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Towards socio-digital rural territories to drive digital transformation: General conceptualisation and application to the olive areas of Andalusia, Spain

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ABSTRACT

The future of rural areas, in different geographical contexts around the world, faces enormous challenges and uncertainties, with the emergence of complex territorial dynamics. One of the main disruptive factors underlying the current challenges in rural realities is digital transformation (DT). This study has two objectives: 1) to develop a theoretical framework for the analysis of DT in rural areas from a territorial perspective, through the proposal of the concept of 'socio-digital rural territories' (SDRT); and 2) to analyse the specific case of the olive areas of Andalusia where DT is starting in recent years. For this purpose, Social Network Analysis (SNA) techniques are used, both to build the theoretical framework and to evaluate the concepts developed at a practical level in the case study. The results obtained show that addressing DT in rural areas from a territorial approach should consider the technological innovation system (TIS) and relational social capital (RSC), embedded in the technological and social dimensions of a territory, as key elements to promote successful dynamics towards a SDRT. On the other hand, the analysis of the DT network in the olive-growing areas of Andalusia (the DT olive network) shows that the actors that stand out for their role as knowledge emitters include digital technologies companies, knowledge generation agents, knowledge transfer agents and the scientific and informative media. On the contrary, the main receiving knowledge actors are olive growers, cooperatives or cooperative groups, non-cooperative groups and agricultural organisations. The density of connections in the network is high considering the type of actors and connections analysed. The DT olive network has a high potential for the creation of RSC. Thus, there is bonding capital, in which a high number of connections between actors predominate, although with low homogeneity in the typology of actors. And there is bridging capital, in which organisations of different types participate, and as it is a decentralised network, it favours the lack of concentration of power. Finally, this article offers a novel explanation of how knowledge is exchanged and created in a social network, and how this exchange creates new intellectual capital. This capital, which in the case of DT is territorial digital capital, is translated into digital technologies. The results indicate that the DT olive network and its RSC lead to the potential formation of an SDRT in Andalusian olive areas.

1. Introduction

The future of rural areas, in different geographical contexts around the world, faces enormous challenges and uncertainties, with complex territorial dynamics emerging. One of the main disruptive factors underlying the current change in rural realities is digital transformation (DT) (Cowie et al., 2020; Klerkx et al., 2019; Räisänen and Tuovinen, 2020; Reina-Usuga et al., 2021; Rijswijk et al., 2021). DT of rural areas through the so-called digital agriculture or agriculture 4.0 (Klerkx et al., 2019), represents a new field of opportunities (Alam et al., 2018; Klerkx et al., 2019; Parra-López et al., 2021; Vázquez et al., 2019). However, it also poses many challenges and barriers, both technological and

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institutional, which can limit its development (Kernecker et al., 2020; Knierim et al., 2019; Parra-López et al., 2021; Shepherd et al., 2018) and negatively affect both the agricultural sector and the rural areas where it is based (Lioutas et al., 2019; Rijswijk et al., 2021). Digital technologies related to sensorisation, remote sensing, GIS, drones, big data, artificial intelligence, machine learning, robotics, IoT, e-commerce, blockchain, among others, are radically changing production, marketing and consumption processes in the agri-food system (Busca and Bertrandias, 2020; Hassoun et al., 2023, 2022; Helo and Hao, 2019; Klerkx et al., 2019; Koch and Windsperger, 2017; Zhu et al., 2020). These changes, in turn, raise new questions about ethical issues of data ownership rights and their impact on rural employment and the equitable sharing of DT benefits (Bronson, 2018; Bronson and Knezevic, 2016), governance (Knickel et al., 2021; Parra-López et al., 2021), and moral issues in the framework of responsible research and innovation (Knickel et al., 2021) (Knickel et al., 2021) DT in agriculture and rural areas should therefore not be driven by digital technologies per se, but by the search for solutions to the specific problems faced by a territory (Klerkx and Rose, 2020; Lajoie-O'Malley et al., 2020; Rijswijk et al., 2021), through the use of refined, adapted and improved digital technologies in their own innovation system (IS). This IS refers to the network of actors and institutions that develop, disseminate and use innovations (Carlsson et al., 2002; Edquist, 1997; Markard and Truffer, 2008). DT should therefore not only be a question of technology availability and its adoption in agri-food systems, but should be conceived as a transformation beyond the technical domain, involving the different socio-economic, physical, technological and biological sub-systems or components that converge in rural areas (Rijswijk et al., 2021).

Andalusia, located in southern Spain, is the most important olive-growing region in the world. It accounted for 15.35% of the olive-growing area and 40.81% of world olive oil production, in 2018, latest available data (FAOSTAT, 2021). Nowhere else in Europe is there a similar concentration of a single tree species cultivated over such a large area. Olive growing in Andalusia has contributed to the productive structure of the region by introducing new cultivation methods, organisational innovations and new products to the market (Gallardo-Cobos and Sánchez-Zamora, 2017). Olive growing also has social and environmental benefits. For example, it has led to the creation of innovation networks (Parra-López et al., 2021; Reina-Usuga et al., 2022), has contributed to the maintenance of the population and the maintenance of settlements in rural areas of Andalusia, for example through the agricultural unemployment allowance (Cejudo García et al., 2016), has promoted the maintenance of livelihoods (Areal and Riesgo, 2014), strengthened the resilience of olive-growing landscapes (Ortega et al., 2020), and created collective strategies for water use in a drought-affected area (Ortega et al., 2020). This has not only contributed to the economic aspect but have also led to the enhancement of the Andalusian landscape, tourism and cultural heritage associated with olive groves and olive oils (Gallardo-Cobos and Sánchez-Zamora, 2017). The promotion of cultural and natural heritage through olive oil tourism has allowed tourists to experience the historical, artistic, ethnographic, gastronomic and natural aspects of the region (Parras Rosa et al., 2021) Consequently, olive cultivation has fostered rural development in Andalusia by leveraging the natural, heritage, economic, and cultural resources of the area and involving territorial actors (Gallardo-Cobos and Sánchez-Zamora, 2017).

Olive areas are therefore a preferential scenario for the application of public and private actions that combine a dual sectoral and territorial approach. However, in studies on rural areas development, the sectoral view, based on supply chains or on the notion of value chains (Costa et al., 2013; Foran et al., 2005; Kaplinsky and Morris, 2016) has prevailed. It is only in recent years that the territorial approach has been incorporated (Amdam, 2002; Doernberg et al., 2019; Marsden and Sonnino, 2008; Sánchez-Zamora et al., 2014; Ward et al., 2003). This situation has also been evident in European public policies, as it is from Agenda 2000 onwards that the Rural Development Regulation (RDR) or Second Pillar of the CAP was transformed to promote the transition from a sectoral to a more territorial approach (Marsden and Sonnino, 2008; Ward et al., 2003).

The territorial approach is based on the concept of territory as a social structure, which places territorial actors at the heart of the social construction process (Pecqueur, 2001). These actors have the capacity to influence the development path of their own territory, by driving a collective, endogenous and therefore territorial dynamic (Colletis-Wahl and Pecqueur, 2001). Thus, joint action between social actors is essential in the construction and development of a territory, and this capacity for joint action refers to what is known as relational social capital (Woolcock, 2001). This perspective differs from the scope of the sectoral approach and brings a broader vision to the studies, since in addition to integrating the various sectors found in a specific territory, it focuses on the coordination of actors from different spheres and levels (national, regional and local), in order to generate synergies to achieve a common and specific objective of that territory (Colletis-Wahl and Pecqueur, 2001; Moragues-Faus et al., 2020; Sánchez-Zamora et al., 2014).

On another note, the research on DT in agriculture has focused on countries and regions that are more dependent on agricultural production, where agricultural production is a key economic sector or where the agri-food sector is an important source of employment (Bahn et al., 2021). Particularly, in Spain, some works analysed the barriers and proposed recommendations for the development of DT in the agri-food system in general (MAPA, 2018a, 2018b) and in the agri-food cooperative sector in particular (Vázquez et al., 2019) By economic sectors, the research on DT in the Spanish olive agri-food sector stands out, given its economic importance, as Spain accounted for 24.59% of the total area and 50.09% of total olive oil production worldwide in 2018, the latest available data (FAOSTAT, 2021; MAPA, 2020), being also the world's leading exporter of olive oil (IOC/COI, 2019).

In the specific case of research on DT in olive areas, a sectoral technological/economic approach is also mainly applied, focusing on some digital innovations related to the use of remote imagery to predict harvesting time, harvest damage, irrigation needs and disease monitoring (García Torres et al., 2008; Hornero et al., 2020; Jiménez-Jiménez et al., 2013; Modica et al., 2020; Noori and Panda, 2016), the use of unmanned aerial vehicles (UAVs) to select potential cultivars for different cropping systems (Gómez-Gálvez et al., 2021), the use of IoT for precision agriculture (Boursianis et al., 2020), and the development of a chemical QR code for the identification of olive oil odor (Conrado et al., 2021). Only recently, an study on the conditioning factors (political, economic, social, technological, legal, and environmental factors) of DT and its guidelines for public policies analyses more than just technological and economic factors (Parra-López et al., 2021). Despite the significant potential of DT in the Andalusian olive areas, to our knowledge there are no scientific studies that address DT from a territorial approach.

