including digital environments as the Internet as another type of source of information that is not usually contemplated in studies on the adoption of innovations. According to the study conducted by Charatsari & Lioutas (2013) the use of the internet as a tool for agricultural information is usually used for quick decision making, while for complex issues Adviser/Consultants remain the most effective source.

6. Conclusions

The adoption of agricultural innovations remains today an important part of the transition towards efficient and sustainable practices (Brunori et al., 2013; Merot et al., 2020). Knowledge sharing and the role of influential actors transcends geographical scales, as face-to-face is not necessary to have information that can drive innovations.

Without forgetting the prospective and introductory character of this study, it would contribute to a better understanding of the identification of influential actors or social entities that contribute to knowledge sharing and adoption processes, based on both farmers' innovation profiles and the importance of influential actors in the adoption of innovations. In addition, we contribute to the use of multiple analysis methodologies, which remains limited (Pathak et al., 2019).

Importantly, social network analysis helps to understand complex processes linked to territory and institutions. The approach based on adoption index and speed of innovation adoption in relation to personal network analysis offer insights into many of the processes over time, and could be used to project future scenarios.

As such this study has developed a novel methodology that combines innovators' profiles with the analysis of egocentric mode two social networks, which opens up possibilities for analysis by combining different levels of actors, such as farmers and their relationship with other actors and entities. This reveals some interesting areas for future research to be applied in broader studies.

7. Future orientaions

Through face-to-face data collecting, a larger sample, more innovations, and the use of semi-structured interviews, this research provides the way for the creation of more extensive fieldwork. Additionally, it makes it possible to compare information sources, innovative behaviour, and innovation adoption among UK farmers of both arable and livestock farmers.

8. Acknowledgments

I gratefully acknowledge Julie Ingram for helping with this study's design, both in terms of the survey's development and her writing-process advice.

I am especially appreciative of the assistance the University of Gloucestershire's Countryside and Community Research Institute provided in managing the surveys.

This research has been funded by the Spanish Ministry of Universities through the FPU17/02591 pre-doctoral contract. The stay in the United Kingdom was partially funded by the international mobility aid of 2021, within the University of Valencia's Mobilitat Erasmus Postgrau program.

9. Annex

This section shows the online survey conducted. It is divided into five sections: 1) attributes of the farmers; 2) attributes of the production system; 3) questions about the adoption of innovations; 4) answers about the actors or influential entities in the adoption of the adopted innovations; 5) relationships between the influential actors or entities.

The survey was designed as a logical sequence. Depending on whether the respondent was a farmer or a rancher and on the statements regarding the adoption of innovations (Yes/No) the survey followed one path or the other.

SECTION I: ATTRIBUTES

1. Farmers' attributes

1.1 What is your gender?

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ I prefer not to say

1.2 Which age bracket do you fall in?

- ☐ 18 – 24
- ☐ 25 – 34
- ☐ 35 – 44
- ☐ 45 – 54
- ☐ 55 – 64
- ☐ 65 – 74
- ☐ +75

1.3 What is your highest level of qualification?

- ☐ Below GCSE
- ☐ GCSE or equivalent
- ☐ A-Level or equivalent
- ☐ HND/BA/BSc degree or equivalent
- ☐ MA/MSc degree or equivalent
- ☐ Doctoral degree or equivalent
- ☐ Other

1.4 In which region is your farm located?

- ☐ South East; London
- ☐ North West
- ☐ East of England
- ☐ West Midlands
- ☐ South West

- ☐ Yorkshire and the Humber
- ☐ East Midlands
- ☐ North East; Scotland
- ☐ Northern Ireland
- ☐ Wales
- ☐ Other (outside UK)

1.5 Which town are you nearby?

1.6 Attributes of the farmers' production system

- ☐ 1.7 How would you describe your main farming system?
- ☐ Organic with certification
- ☐ Organic non-certification
- ☐ Agro-ecological
- ☐ Regenerative farming
- ☐ Conventional
- ☐ Other

1.8 What is your main type of farm?

- ☐ Arable
- ☐ Livestock

1.9 What is your main type of crop?

- ☐ Cereal
- ☐ Other arable crops (Sugar beet, maize, forage, fodder, oilseeds, protein crops)
- ☐ Potatoes
- ☐ Horticulture (vegetables, fruit crops)
- ☐ Temporary pasture
- ☐ Permanent pasture
- ☐ Woodland
- ☐ Other

1.10 Total hectares in your farm:

1.11 What is your main type of livestock?

☐ Dairy cattle

☐ Beef cattle

☐ Sheep

☐ Poultry

☐ Pigs

☐ Other

1.12 Number of animals:

1.13 Total hectares:

SECTION II: ADOPTION OF INNOVATIONS

2. Questions about innovations

2.1 Arable

Practice 1: Have you introduced pasture improvements? Yes/No

Practice 2: Have you made any significant changes that improve animal welfare? Yes/No

Practice 3: Have you made changes in animal grazing, feeding and supplementation (e.g. mob grazing, dietary change)? Yes/No

Practice 4: Do you carry out practices for the improvement or extension of hedgerows or borders or other landscape elements? Yes/No

2.2 Livestock

Practice 5: Do you use alternative fertilisation methods or fertilisers (e.g. biofertilizers, inoculants, etc)? Yes/No

Practice 6: Have you introduced precision farming techniques (e.g. variable rate application, yield mapping)? Yes/No

Practice 7: Do you carry out any non-inversion tillage method? Yes/No

Practice 8: Have you made any improvements to machinery and equipment? (e.g purchased or upgraded a tractor, implement or auxiliary equipment)? Yes/No

SECTION III: SOURCES OF INFORMATION

3. Questions about the actors and/or entities influencing the adoption of innovations.

3.1 Year did you introduce the practice on your farm: Select a year between 1990 -2021.

3.2 Who was the main influence on your decision to try this practice?

- ☐ Farmer neighbour
- ☐ Family or friends
- ☐ Representative of company
- ☐ Representative of company or farmers in event or fair
- ☐ Representative of Adviser/Consultant (private or public)
- ☐ Representative of Industry bodies (NFU, AHDB)
- ☐ Representative of NGOs (FWAG, Soil Association, Innovative Farmers)
- ☐ Representative of Government (for regulations/recommendations)
- ☐ Influencer in Internet (social media, YouTube, etc.)
- ☐ Other

3.3 Location of this influencer (or nearby town):

3.4. Relationships between actors and entities based on the innovations adopted:

If you ticked "Yes" in more than one of the above answers, can you tell us whether the persons who influenced you to introduce the practices share any professional information with each other?

3.5 Arable

Influencers from Practice 1 and Practice 2 share information with each other: Yes/No

Influencers from Practice 1 and Practice 3 share information with each other: Yes/No

Influencers from Practice 1 and Practice 4 share information with each other: Yes/No

Influencers from Practice 2 and Practice 3 share information with each other:

Yes/No

Influencers from Practice 2 and Practice 4 share information with each other: Yes/No

Influencers from Practice 3 and Practice 5 share information with each other: Yes/No

3.6 Livestock

Influencers from Practice 5 and Practice 6 share information with each other: Yes/No

Influencers from Practice 5 and Practice 7 share information with each other: Yes/No

Influencers from Practice 5 and Practice 8 share information with each other: Yes/No

Influencers from Practice 6 and Practice 7 share information with each other: Yes/No

Influencers from Practice 6 and Practice 8 share information with each other: Yes/No

Influencers from Practice 7 and Practice 8 share information with each other: Yes/No

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