In this context, this paper aims to contribute both theoretically and practically to the understanding of the development of DT in rural territories. Thus, this manuscript has two objectives: 1) to develop a theoretical framework for the analysis of DT in rural areas from a territorial perspective, through the proposal of the concept of 'socio-digital rural territories' (SDRT); and 2) to analyse the specific case of the olive areas of Andalusia where DT has advanced in recent years. For this purpose, Social Network Analysis (SNA) techniques are used, both to build the theoretical framework and to evaluate the concepts developed at a practical level in the case study.

2. Conceptual framework

This section briefly reviews the concepts of territory, territorial dynamics, technological innovation systems (TIS) and relational social capital. Then, the concept of SDRT is proposed as a theoretical and methodological construct to address and promote DT processes.

2.1. Territory and territorial dynamics

The concept of territory in the proposed framework goes beyond the reductionist and static idea of a mere given physical space, provider of natural and material resources, to be conceived as a process of social construction determined by local actors and their connections to enhance the value of the territorial resources available (Pecqueur, 2001; Sánchez-Zamora et al., 2014), generating specific endogenous potentialities. The dynamic and evolutionary approach to the territory becomes important here, both in terms of the physical space (changes in the availability of resources) and the forms of appropriation of the space by the actors who constantly interact in it (Moranta Vidal and Pol Urrútia, 2005). Thus, the territory can be understood, from an operational point of view, as an evolving complex system (Sánchez-Zamora et al., 2016). The territory consists of three closely interrelated sub-systems (Camagni, 2017; Campagne and Pecqueur, 2014; Emery and Flora, 2006; Moine, 2006) : i) territorial resources, associated with five types of territorial capital: economic, human, social, cultural and natural; ii) the actors that make the territory: the state, civil society and associations, and private actors; and iii) the institutional arrangements that are established between them; these arrangements are closely linked to the relational social capital and governance processes.

Territorial dynamics are implicitly embedded in the very definition of territory when it is conceived as a social construction (Sánchez-Zamora et al., 2016). These territorial dynamics refers to the processes of evolution in the economic and social structure, the institutional framework and the natural capital of rural territories and the concomitant changes in the effects of development (RIMISP, 2007). Among the set of factors associated with processes of evolution, those that promote territorial dynamics capable of overcoming the common problems faced by rural areas are particularly important. These problems could be demographic (population loss, ageing, etc.), economic (unemployment, lack of economic diversification, etc.), social (quality of life, urban disparities, etc.) and environmental (environmental degradation, loss of biodiversity, etc.). Thus, the results of these processes of evolution and their impact on development may vary from one territory to another, due to their specific features, highlighting the existence of territorial disparities (Sánchez-Zamora et al., 2016). An example of this is the uneven and sometimes negative results that have become evident in rural territories due to the disparities in the implementation of the Common Agricultural Policy and the LEADER approach (Cañete et al., 2018). Therefore, development dynamics that are able to respond to these specific problems of rural areas and generate situations of economic growth, social cohesion and environmental sustainability are considered successful rural territorial dynamics (RIMISP, 2007).

2.2. Innovation and relational social capital

Among the factors contributing to a successful rural territorial dynamic is innovation (Carlsson and Stankiewicz, 1991; CELAC, 2017; Guzal-Dec 2018; Hayat, 2016; North and Smallbone, 2000). Innovation in this context may have different nuances related to the degree to which new technologies are adopted (Hinojosa-Rodríguez et al., 2014; Leeuwis and Aarts, 2021; Parra-Lopez et al., 2007; Rogers, 1995), the degree to which diversification and/or specialisation exists (Bronson, 2018; Guzal-Dec 2018; Hinrichs et al., 2004; Knickel et al., 2009; Marsden and Sonnino, 2008), the configuration of innovation systems (Adamowicz and Zwolińska-Ligaj, 2020; Bergek et al., 2008; Carlsson et al., 2002), or the responsibility for systemic change in the context of agriculture and rural areas (Rijswijk et al., 2021). Different types of innovations have been proposed in the literature, including technological innovations (products or processes) and social innovations (markets or organisations) (Cuevas-Rodríguez et al., 2014; Lioutas et al., 2019; Vercher et al., 2022; Wieczorek and Hekkert, 2012).

In terms of technological innovations, the Technological Innovation System (TIS) framework stands out in their analysis (Bergek et al., 2008). A TIS is defined as a set of networks of actors and institutions that interact together in a specific technological field and contribute to the generation, diffusion and use of a new technology/product or variants of the same technology/product (Bergek et al., 2015; Carlsson and Stankiewicz, 1991; Markard and Truffer, 2008). A TIS accounts for the complexity of innovation processes and their different interaction dimensions (Markard et al., 2015). The core of this framework is to combine an analysis of the structural components that make up a TIS (actors, networks and institutions) with an analysis of the main functions of this TIS (business activities, knowledge development, knowledge transfer, research orientation, market formation, resource mobilisation and legitimacy creation) (Bergek et al., 2008) Given the theoretical proximity between the TIS framework and the territorial approach, specifically because both emphasise the importance of actors, networks of relationships and the construction of agreements in a specific field (Fig. 1), the TIS framework has been adopted here to address the analysis of rural territories in the face of the challenges and opportunities of DT.

The TIS framework allows analysing how actors, and their networks, interact to influence institutional change (Bergek et al., 2015) in a particular territory. This institutional change can lead to successful rural territorial dynamics and contribute to territorial development. For this to happen, TIS actors and their networks need to build relational social capital (RSC), i.e., their relationships need to be based on principles of cooperation supported by trust, mutual recognition, norms of reciprocity and civic engagement (Coleman, 2003; Moyano, 2005). RSC refers to the connections between individuals expressed through social networks and the norms of reciprocity and trust that arise from them (Putman, 2001). This concept is particularly interesting for innovation studies, where RSC is considered one of the key components of innovation (Hellsmark et al., 2016), as it facilitates networking, knowledge diffusion, collective action and governance processes (Borg et al., 2015; Dressel et al., 2020; Flora and Bregendahl, 2012; Pisani and Micheletti, 2020; Reina-Usuga et al., 2018, 2020).

2.3. Socio-digital rural territories

DT is a disruptive process in the agri-food sector (Alam et al., 2018; Klerkx et al., 2019; Parra-López et al., 2021; Vázquez et al., 2019), being currently one of the main driving forces of profound changes not only in the sector itself but also in the rural territories in which it is placed. The effects of this process result in the configuration of different types of territorial dynamics, which lead territories to new states of development. Faced with this new situation, it is the territorial actors themselves who are at the centre of the processes of social construction, and who have the capacity to influence the path to development of rural areas through innovative actions based on the impulse of a collective, endogenous and therefore territorial dynamic (Colletis-Wahl and Pecqueur, 2001; Sánchez-Zamora et al., 2016). Indeed, in the face of a disruptive process such as DT, the TIS and the RSC, embedded in the technological and social dimensions of a territory, respectively, turn out to be key elements to promote successful territorial dynamics that facilitate the transition towards what we will define as a socio-digital rural territory (SDRT).

DT therefore affects the territory and generates responses from the interaction of the territorial components of the TIS. When, as a result of this interaction, RSC is created, the territorial dynamics that exist can be defined as successful, and lead to the building of a SDRT (Fig. 1). On the contrary, when RSC is not created because a TIS is not configured or because not all the territorial components are taken into account, the territorial dynamics can be qualified as unsuccessful and may generate or deepen some common undesired outcomes in the rural territories such as intensified rural depopulation, increased unemployment, loss of biological and cultural diversity, and economic slowdown (Sánchez-Zamora et al., 2017, 2014). SDRT is therefore the result of a process of social construction triggered by DT that, through successful territorial

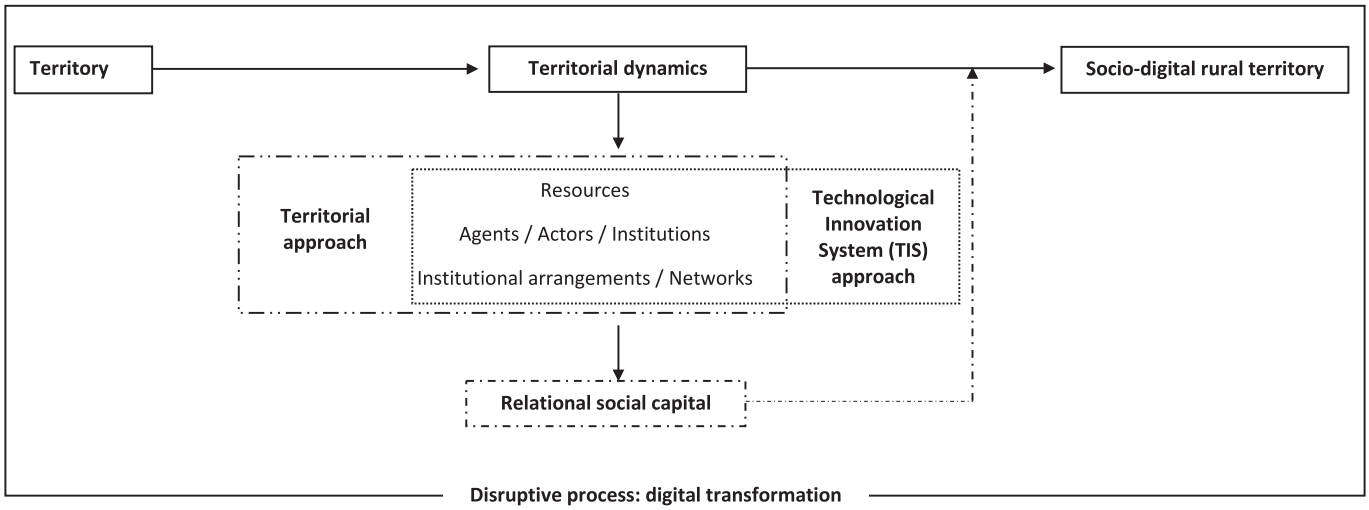

Fig. 1. Configuration of a socio-digital rural territory (SDRT). *Source: Own elaboration.*

dynamics, based on the RSC of the TIS, responds to the specific problems of the territory and contributes to the development of rural areas by making use of digital technologies. A very relevant role is given in this definition to innovation as a catalyst for rural development.

3. Materials and methods

3.1. Case study: The olive areas of Andalusia

Olive grove is the most representative agro-ecosystem in Andalusia and plays an important socio-economic role in this region (Gallardo-Cobos and Sánchez-Zamora, 2017; Gómez-Limón and Arriaza Balmón, 2011; Parra-López et al., 2021). In fact, the production of olive oil and table olives account for 18.1% of the total production of the Andalusian agricultural sector in 2020 (CAGPDS, 2020) and generates around one third of agricultural employment, of which between 20% and 60% is family-based (CAPDR, 2017; Gómez-Limón and Arriaza Balmón, 2011). Additionally, it has a wide territorial presence, covering 28.77% of the Andalusian agricultural area (CAGPDS, 2018) (Fig. 2). Most of the olive grove is cultivated in a traditional extensive way (47.5% of the surface area), followed by olive groves on steep slopes (23.3%) and intensive and super-intensive olive groves (15.4%) (CAPDR, 2017). Thus, from a territorial point of view, not only the production activities, but also the transformation and marketing of the olives and their by-products, have a

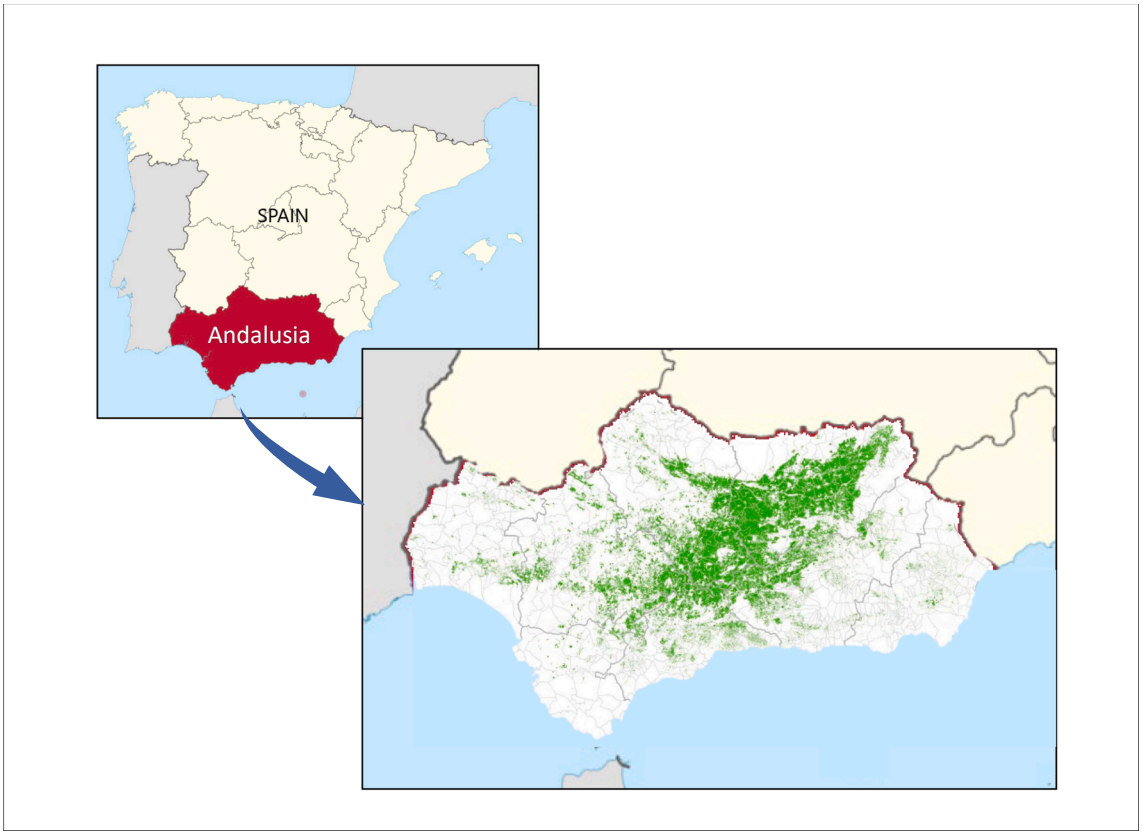

Fig. 2. The region of Andalusia and the distribution of olive growing. Source: Based on *https://simple.wikipedia.org/wiki/Andalusia* and CAGPDS (2020).

decisive weight in Andalusia, with more than 300 municipalities whose socio-economic structure is linked to these activities (CAGPDS, 2018). The importance of the olive crop has justified the approval in Andalusia of Law 5/2011, of 6 October, on the Andalusian olive grove, in which it is stressed that the olive areas are essential elements in the social and territorial cohesion of the regions in which activities linked to the crop are carried out. Moreover, the approval of the candidacy of the Andalusian olive landscape for the UNESCO World Heritage List by the Spanish Historical Heritage Council recognises that the agricultural landscape associated with this crop is unique, not only because of its high aesthetic value, but also because it is associated with an important historical, cultural and environmental value (Gallardo-Cobos and Sánchez-Zamora, 2017; Martínez and Almonacid, 2017).

However, despite the importance of the olive grove and its social, economic, cultural and territorial implications, it continues to face a series of problems that must be tackled to ensure its global sustainability in the medium and long term. Thus, the small size of the farms dedicated to this crop, the weak professionalisation, the scarce innovative attitude of farmers, the low mechanisation of some mountain areas, the high volatility of prices, and the tariffs of the USA (currently on stand-by), one of the main non-EU destinations for Spanish exports, are endangering the profitability and survival of different agents of the olive sector (CAPDER, 2015; Parra-López et al., 2021; Parras Rosa et al., 2021; Rodríguez-Cohard and Parras, 2011). In this context, DT is opening up opportunities for the design of new strategies that, from a rural development perspective, can respond to the sectoral and territorial needs of the olive areas.

3.2. Social network analysis

Since the TIS framework and the territorial approach emphasise the importance of actors and their networks, Social Network Analysis (SNA) has been selected for the analysis of the empirical information. SNA consists of a set of analytical techniques for the study of the connections between actors in a system, and the social structures, in the form of networks, that emerge from them (Scott, 2017). Networks are composed of two basic elements: the actors (nodes) and the connections between them (edges). The former are represented by points on the network and the latter by lines on the network map. The mathematical language of graph theory, matrices and relational algebra is used for their analysis (Sanz Menéndez, 2003; Semitiel García and Noguera Méndez, 2004). SNA allows the calculation of a set of indicators to characterise the position of the nodes and the structure of the network (Table 1). Node indicators are individual measures for each node and structure indicators are measures of the entire network. From the structure of the network, analyses can be derived on the type of RSC that network actors configure (Buciega and Esparcia, 2013).

Based on these indicators and other descriptive variables of the network (Table 2), it is possible to identify the type of network that is configured: 1) closed networks, in which all nodes are connected (Buciega and Esparcia, 2013; Coleman, 2003), which is associated with the bonding RSC; and 2) bridging networks, in which edges are not as strong but there are connecting nodes (Buciega and Esparcia, 2013), which is associated with the bridging RSC. For instance, a high network density and degree of the nodes, non-centralisation of the network, as well as many connections between actors with similar characteristics, indicate the network is closed and the predominance of bonding social capital.

RSC can be of two types (Putman, 2001): i) bonding RSC, which refers to connections between relatively homogenous and closed groups (e.g. family or friends); this capital is important for facilitating the internal functioning of the network, as it acts as a 'facilitator' of the connections of the actors in the network; and ii) bridging RSC, which refers to less close and intense and more diverse connections (e.g. distant friends, colleagues or relatives); this type of capital is important for networks to move forward and evolve into more cohesive forms.

Table 1
Main SNA indicators. Source: Own elaboration based on (Buciega and Esparcia, 2013).

Node indicators		Network indicators	
Degree	Number of connections of a node; they can be incoming or outgoing	**Medium degree**	Arithmetic mean of the connections that each node has
Proximity	Closeness in terms of intermediate nodes of a node to the rest of nodes	**Net diameter**	The greatest distance in terms of intermediate nodes between two nodes
Authority	Quality and connectivity of the nodes connecting a node; a node has a high authority when it is connected by many other nodes which in turn are connecting many other nodes.	**Density**	Number of connections established in the network out of the total number of possible connections; measures how close a network is to being complete; a complete network has all possible edges (connections) and a density equal to 1
Centrality	Number of nodes to which a given node is connected; a node with a high degree of centrality can be considered 'well connected'.	**Modularity**	Strength of the division of a network into modules or communities; a network with high modularity has strong connections between nodes in the same module, but few connections between nodes in different modules.
Betweenness	Number of times a node is on the path connecting all other nodes		

Table 2
Types of networks and RSC according to SNA indicators and other descriptive variables of a network. Source: Own elaboration based on Buciega and Esparcia (2013).

Type of network (RSC)	SNA indicators and other descriptive variables	
Closed network (bonding social capital)	SNA indicators*	■ Density (+)
		■ Degree (+)
	Descriptive variables	■ Centralisation (-): The extent to which the network is or is not organised around a central node
		■ Existence of connections between actors with similar characteristics (+)
Bridging network (bridge social capital)	SNA indicators*	■ Density (+)
		■ Betweenness (+)
	Descriptive variables	■ Existence of connections between actors with different characteristics (+)

Note: A positive sign indicates a positive relationship of the indicator/variable with RSC, while a negative sign indicates the opposite.
* For description see Table 1.

Bridging connections are strategic and provide access to other types of resources, knowledge and innovations, which would not be available if actors acted individually (Arnott et al., 2021; Buciega and Esparcia, 2013; Cofré-Bravo et al., 2019; Putman, 2001).

3.3. Phases of the empirical research

In order to achieve the empirical objective of this study, a sequential process was developed in three phases:

Firstly, the actors involved in the DT both in Andalusia and in the agri-food system were identified, with a particular focus on those related to olives. The information on the main actors of the social network of the TIS associated to the DT of the olive sector of Andalusia (from now on the DT olive network of Andalusia or simply the DT olive network) was collected from recent scientific studies on innovation and DT in the study region, as well as from public policy documents on the regional innovation system (Junta de Andalucía, 2015; Parras Rosa et al., 2021). In this way, 21 actors with influence or interest in DT in the olive sector in Andalusia were identified (Table 3).

Secondly, the connections between actors were identified and quantified through a survey of 33 experts related to DT in olive in Andalusia between August and October 2020. These experts were selected for their experience and extensive knowledge of olive growing, innovation and/or digitalisation. The interviewed experts belong to five stakeholder groups: public administration (5), R&D organisations (13), agri-food companies (5), digital technologies companies (5) and other olive support organisations (5). The collection was carried out by means of i) online personal interview; and ii) online questionnaire. The survey was carried out by means of i) an online personal interview and ii) an online questionnaire. Given the wide range of links between actors in DT, we focused on the knowledge transfer (KT) function, as this is one of the functions of a TIS where there may be a greater link with different types of actors (Markard et al., 2015). Furthermore, it is suggested that knowledge transfer is a networked activity (Dasanayaka and Matsuda, 2022; Hekkert et al., 2007) that involves individuals or organisations as potential generators, transmitters and adopters (Dasanayaka and Matsuda, 2022; Klarl, 2014). Therefore, it is possible that more actors with different roles are involved in the KT function than in other functions. This provides an overview of the main actors in the DT olive network. It is important to note that knowledge transfer refers to both scientific and traditional knowledge.

The experts answered to the following question: “Identify, according to your experience, the knowledge transfer connections related to the digital transformation of the olive grove (digital technologies and their applications) that take place between the different actors indicated“. Thus, for each connection, the intensity of KT activities between the DT actors was rated by the experts/stakeholders between 0 and 9 (0 = no connection, 9 = very high connection intensity).

Finally, the free and open source software Gephi 0.9.2 (https://gephi.org/) was used for data analysis. The ForceAtlas distribution was implemented with a repulsion force of 200,000 and a gravity of 30.0. This configuration minimises the number of crossings between edges, i.e. nodes do not overlap connections that do not affect them, and maintains a uniform edge length (Camacho et al., 2020). The results presented here generally refer to the global connections, obtained as an average of the averages of the different expert groups.

Table 3
Actors of the DT olive network.

1. Olive grower	13. Private consultant
2. Cooperative / cooperative group	14. Company supplying agricultural inputs
3. Non-cooperative group (Interoil, etc.)	15. Digital technologies company
4. Protected Designation of Origin (PDO)	16. Knowledge-generating agent (University, IPO, etc.)
5. Agricultural association (SAT, ATRIA, API)	17. Knowledge transfer agent (Technology Centre, etc.)
6. Agricultural organisation (UPA, COAG, ASAJA)	18. Knowledge Management Agent (IDEA, RETA, etc.)
7. Refinery	19. Public administration (Agricultural Delegation, OCA, County Council, etc.)
8. Packaging company	20. Financial institution (bank, savings bank)
9. Distribution agent	21. Scientific and dissemination media (journals, internet, etc.)
10. Rural Development Group (RDG)	
11. Communal Olive Heritage	
12. Interprofessional olive oil	

4. Results

4.1. Actors and connections in the DT olive network

4.1.1. Overall view

This section analyses the aggregated view of all stakeholders. The DT olive network in Andalusia is composed of 21 actors (Table 3) and 441 connections. This overall analysis focuses on the “global” DT olive network based on the accumulated connections, regardless of their quality (i.e., type and intensity of connections).

Fig. 3 shows that the main actors sending knowledge are, from highest to lowest degree: 15. Digital technologies company, 16. Knowledge generation agent, 17. Knowledge transfer agent, 21. Scientific and dissemination media, 2. Cooperative / cooperative group, and 19. Public administration. On the other hand, Fig. 4 shows that the main actors receiving knowledge are, from highest to lowest degree: 1. Olive grower, 2. Cooperative / cooperative group, 3. Non-cooperative group, 6. Agricultural organisation, 5. Agricultural association, 4. Protected designation of origin, and 19. Public administration. It is important to highlight the dual role of 2. Cooperative / cooperative group and 19. Public administration, both sending and receiving knowledge.

In terms of connections, not all of them have the same weight for the DT olive network. Table 4 classifies these connections into 3 categories of strength according to the weight given by the stakeholders. It is highlighted that 98.19% of the connections are classified as ‘weak’, and only 1.81% as ‘medium’, and there is no connection in the ‘strong’ category. Fig. 5 shows the actors that establish medium connections.

Figs. 3 and 4 show that there is a high number of relationships (edges) between actors, indicating a high density (Table 1). The greater the number of contacts of an actor, the larger his or her network and the more resources, information, or knowledge he or she has access to. However, in the case of the DT olive network, a large percentage of its connections are weak (Table 4), indicating that, although actors are connected, this connection may not be constant or fluid (weight of the intensity of the connection) and therefore, if not strengthened, may break. If weak connections break down, actors may become isolated, implying a decrease in network density, which could lead to an eventual fragmentation or dissolution of the network.

4.1.2. Stakeholders’ views

In the previous section, the DT olive network was illustrated on the basis of the average of five stakeholder groups linked to the DT of the olive sector in Andalusia (see section 3.2). In this section, the network of each stakeholder group interviewed is analysed in order to identify similarities and differences between their points of view, which could be linked to their own characteristics and the particular interests of their field of action. Also, the vision of each stakeholder group could influence their future actions in the DT olive network. The view of each stakeholder group is similar to the overall view analysed in the previous section (Figs. 3 and 4). However, some of the disparities found are discussed below:

- In terms of knowledge sending actors, the main differences are found in the prioritisation of the order that each stakeholder group assigns (6). For example, public administration ranks itself as the second organisation that carries out this type of process (Fig. 6a). R&D organisations rank themselves first (Fig. 6b). Agri-food companies and other support organisations do not rank the 19. Public administration as the main actor, but they highlight the actor 13. Private

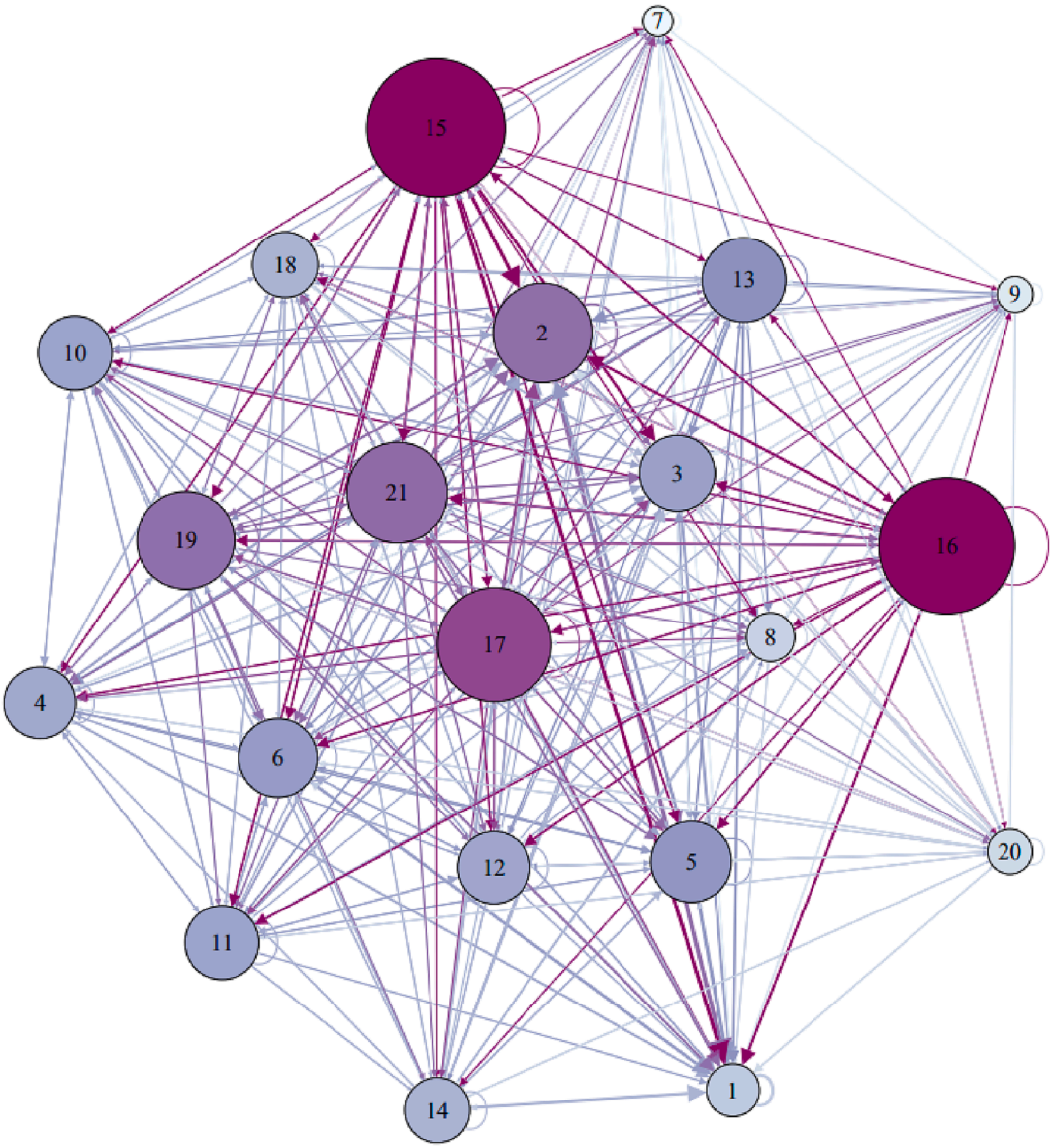

Fig. 3. Actors sending knowledge in the DT olive network. Note: The size and colour of the nodes indicates the degree of output: the larger and darker the node, the greater the degree of knowledge emission. The colour of the edge corresponds to the colour of the source node.

consultant (Fig. 6c and 6f). Digital technologies companies point to the role in KT of the actors 11. Communal Olive Heritage and 12. Interprofessional olive oil. As for the actors receiving the knowledge (Fig. 7), R&D organisations (Fig. 7b), and digital technologies companies (Fig. 7d) do not highlight 3. Non-cooperative group at the top, as do the other three stakeholder groups (and the overall view).

- In terms of the weight of the connections according to each interest group and in relation to the overall average, it is worth noting that public administration ranks 23.12% as 'medium' and 1.37 % as 'strong', which contrasts with the rest of the groups and with the overall percentage (Table 5). Agri-food companies, digital technologies companies and other support organisations show very similar trends in the ranking of the edges. R&D organisations is the group with the highest ranking in the 'weak' category with 96.81%.

From the above differences, two blocks of views stand out: that of stakeholders directly involved in KT activities (R&D organisations, Digital technologies companies and Agri-food companies), and that of other stakeholders who are not directly involved in KT activities but who are important in the TIS (Public administration and other support organisations). The trends in the first group are the most consistent with the overall results (section 4.1.1). In the second block, the public administration interest group has a slightly different view. It has highlighted itself as a main KT sending actor, when the other groups do not rank public administration as a main sending actor. In addition, the public administration has a more optimistic view on the status (weight) of stakeholder connections than the other groups, as it rates the highest percentage of strong connections.

4.2. *Structure and characteristics of the DT olive network*

4.2.1. *Network structure*

An approach to the structure of the DT olive network of Andalusia is provided by two measures that give information on the network as a whole: the density and the centralisation of the network. Table 6 indicates that the density of connections recorded in the network is high considering the type of actors and connections being analysed (more than 0.8 in all cases). Moreover, it is a complete network, as there are no disconnected actors. In terms of centralisation, it stands out that there is no single central actor (centralised network), but rather there is a set of

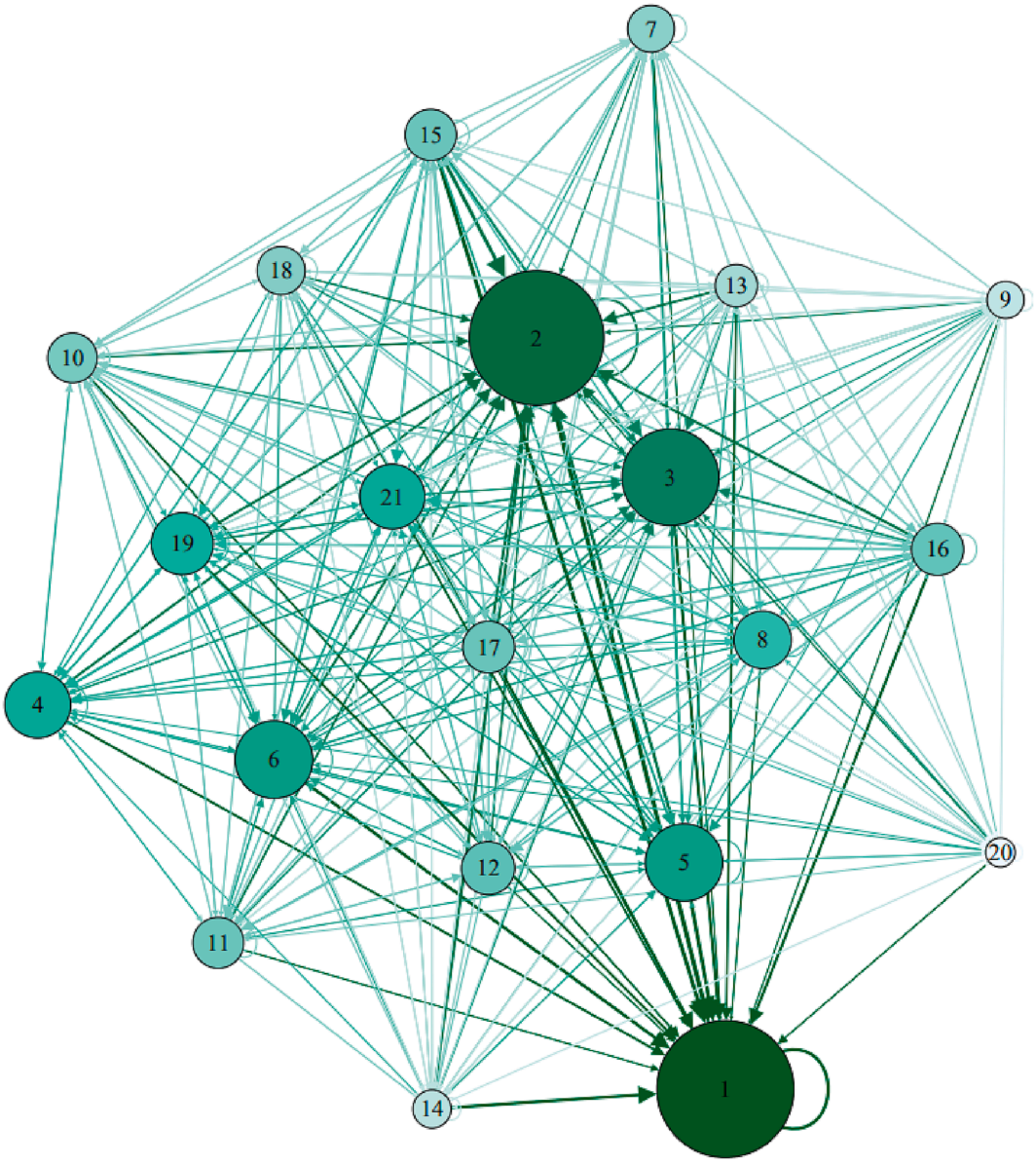

Fig. 4. Actors receiving knowledge in the DT olive network. Note: The size and colour of the nodes indicate the degree of input: the larger and darker the node, the greater the degree of knowledge reception. The colour of the edge corresponds to the colour of the destination node.

Table 4
Classification of connections.

Scale	Weight range	% Connections
Strong	6.01– 9.00	0 %
Medium	3.01 – 6.00	1.81 %
Weak	0 – 3.00	98.19 %

actors at the centre of the network, structuring a decentralised network, which indicates that power is substantially distributed throughout the structure (Figs. 3 and 4).

On the other hand, Table 6 shows the main differences between the stakeholders on the indicators that determine the structure of the network. These differences include the higher average degree and the low density identified by the public administration, agri-food companies and support organisations (given the existing edges of the network), compared to the overall network. Finally, with regard to the diameter of the network, it should be noted that R&D organisations and digital technologies companies give it 1, following the overall view of the network.

4.2.2. *Network characteristics*

In the DT olive network, no single node stands out as a bridging actor (betweenness). However, there are some organisations with a high degree of centrality and authority. By way of illustration, Table 7 presents the 10 most important organisations with their centrality and authority values. Only the actors 2. Cooperative / cooperative group and 1. Olive grower, stand out for their authority in the network.

Finally, Fig. 8 shows the modularity analysis and indicates the formation of two communities:

i. Community of active promoters of transfer processes in DT (pink), which are actors with the highest degree of knowledge emission.
ii. Community of beneficiaries of the DT transfer processes (blue colour), which are actors that are direct or indirect users of DT, with a high degree of degree centrality and authority.

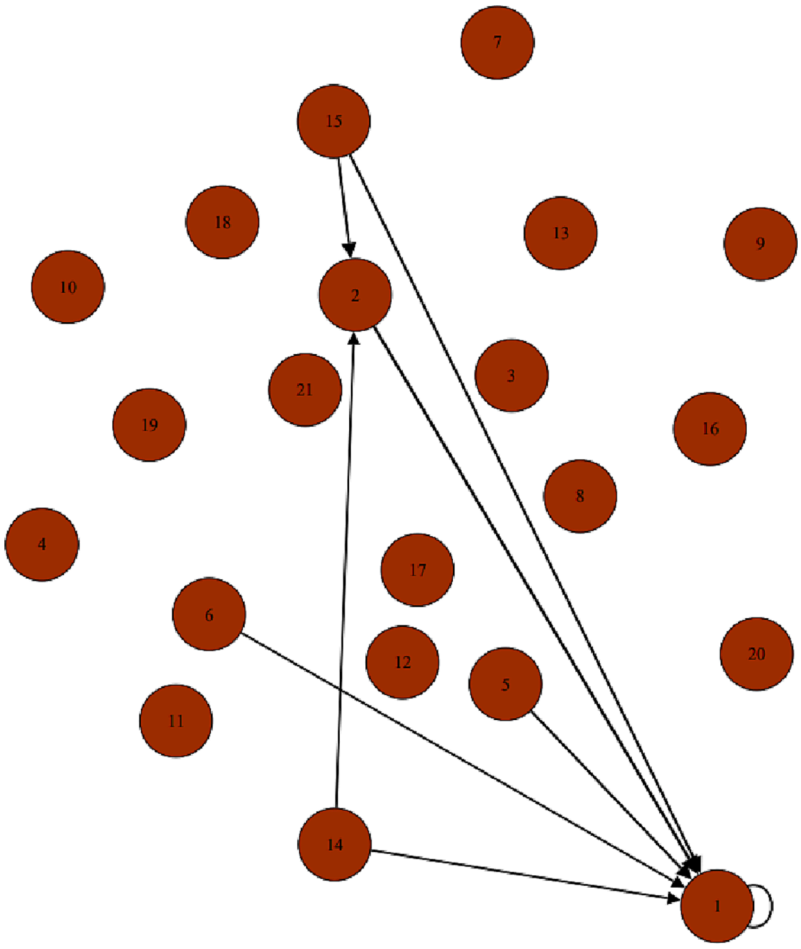

Fig. 5. Actors with medium-weight connections in the DT olive network.

4.3. Relational social capital in the DT olive network

4.3.1. Bonding capital

To analyse this internal dimension, four important indicators must be considered (Table 2). The first indicator is density, which has a positive connection with RSC, because the higher the density, the higher it tends to be. For the DT olive network, it has already been mentioned that there is a high density, although this is nuanced by the large percentage of weak connections.

The second indicator is the existence of strong connections (degree), since if we take into account that one of the clearest benefits of the existence of RSC is that it facilitates access to and dissemination of knowledge, to the extent that the weight of connections (degree) is high, we can speak of a greater RSC. In the case of the DT olive network a complete network is evident, for which there is a medium degree that connections more than 90% of the actors of the DT olive network, and a degree that highlights the actors sending knowledge as central to the system. This could indicate an incipient development of the connections that have been established, and that the foundations for the cohesion of the DT olive network have yet to be consolidated.

The third indicator is centralisation and has a negative relationship with RSC since a higher concentration of connections by a number of nodes would imply less RSC. For the DT olive network, it has been shown that there is a low level of centralisation, which indicates that there are not very centralised power relations that are facilitating the gestation of bonding capital between the different actors.

The fourth, and last, indicator from the SNA is the connections between actors with similar characteristics (homophily), in a network where its members have similar characteristics, trust, consistency, and ultimately a bonding RSC will be more easily generated. For the DT olive network, a low number of connections between actors with similar characteristics has been observed, given the great diversity of actors involved in the system.

4.3.2. Bridging capital

To identify this type of RSC, reference can be made to three indicators (Table 2). The first indicator is density; as in the case of the boding capital, a high density favours this type of RSC, a condition which is met by the DT olive network.

The second indicator is the betweenness centrality. Actors with a high intermediation capacity (bridge actors) tend to occupy positions of power insofar as they control information and communication flows. It is striking that in the DT olive network there is no high intermediation value, given that it is in an initial phase of formation, quite diverse in terms of its composition, and in which the presence of actors that help to bring together interests and generate cohesion is key. In fact, the approach of the DT olive network and the creation of specific actions such as the Andalusia Agrotech Digital Innovation Hub is to generate added value from the interaction between sectors and arenas, from which the territory benefits. Thus, interactions that bring together actors from different fields are not only interesting in themselves, but also for what each actor brings to this connection in terms of their own RSC, and for the benefits that arise from it.

The third indicator is the existence of connections between actors with different characteristics, i.e., high heterophile, which means greater exposure to a wider range of ideas. This aspect is particularly relevant since it is precisely this interaction between different actors that gives rise to the bridging capital. One of the main added values of DT

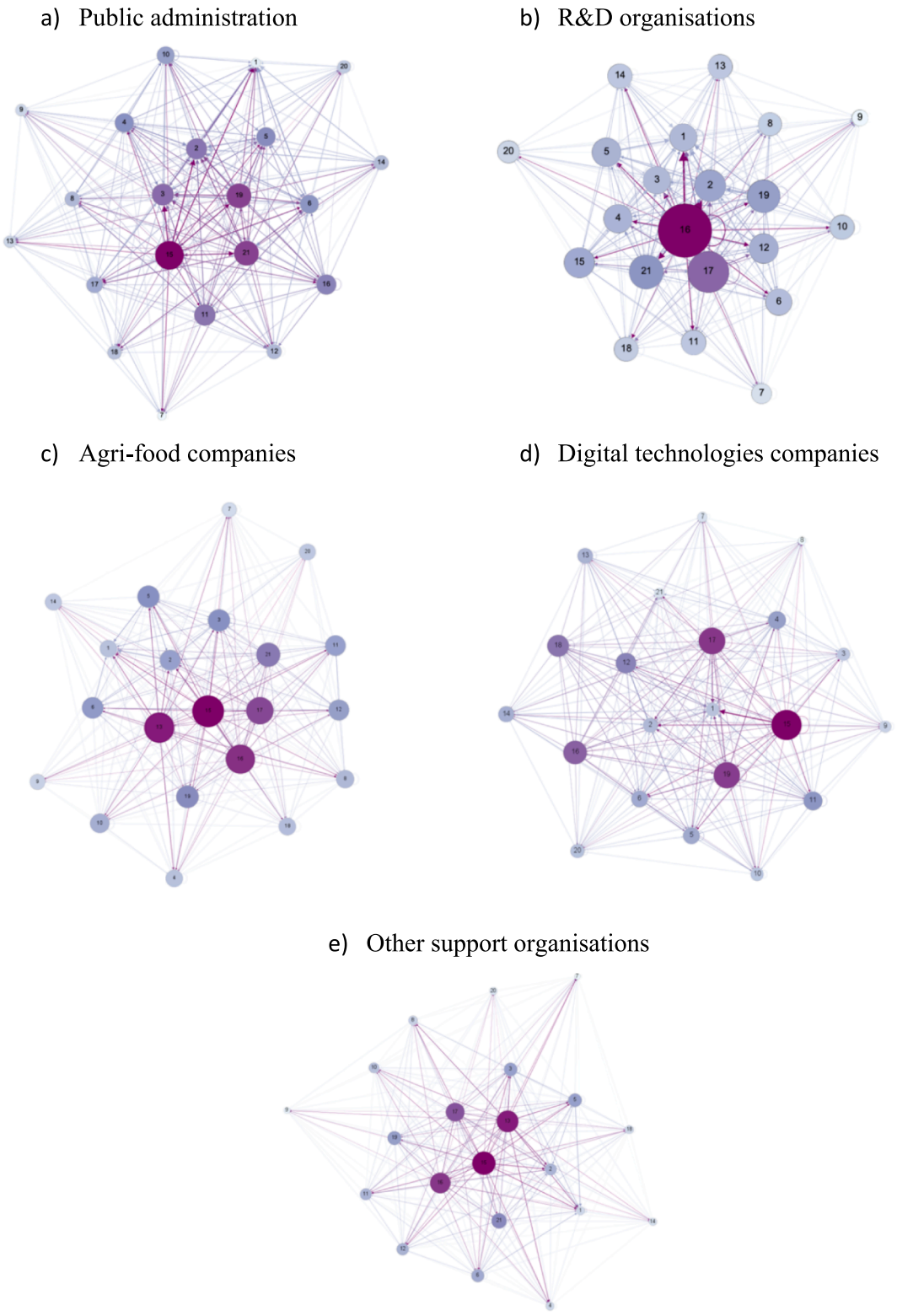

Fig. 6. Knowledge sending actors in the DT olive network by stakeholders.

olive network is to generate connections between actors of different natures (private or economic actors, public actors, social actors, knowledge generation actors, end users, etc.). It is hoped that synergies will emerge from this connection that will ultimately benefit the DT olive network as a whole and the territory in which they take place. In this sense, in the DT olive network it has been observed that the actors tend to relate to each other regardless of whether they belong to a particular typology, i.e., public administration actors relate to private actors, knowledge-generating actors relate to potential users, etc.

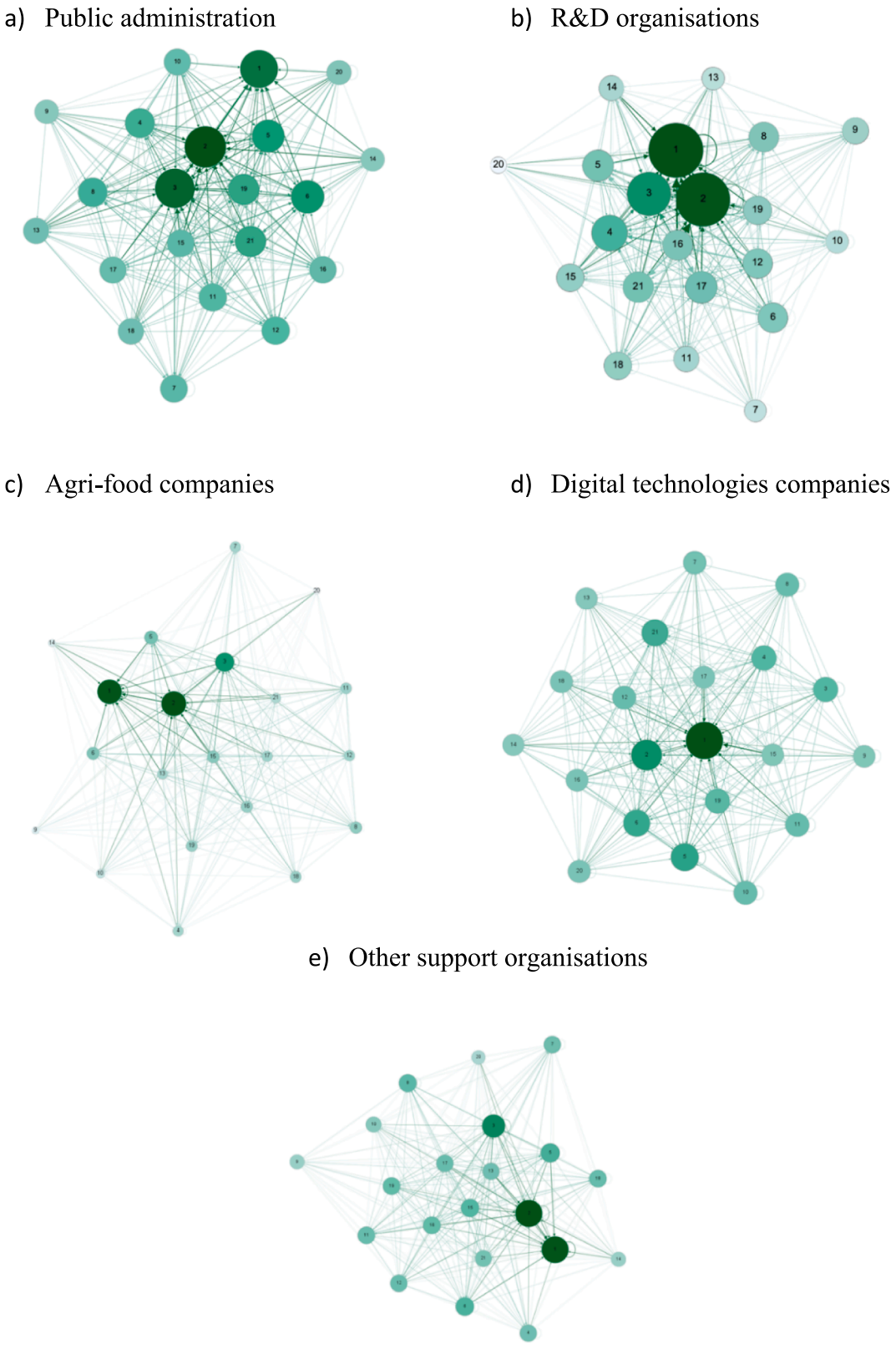

Fig. 7. Knowledge receiving actors in the DT olive network by stakeholders.

5. Discussion

5.1. Contributions to the socio-digital rural territory

In order to approach the contributions that the DT olive network makes to the shaping of a socio-digital territory, the pros and cons of the network will be presented. First of all, with regard to the pros, the DT olive network mobilises the different elements of the territory (territorial resources, actors and institutional arrangements). Thus, it has been found that: 1) different actors involved in the olive growing and olive oil

Table 5
Ranking of connections by stakeholder groups.

Scale	Weight range	% of edges				
		Public administration	R&D organisations	Agri-food companies	Digital companies	Other organisations
Strong	6.01– 9.00	1.37 %	0.24 %	0.25 %	0.23 %	0.25 %
Medium	3.01 – 6.00	23.12 %	2.95 %	5.45 %	6.35 %	5.45 %
Weak	0 – 3.00	75.51 %	96.81 %	94.30 %	93.42 %	94.30 %

Table 6
Network indicators in the DT olive network.

	Nodes	Edges	Medium degree	Net diameter	Density
General	21	441	21	1	1
Public administration	21	437	20.81	2	0.95
R&D organisations	21	439	20.90	1	1
Agri-food companies	21	404	19.23	2	0.96
Digital technologies companies	21	441	21	1	1
Other support organisations	21	404	19.23	2	0.84

Table 7
The 10 actors with the highest ratings of degree centrality and authority.

Actor	Centrality (weighted)	Actor	Authority
2. Cooperative / cooperative group	77.8203	1. Olive grower	0.894428
1. Olive grower	67.2184	2. Cooperative / cooperative group	0.44212
15. Digital technologies company	62.8007	15. Digital technologies company	0
16. Knowledge generation agent	62.5029	16. Knowledge generation agent	0
3. Non-cooperative group	60.8064	3. Non-cooperative group	0
21. Scientific and popular media	57.5835	21. Science and popular media	0
17. Knowledge transfer agent	56.9378	17. Knowledge transfer agent	0
5. Agricultural association	56.4448	5. Agricultural association	0
19. Public administration	56.0665	19. Public administration	0
6. Agricultural organisation	55.9384	6. Agricultural organisation	0

*Calculated for actors with medium weight edges.

value chain have been involved, in addition to public institutions and other support organisations present in the territory; 2) the connections established between the participating actors are based on the creation of agreements, formal and informal, which allow DT processes to flow between generators and beneficiaries, either directly or with the intervention of facilitators. Therefore, these agreements between actors converge in the creation of the DT olive network; and 3) the networks created between DT actors, whether formal or informal, make use of the initial resources of the territory and create new digital resources, tested, adapted and improved to the specific conditions of olive in Andalusia, so it could be said that they form a new typology of resources or territorial capital: the digital resource. This is in line with theoretical approaches that the sharing of knowledge and resources within a social network ultimately creates intellectual capital (Eiteneyer et al., 2019; Gedajlovic et al., 2013).

Moreover, it should be noted that the emergence of such a social network is already a (social) innovation in itself, and not just a means of introducing technological innovations, which has implications for territorial development and social change in the areas involved (Vercher et al., 2022). Furthermore, the network could be qualified as a neo-endogenous development strategy, as it is the response of the territory to a combination of internal and external forces (Shucksmith, 2010) related to DT, and could therefore be considered as a successful territorial dynamic. The interactions in the DT olive network, which converge with the elements of the territory, trigger processes that configure RSC. This RSC is of two types, bonding and bridging, which favours the creation of spaces for participation, collective learning and dissemination of digital technologies among actors (Nambisan et al., 2017). Thus, it has been confirmed that the RSC theory (Coleman, 2003; Moyano, 2005) is an appropriate theoretical approach to understand the dynamics of DT in territories.

Secondly, with regard to the cons, it is clear that this RSC is in the process of formation, given that the DT network in the olive areas is recent, and it is necessary to strengthen the connections (edges) established between the actors, as many of them are considered weak. Otherwise, there is a risk that the network will fragment and only those nodes with stronger connections will remain linked. When weak connections are broken, they can lead to a decrease in knowledge transfer, and some actors may even become isolated from the knowledge in DT in Andalusia. Knowledge isolation can have various effects, such as a decrease in territorial competitiveness, an increase in rural unemployment, rural–urban migration and rural depopulation.

The strength of weak connections has long been recognised in social networks (Granovetter, 1985, 1973). Indeed, previous studies confirm that they provide actors and entire networks with access to diverse information and resources (Prell et al., 2009)and favour the creation of bridging RSC (Buciega and Esparcia, 2013). They also have the potential, unlike bonding RSC, to overcome barriers to public policy adoption by combining actors' internal openness to change and external support (Arnott et al., 2021). However, other authors also warn that actors who share weak ties may lack the trust and understanding necessary for in-depth dialogue on issues of common interest (Prell et al., 2009; Burt, 2001) and may have negative, undesirable effects, such as negative social capital or dark social capital, which implies actions of exclusion of key actors for the network, concentration of power and/or dependence on some actors (Arnott et al., 2021; Cofré-Bravo et al., 2019; King et al., 2019). Thus, while weak ties are a good means of transporting information, they are less useful for promoting collective mobilisation; and strong ties are essential for building coalitions and synchronising collective action in social networks (Bond et al., 2012; Giurca and Metz, 2018).

Finally, this research has shown that the DT olive network has a high level of bonding and bridging capital, despite the fact that it is a recent topic and is in the midst of theoretical and empirical construction. This RSC contributes positively to the creation (dynamics) of a constructed SDRT in the Andalusian olive (Fig. 1). Given that the DT olive network is in the process of being established, it is normal that it has weak links that need to be strengthened through territorial dynamics that promote the participation of different actors and the building of connections of trust through internal governance mechanisms. This panorama is encouraging for the olive territory and its renewal in the direction of an SDRT and, at the same time, it constitutes a guideline for its progress, since the non-inclusion of some of the aforementioned elements in the future may lead to undesirable results, not only in terms of negative social capital, but also in terms of negative consequences for the territory in general.

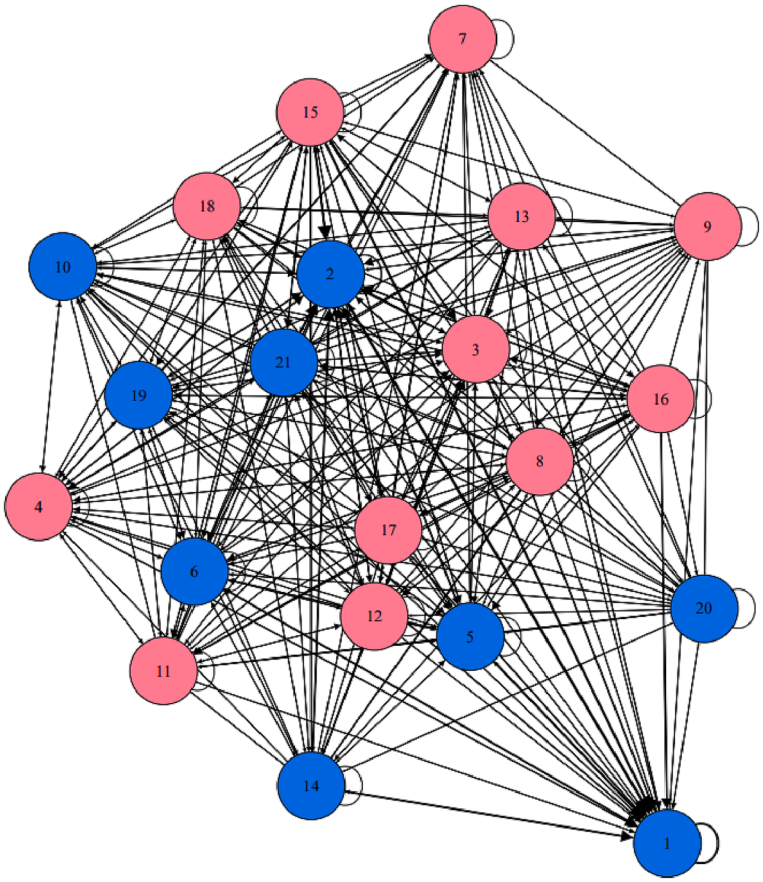

Fig. 8. Modularity analysis of the DT olive network.

5.2. Contributions to the understanding of DT in rural areas

Klerkx et al. (2019) identified five thematic clusters in the scientific literature on DT in agriculture: 1) adoption, use and adaptation of digital technologies on farms; 2) effects of digitisation on farmers' identity, farmers' skills and farm labour; 3) power, ownership, privacy and ethics in the digitisation of agricultural production systems and value chains; 4) digitisation and agricultural knowledge and innovation systems (AKIS); and 5) economics and management of digitised agricultural production systems and value chains. Thus, in cluster 1, they identified support networks and social capital affecting the adoption and adaptation of digital technologies as an emerging topic for future studies. This research is framed in this line, exploring the configuration of the olive DT network, using a validated methodology such as the SNA, and including the analysis of the resulting relational social capital. This is in line with the findings of Cofré-Bravo et al. (2019) in exploring the types of social capital originating in agricultural innovation systems networks in Chile.

On the other hand, in line with cluster 2, Klerkx et al. (2019) calls to study the co-evolutionary processes that are triggered between digital agricultural technologies and the context in which they are embedded, this research proposes a territorial approach to the study of these processes, emphasising territorial dynamics and the configuration of SDRTs. In this vein, previous research has already highlighted that digital technologies, such as big data, can not only transform agriculture, but also influence the transformation of farming communities and the configuration of the agri-food system (Lioutas et al., 2019; Vik et al., 2019).

Finally, other studies on innovation systems in olive-growing areas have shown that networks, such as agricultural associations, irrigation communities or Protected Designations of Origin, play a key role in the process of innovation adoption in the Andalusian olive sector, as they can generate social capital that favours these processes (Parra López and Calatrava Requena, 2005; Rodríguez-Entrena and Arriaza, 2013). Likewise, in line with the views of stakeholders, Parra-López et al. (2021) found that although DT in the Andalusian olive sector is currently in a situation with optimistic prospects, representatives of public administration recognise the situation of DT more optimistically than other stakeholders such as R&D organisations and digital technologies companies.

6. Conclusions

Despite the fact that different authors have suggested the importance of studying and determining the effects, both desired and undesired, of Digital Transformation (DT) in rural areas, a study with a territorial approach, in which the territory is the unit of analysis, has not been addressed so far in the academic literature. This research is based on the concept of territory as a dynamic unit that arises from the social construction of the interactions of its actors, which allows us to delve into the processes triggered by the DT in the dynamics of rural areas. This represents a novelty for this research.

This manuscript has laid the conceptual foundations and the first empirical description of the actor networks and the Relational Social Capital (RSC) of the Technological Innovation System (TIS) associated to the DT in the olive of Andalusia (the DT olive network). Although the network map is not exhaustive, as it is based on a list of previously identified actors that could potentially be extended as the DT process in the sector progresses, this research offers a first approach to the panorama of knowledge transfer (KT) in this area and identifies the actors that stand out both in the emission and in the reception of this knowledge.

The results show that the actors that stand out for their role as senders of knowledge include digital technologies companies, knowledge generation agents, knowledge transfer agents and the scientific and informative media. On the other hand, the main receiving knowledge actors are olive growers, cooperatives or cooperative groups, non-cooperative groups and agricultural organisations. It is important to highlight the dual role of the cooperatives or cooperative groups and the public administration, both as senders and recipients of knowledge. The density of connections in the DT olive network is high considering the type of actors and connections being analysed. Moreover, it is 1) a complete network, as no actor is disconnected, and 2) decentralised, indicating that power is substantially distributed throughout the network. However, despite the high density, the type of connections established by the actors are mostly weak, as 98.19% of the connections have an intensity weight of less than 3 (on a scale of 0–9) and therefore, if not strengthened, may break. If weak connections are broken, they may lead to a decrease in knowledge transfer, and some actors may even become isolated from knowledge about DT in Andalusia. Therefore, promoting knowledge transfer actions, both in frequency and intensity, among network actors can counteract this situation.

In accordance with the configuration of the DT olive network in Andalusia, it can be considered this network to have a high potential for the creation of RSC. On the one hand, there is a bonding capital, in which a high number of connections between actors prevails, although with low homogeneity in the typology of actors. On the other hand, there is a bridging capital, in which organisations of different types participate, and as it is a decentralised network, it favours a lack of concentration of power.

This research offers a novel explanation of how knowledge is exchanged and created in a social network, and how such exchange creates new intellectual capital, which in the case of DT is territorial digital capital, which translates into digital technologies. This combination of elements makes it possible to state that the DT olive network and its RSC, leads to the potential formation of a SDRT in the Andalusian olive areas. However, it should be noted that the DT olive network is not static, but a dynamic entity in formation, which requires constant monitoring by territorial actors to avoid deviation from the initial objective of DT, and to avoid generating negative effects on the territory. Future studies could further analyse indicators to characterise the network by type of actor, as well as the type of knowledge being transferred (scientific or traditional).

CRediT authorship contribution statement

Liliana Reina-Usuga: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Carlos Parra-López:** Conceptualization, Methodology, Validation, Formal analysis, Writing – review & editing, Project administration, Funding acquisition. **Pedro Sánchez-Zamora:** Conceptualization, Writing – review & editing. **Carmen Carmona-Torres:** Conceptualization, Methodology, Validation, Formal analysis, Writing – review & editing, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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